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Overperceiving Disease Cues: The Basic Cognition of the Behavioral Immune System

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The behavioral immune system is designed to promote the detection and avoidance of potential sources of disease. Whereas previous studies of the behavioral immune system have provided insight into the types of heuristic cues used to identify disease carriers, the present research provides an understanding of the basic psychological processes involved in the detection of those cues. Across 4 studies, feeling vulnerable to disease, whether that feeling stemmed from dispositional tendencies or situational primes, facilitated a disease overperception bias—a tendency to overperceive people in the environment displaying heuristic disease cues. This disease overperception bias was observed in the outcomes of 2 cognitive processes: categorization and memory. When concerned about disease, participants set a lenient threshold for categorizing targets as displaying heuristic disease cues (e.g., obesity, old age). Additionally, concerns about disease led participants to set a lenient threshold for reporting on a recognition task that they had previously seen individuals displaying those disease cues. The present research provides insight into the basic cognitive mechanisms underlying the operation of the behavioral immune system.

Keywords: disease avoidance, memory, categorization, signal detection, error management

For millions of years, humans and their ancestors have faced formidable threats posed by communicable diseases. Throughout our evolutionary past, being infected by any one of thousands of viruses, parasites, or bacteria could have led to severe bodily harm or death. As a consequence, humans, like many other vertebrate animals, developed a physiological immune system designed to detect and destroy harmful organisms that have entered the body.

Although efficient, the physiological immune system is not perfect; it sometimes fails to successfully respond to and overcome harmful diseases. Moreover, even when the physiological immune system does successfully eliminate a pathogen, it does so at the cost of using limited bodily resources that could have been used for other important goals. Thus, the physiological immune system is supplemented by a behavioral immune system—a psychological system designed to promote the detection and avoidance of disease-carrying individuals (Schaller & Duncan, 2007; Schaller & Park, 2011). The behavioral immune system prompts people to be sensitive to cues displayed by others that are heuristically associated with the presence of disease (e.g., rashes, lesions; Ackerman et al., 2009; Miller & Maner, 2011). When people are exposed to such cues, people display affective (e.g., disgust) and behavioral (e.g., avoidance) reactions that help protect against potential health threats (Curtis, Aunger, & Rabie, 2004; Mortensen, Becker, Ackerman, Neuberg, & Kenrick, 2010; Oaten, Stevenson, & Case, 2009; Tybur, Lieberman, & Griskevicius, 2009).

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Although researchers have only recently begun to investigate the behavioral immune system, it has already been linked to important social processes such as prejudice and discrimination. For example, an emerging body of evidence indicates that concerns about disease contagion cause people to stigmatize groups that are heuristically associated with disease (Park, Faulkner, & Schaller, 2003; Park, Schaller, & Crandall, 2007). Although studies have examined implications of the behavioral immune system for social processes, little research has examined the basic cognitive mechanisms involved in its operation. In the present research, we begin to fill this gap in the literature by investigating the cognitive processes involved in the operation of the behavioral immune system.

In this article, we propose that the behavioral immune system biases people toward overperceiving the presence of others displaying heuristic disease cues. In the following sections, we describe theory and predictions pertaining to the ways in which disease threat leads people to vigilantly overperceive heuristically "diseasey" others in the environment, and the ways in which this vigilance is reflected in the biased outcomes of two cognitive processes (categorization and memory).

Immune System Biases

Why do people have allergies? Ask any medical practitioner, and she or he will likely tell you that allergies stem from an overzealous immune system reacting to harmless foreign substances entering the body. In other words, allergies reflect a bias in the body's natural defense system toward assuming some microorganism is a health threat, even though it is not. From an error management perspective (Haselton & Nettle, 2006; Nesse, 2005), such biases are highly functional. Assuming that a foreign substance is a health threat even when it is not is a much less costly error than assuming that a foreign substance is not a health threat when it actually is. The costs associated with the former (e.g., some sneezing and watery eyes) are not nearly as bad as the costs associated with the latter (e.g., severe illness and death). Consequently, the immune system is designed to err on the side of caution in its responses to potential disease.

Similar to the physiological immune system, the behavioral immune system also should follow an error management approach to detecting threats. The costs of mistakenly assuming that a disease carrier is healthy are much greater than the costs of mistakenly assuming that a healthy person is a disease carrier; failing to identify and avoid a contagious individual could lead one to catch a potentially harmful, energetically depleting, and perhaps fatal disease. As a result, people should possess mechanisms that minimize the probability of mistakenly assuming a disease carrier is healthy, even if it means increasing the probability of mistakenly assuming a healthy person is sick.

An emerging body of research supports this logic by demonstrating that people overgeneralize the cues used to identify disease carriers. Many diseases produce physical abnormalities on a person's body (e.g., rashes, lesions, swelling). However, such symptoms can be complex, varying in subtle ways across people and different types of diseases. Consequently, rather than holding strict rules about the specific physical cues associated with disease, people display a low threshold for perceiving cues as indicative of potential parasitic infection (Kurzban & Leary, 2001). Indeed, feeling vulnerable to infection leads people to display overgeneralized assumptions about what constitutes a disease-connoting cue (Zebrowitz, Fellous, Mignault, & Andreoletti, 2003; Zebrowitz & Rhodes, 2004). When concerned about becoming ill, for example, people tend to associate disease with obesity (Park et al., 2007), facial birthmarks (Ackerman et al., 2009), facial manifestations of aging (Duncan & Schaller, 2009), physical disabilities (Park et al., 2003), and foreign nationality (Schaller, Park, & Faulkner, 2003).

As a consequence of this overgeneralization, people display aversive reactions (reactions designed to protect against disease threats) to many groups of individuals who are, in fact, not contagious. Just as the physiological immune system overreacts to harmless substances to produce allergies, the behavioral immune system overreacts to harmless others to produce something akin to "psychological allergies." When feeling vulnerable to infection, people display antipathy and prejudice toward groups of individuals who are merely heuristically associated with disease (Crandall & Moriarty, 1995; Faulkner, Schaller, Park, & Duncan, 2004; Navarrete & Fessler, 2006; Park et al., 2007).

Although previous research has demonstrated that the behavioral immune system causes people to overgeneralize the types of cues used to identify people with disease, a functional perspective implies that the behavioral immune system should also promote a variety of basic cognitive biases linked to the detection of others displaying those disease cues. In the following sections, we describe hypotheses pertaining to biases in the basic cognitive processing of heuristic disease cues.

Overperceiving the Presence of Disease Cues

Error management approaches to self-protection (e.g., Haselton & Nettle, 2006; Neuberg, Kenrick, & Schaller, 2011) imply that concerns about a particular threat should lead people to overperceive the presence of others displaying cues of that threat. For example, when concerned about physical danger, people are biased toward categorizing others as belonging to groups that are heuristically viewed as physically aggressive (Miller, Maner, & Becker, 2010). People are also biased toward seeing in others specific cues of physical aggression (angry facial expressions) even when those cues are not really there (Maner et al., 2005). By overperceiving the presence of threat, people decrease the probability of failing to behave in a self-protective manner when a true threat might exist, thereby also decreasing the probability of sustaining injury.

Similarly, when concerned about catching a disease, people may display a disease overperception bias—a tendency to overperceive the presence of other individuals in the environment who display heuristic disease cues. By doing so, people would decrease the probability of failing to avoid situations and individuals that threaten their health. Thus, just as one may err on the side of caution by overgeneralizing the types of physical cues used to indicate the presence of disease (Ackerman et al., 2009; Park et al., 2003, 2007), one may also err on the side of caution by overperceiving the presence of people in the social environment who display those cues.

Factors Promoting the Activation of Behavioral Immune System Biases

This type of overperception bias is hypothesized to stem from the behavioral immune system, and thus should be observed primarily under conditions that activate that system. Constantly assuming that the environment is filled with contagious others would make social interactions extremely difficult and hinder one's ability to achieve important social goals (e.g., forming friendships or romantic relationships). Consequently, a disease overperception bias should be applied selectively when the behavioral immune system is active.

Evidence suggests that the behavioral immune system is activated by situational cues indicating the need to protect oneself from disease. For example, reminding people of the ease with which bacteria and germs are transmitted increases attention to disfigured faces—those conveying heuristic signals of potential infection (Ackerman et al., 2009), and increases prejudice toward foreign immigrants who are perceived as unhealthy (Faulkner et al., 2004). Just as other behavioral immune system biases operate selectively in situations in which the threat of disease contagion is heightened, we expect people in the present research to display a disease overperception bias selectively in situations that prime concerns about disease transmission.

In addition to testing effects of situationally activated disease concerns, our investigation also focused on an individual-difference variable—perceived vulnerability to disease (Duncan, Schaller, & Park, 2009)—expected to cause the overperception of people displaying heuristic disease cues. People differ substantially with regard to whether they believe they are susceptible to disease. Whereas some individuals worry a lot about contracting infectious diseases from others, other individuals display less concern over potential disease threats. Even in the absence of situational disease primes, people who chronically worry about contracting diseases tend to display behavioral immune system biases (Faulkner et al., 2004; Park et al., 2003, 2007). On the basis of this literature, one would expect that, even under baseline circumstances (i.e., in the absence of a situational disease prime) higher levels of perceived vulnerability to disease would be associated with a greater tendency to overperceive individuals in the environment displaying heuristic disease cues. That is, regardless of situational priming, those high in perceived vulnerability to disease are expected to display a disease overperception bias. In contrast, those low in perceived vulnerability to disease should be less chronically concerned about disease threats and thus less likely to display a disease overperception bias under baseline conditions. Instead, individuals low in perceived vulnerability to disease may only display a disease overperception bias in response to situations that prime the threat of disease. Thus, whereas those high in perceived vulnerability to disease may be biased toward overperceiving others with heuristic disease cues across conditions (i.e., after a control prime or after a disease prime), those low in perceived vulnerability to disease may display such a disease overperception bias only under conditions in which disease concerns are experimentally primed.

Cognitive Biases

The avoidance of disease might be facilitated by a variety of cognitive biases operating at relatively basic levels of social cognition. Indeed, how individuals initially perceive their social world plays a key role in virtually all downstream forms of social cognition and behavior (e.g., Bodenhausen & Macrae, 1998; Brewer, 1988; Fiske & Neuberg, 1990). Consequently, providing insight into lower order cognitive processes associated with the behavioral immune system is of critical importance for understanding the more downstream processes (e.g., overt prejudice and discrimination) that result from concerns about disease.

The overarching hypothesis guiding the present research is that feeling vulnerable to disease (either because of situational primes or because of individual differences in perceived vulnerability to disease) should cause people to overperceive the presence of individuals in the environment who display heuristic cues of infection. We propose that this disease overperception bias will be observed in the outcomes of two lower order cognitive processes: categorization and memory.

Categorization

A fundamental aspect of initial social perception is categorization—placing others into group-level categories. Within seconds of encountering other individuals, one tends to categorize them along a variety of dimensions (e.g., race; age; attractiveness; sex; Macrae & Bodenhausen, 2000, 2001; Stangor, Lynch, Duan, & Glass, 1992). By placing others into categories, one can use knowledge of a social category to infer information about members of that category, such as their social roles, abilities, and personality traits (e.g., Deaux & Lewis, 1984). Those inferences, in turn, shape how one interacts with and evaluates members of that category (e.g., Brewer, 1988; Gramzow & Gaertner, 2005; Tajfel, 1978).

Although group categorization can occur quickly and without effort (Brewer, 1988; Devine, 1989; Fiske & Neuberg, 1990), the specific category to which a person is assigned is highly flexible and depends on the immediate social context. In particular, social contexts that elicit feelings of vulnerability to threat can lead people to categorize others as members of a heuristically threatening group. For instance, concerns about physical danger bias people toward categorizing others as belonging to stereotypically aggressive groups (Miller et al., 2010) and as displaying aggressive social cues (Maner et al., 2005). Such biases reduce the chances of being unprepared should an actual threat arise.

In the present research, we reasoned that, if people overperceive the prevalence of others displaying heuristic disease cues, this overperception would be manifested in a bias toward categorizing others as belonging to groups heuristically associated with disease. By initially categorizing a person as displaying heuristic disease cues, one should be better prepared to behave in ways designed to reduce contact with a potential disease carrier. Indeed, initially categorizing someone as carrying a contagious disease would promote behavioral forms of avoidance. In contrast, failing to correctly categorize a person as infected may be highly detrimental because it may cause one to come into contact with a true pathogen carrier. Thus, concerns about disease may cause one to err on the side of caution and categorize individuals as displaying heuristic disease cues, regardless of whether those cues are, in fact, present.

One way of testing this hypothesis is by examining categorization biases using signal detection theory (SDT; Green & Swets, 1966/1974; MacMillan & Creelman, 1991). SDT allows one to examine two independent categorization outcomes. First, SDT provides a measure of categorization accuracy, indicated by the sensitivity statistic d'. High d' values reflect a greater ability to correctly categorize all targets into their appropriate groups. Second, SDT provides a measure of the degree to which people are biased toward categorizing targets into one particular category, indicated by the criterion statistic c. Low c values (values below zero) reflect a bias wherein one sets a low threshold for categorizing targets into a particular group, regardless of whether those targets do or do not belong to that group. It is important to note that these measures are independent of one another: Two people can have the same overall accuracy (indicated by d') but different thresholds for bias (indicated by c).

An integration of SDT and error management theory (EMT) suggests that concerns about disease should lead to lower c values for targets displaying heuristic disease cues. Such an outcome would indicate that people are biased toward categorizing targets as displaying heuristic disease cues. For example, obesity is one heuristic cue of disease (Park et al., 2007). Consequently, on a weight-based categorization task, feeling vulnerable to disease may cause people to display low c values, reflecting a bias toward categorizing others as obese, regardless of whether they are actually obese or not. In line with EMT, which is a theory pertaining to cognitive biases, our hypotheses pertain specifically to c values (bias); we had no a priori predictions pertaining to d' values (sensitivity/accuracy). In other words, disease concerns should heighten tendencies to categorize targets as displaying heuristic disease cues (indicated by low c values), without necessarily influencing overall categorization accuracy (indicated by d' values).

Memory

Memory is adaptively tuned (e.g., Ackerman et al., 2006; Klein, Cosmides, Tooby, & Chance, 2002; Kurzban, Tooby, & Cosmides, 2001). For example, people tend to remember well the spatial location of individuals who pose particular social threats; the location of less threatening individuals tends to be forgotten more readily (Becker, Kenrick, Guerin, & Maner, 2005; Maner, Miller, Rouby, & Gailliot, 2009). By remembering the location of social threats, people can subsequently avoid those locations in the future.

From an error management perspective, people should not just remember where threats are located; they should also overestimate the prevalence of threats (Maner et al., 2003). For example, after encountering a few apparently dangerous people in one part of an unfamiliar city, one might remember encountering numerous dangerous individuals (more than were actually encountered). Doing so would presumably prompt avoidance of that part of the city in the future. Consistent with this hypothesis, people sometimes remember seeing threatening stimuli in a recognition memory task even when those stimuli were not previously encountered (Dougal & Rotello, 2007).

Similar biases should emerge for disease threats. That is, disease concerns should ultimately facilitate avoidance of situations in which there are likely to be pathogen carriers. If one encounters individuals displaying disease cues in a particular situation, it would behoove one to avoid similar situations in the future, particularly when disease concerns are heightened. To facilitate that avoidance, the mind may overestimate the presence of disease carriers in memory. When thinking back about a certain situation, overremembering the presence of disease cues would promote avoidance of that situation in the future. Consequently, the mind may err toward overremembering disease cues, so as to avoid situations and locations that pose potential disease threats.

Just as SDT can be used to assess biases in categorization, it can also be used to assess biases in recognition memory. High d' values reflect a heightened ability to correctly recognize targets that were versus were not previously seen. Thus, d' reflects overall accuracy and how well one can differentiate targets from one another in memory. In contrast, c values reflect the degree to which people are biased toward thinking they had seen a particular type of target previously, indicated by the statistic c. Low c values (values below zero) reflect a bias wherein people set a low threshold for reporting that they had previously seen a specific type of target, regardless of whether they did, in fact, see that target. Because disease concerns are hypothesized to promote a cautionary bias toward overremembering pathogen threats, disease concerns should lead to low c values for remembering targets heuristically associated with disease. Just as with categorization biases, this effect on memory c values should occur regardless of overall accuracy (i.e., d' values).

The Present Research

We hypothesized that concerns about disease would cause people to display a disease overperception bias—a bias toward overperceiving individuals in the environment displaying heuristic disease cues. We expected that this bias would be observed among individuals high in perceived vulnerability to disease and among individuals situationally primed with concerns about disease. Furthermore, we predicted that a disease overperception bias would be observed in the biased outcomes of two lower order cognitive processes: categorization and memory.

In Study 1, we tested the hypothesis that individuals high in perceived vulnerability to disease would display an overperception of obese targets—targets heuristically associated with disease (Park et al., 2007). We predicted that individuals high in perceived vulnerability to disease would be biased toward categorizing targets as obese (and therefore heuristic sources of potential disease contagion), even when those targets were not actually overweight (reflected by low c values). We also predicted that individuals high in perceived vulnerability to disease would be more likely to report previously seeing obese targets than average-weight targets on a recognition memory task (again reflected by relatively low c values). Studies 2a and 2b were designed to test the hypothesis that similar memory biases would be observed when concerns about disease resulted not from chronic individual differences, but from situational primes. In Study 3, we examined potential interactions between situational disease primes and individual differences in perceived vulnerability to disease. We predicted that regardless of priming condition, individuals high in perceived vulnerability to disease would display a categorization bias associated with disease overperception; individuals low in perceived vulnerability to disease were expected to display that bias only when situationally primed with disease. In Study 4, we tested whether disease overperception biases would generalize to other groups of individuals heuristically associated with disease (the elderly and foreigners; Duncan & Schaller, 2009; Schaller et al., 2003).

Study 1

In Study 1, we examined the association between individual differences in perceived vulnerability to disease and the overperception of disease cues. Previous research indicates that people tend to perceive obesity as one heuristic cue of infection (Park et al., 2007; see also Crandall, Nierman, & Hebl, 2009; Harvey, Troop, Treasure, & Murphy, 2002). Consequently, we hypothesized that chronic concerns about disease would promote a bias toward initially categorizing a target as obese (i.e., as displaying a heuristic cue of disease) regardless of the actual weight of that target (i.e., lower overall c values). This bias would lead to greater accuracy when the target is in fact obese but less accuracy when the target is average weight. This would parallel previous evidence in the domain of physical threat, in which fear of physical threat caused greater accuracy in categorizing heuristically threatening targets, but less accuracy when targets were not heuristically threatening (Miller et al., 2010). Additionally, we predicted that chronic concerns about disease would promote a similar obesity-overperception bias in memory; compared with individuals who tend not to be concerned about disease, individuals high in perceived vulnerability to disease were expected to set a lower threshold for saying that they had previously seen obese targets than average-weight targets on a recognition task (again reflected by lower c values).

Method

Participants. Forty-five undergraduate students (age 18–30; 25 women, 20 men) participated for course credit.

Materials and procedure. Participants were told that the purpose of the study was to examine processes involved in social perception. For the memory portion of the study, participants were told that they would see a series of pictures about which they would later be asked questions. Participants watched a slideshow of pictures containing images of seven obese individuals, seven average-weight individuals, and seven neutral objects. The 14 target individuals were pictures of dieters' "before" or "after" photos taken from a weight-loss website and used in previous research (Park et al., 2007). All participants saw the same average-weight and obese targets during the encoding task. Each picture was presented in the center of the screen for 1,750 ms. Pictures were separated in time by a fixation cross in the center of the screen appearing for 250 ms. The order in which pictures were presented was randomized across participants.

After this encoding phase, participants completed a 3-min distractor task on the computer that did not relate to weight-based biases. Participants then performed the target recognition task. Participants saw the 21 targets they saw previously as well as 21 foils (seven obese individuals, seven average-weight individuals, and seven neutral objects). Each obese and average-weight foil was a corresponding before-or-after picture of the previously seen target pictures (i.e., if target A's "before" weight-loss picture was presented during encoding, target A's "after" weight-loss picture was used as a foil during the recognition task). For each picture, participants indicated via key press if they had or had not seen the picture previously. The order in which pictures were presented was randomized.

Following the recognition task, participants performed a speeded categorization task on the computer. Participants were told that they would see pictures of individuals appear on the computer screen and that they should categorize each individual as "Fat" or "Thin" via a key press as quickly and accurately as possible. During the categorization task, participants viewed 20 pictures of individuals: 10 pictures were targets' "before" weight-loss pictures and 10 pictures were the same targets' "after" weight-loss pictures. On each trial of the categorization task, participants saw a fixation cross appear in the center of the screen for 1,000 ms, immediately followed by the target picture. Targets remained on the screen until participants made a response. The order in which pictures were presented was randomized.

Last, participants completed the Perceived Vulnerability to Disease scale (PVD; Duncan et al., 2009), a 15-item measure used in several previous studies to assess chronic beliefs about personal susceptibility to the transmission of disease (e.g., Faulkner et al., 2004; Park et al., 2003, 2007; Welling, Conway, DeBruine, & Jones, 2007). High scores on this measure indicate greater beliefs about one's perceived vulnerability to disease (e.g., "In general, I am very susceptible to colds, flu, and other infectious diseases"; "I avoid using public telephones because of the risk that I may catch something from the previous user"). Average scores, after reverse scoring appropriate items, were calculated ($M = 3.62$, $SD = 0.85$; $\alpha = .75$).[1]

Results

Categorization. Due to experimenter error, one participant's data from the categorization task were not recorded. On average, participants correctly categorized the weight of target individuals on 96.0% ($SD = 3.2\%$) of trials. We analyzed the categorization data using signal detection analysis. Correctly categorizing an obese target as obese represents a hit, whereas mistakenly categorizing an average-weight target as obese represents a false alarm. When applying this signal detection approach, there was a significant correlation between *c* values and PVD scores ($r = -.34$, $p = .026$), such that higher PVD scores were associated with a more lenient threshold for categorizing someone as obese (reflected by lower *c* values). A similar analysis of d' revealed no significant effects ($r = -.16$, $p = .28$), suggesting that PVD had no effect on overall accuracy (i.e., ability to correctly categorize both obese and average-weight targets).[2]

In addition to an SDT analysis, we also analyzed the categorization data by examining the influence of PVD on specific types of categorization errors. Setting a low threshold for categorizing someone as obese would cause participants high in PVD to more accurately categorize the weight of obese targets than average-weight targets. Thus, categorization errors (number of targets categorized incorrectly) were predicted from PVD, target weight (obese vs. average weight), and their centered interaction. Because errors were highly positively skewed with a modal response of zero incorrect responses, we performed analyses using a generalized estimating equation (GEE) with a Poisson distribution (see Miller et al., 2010, for similar analyses of categorization data). Results revealed the predicted two-way interaction between PVD and target weight, Wald $\chi^2(1, N = 44) = 7.62$, $p = .006$. We subsequently assessed the simple effects of target weight among participants high (1 *SD* above the mean) and low (1 *SD* below the mean) in PVD. Consistent with hypotheses, participants high in PVD were more accurate at categorizing obese targets than average-weight targets, Wald $\chi^2(1, N = 44) = 15.71$, $p < .001$. No such effect was observed among participants low in PVD, Wald $\chi^2(1, N = 44) = 2.74$, $p = .10$ (see Figure 1).[3]

Memory. Due to computer malfunction and experimenter error, three participants' data on the memory task were not recorded. We calculated the number of hits (i.e., remembering that a target had been seen previously) and false alarms (i.e., thinking that a foil had been seen previously) on the target recognition task for each target type (obese and average weight) for each participant. On average, participants' hit rate and false-alarm rate on the memory recognition task were 90.1% ($SD = 10.0\%$) and 18.6% ($SD = 18.4\%$), respectively. Two participants had an extremely high false-alarm rate (greater than 3 *SD*s above the mean); we excluded their data from analyses.

[1] The PVD scale is composed of two subscales: the Germ Aversion subscale (assessing discomfort toward disease-connoting situations) and the Perceived Infectability subscale (assessing beliefs about susceptibility to infectious disease). Ancillary analyses in each study examined the independent effect of each subscale on disease overperception biases. Neither scale consistently emerged as the dominant predictor of bias scores across dependent variables and studies. Our data suggest that individual differences in overall PVD scores served as a better predictor of disease overperception biases than either of the individual subscales.

[2] Due to the design of the categorization task, it is not possible to disentangle signal detection biases for obese targets from average-weight targets. For example, mistakenly categorizing a target as obese is simultaneously both a miss for average-weight targets and a false alarm for obese targets. Thus, lower *c* values represent both a more lenient threshold for categorizing someone as obese and a more stringent threshold for categorizing someone as average weight.

[3] Ancillary analyses probed for effects of participant gender. In no study did participant gender significantly moderate findings.

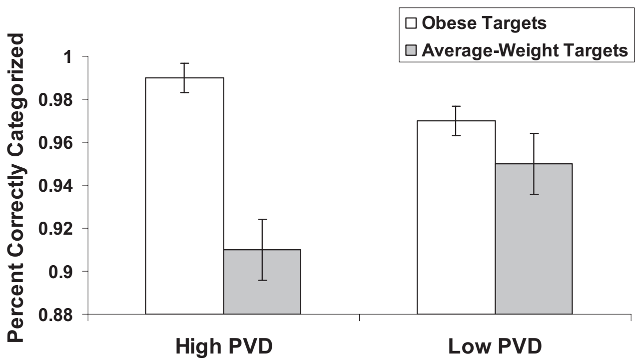

Figure 1. Study 1: High-Perceived Vulnerability to Disease (PVD) participants were less accurate at categorizing average-weight targets than obese targets on a speeded categorization task. Participants' accuracy for categorizing obese and average-weight targets did not differ among participants low in PVD. Error bars = standard errors.

We calculated sensitivity (d') and criterion (c) measures for obese and average-weight targets. Our primary hypothesis was that participants high in perceived vulnerability to disease would set a more lenient threshold (i.e., lower c values) for responding that they had seen obese targets than average-weight targets. Target weight (obese vs. average weight; within subjects), PVD (centered; between subjects), and their interaction were entered as predictors in a mixed model general linear model (GLM). Analysis of c values revealed a significant interaction between PVD and target weight, $F(1, 38) = 5.22$, $p = .028$, partial $\eta^2 = .12$. Follow-up analyses confirmed that participants high in PVD set a lower threshold for responding that they had seen obese targets than average-weight targets, $F(1, 38) = 4.57$, $p = .039$, partial $\eta^2 = .11$. No effect of target weight was observed among participants low in PVD, $F(1, 38) = 1.26$, $p = .27$ (see Figure 2).

Analysis of d' also revealed an interaction between PVD and target weight, $F(1, 38) = 7.05$, $p = .012$, partial $\eta^2 = .16$. High-PVD participants had worse recognition accuracy for obese targets/foils than average-weight targets/foils, $F(1, 38) = 9.19$, $p = .004$, partial $\eta^2 = .20$. That is, high-PVD participants were less sensitive in identifying previously viewed obese targets ($M = 2.15$, $SE = 0.13$) than average-weight targets ($M = 2.48$, $SE = 0.13$). Participants low in PVD displayed no difference in their accuracy for obese targets/foils ($M = 2.36$, $SE = 0.13$) and average-weight targets/foil ($M = 2.28$, $SE = 0.12$; $F < 1$).

Discussion

Study 1 demonstrated that concerns about disease are associated with biases in social categorization and memory. When quickly categorizing targets on the basis of their weight, participants high in perceived vulnerability to disease set a relatively low threshold (lower c values) for categorizing someone as obese. This low threshold was reflected in greater accuracy in categorizing obese than average-weight targets. Participants high in perceived vulnerability to disease also set a lower threshold (i.e., lower c values) for reporting that they had previously seen obese targets than average-weight targets on a recognition task. Obese individuals are heuristically associated with disease and are viewed as posing potential health threats (Harvey et al., 2002; Park et al., 2007). Therefore, both findings are consistent with the hypothesis that feeling vulnerable to infection promotes biases reflecting overperception of other people displaying heuristic disease cues.

Study 1 also demonstrated an effect of disease concerns on sensitivity in recognition memory (d'), suggesting that chronic concerns about disease may be associated with decreased overall accuracy in the ability to identify correctly whether one previously saw or did not see individual targets displaying heuristic cues of disease. However, this finding should be interpreted with caution as it was not predicted a priori, nor conceptually replicated with the categorization measure; replication is required before drawing strong conclusions about sensitivity/accuracy. Nevertheless, Study 1's findings do provide consistent support for biases in memory and categorization that may help protect the self from potential disease threats.

Study 2a

In Study 2a, we extended the previous study by using experimental methods to test for effects of situational disease primes. In Study 1, internal, dispositional factors reflecting chronic perceptions of vulnerability to disease were associated with setting a lenient threshold for remembering people with heuristic disease cues. In Study 2a, we tested the hypothesis that external, situationally primed concerns about disease would lead to a similar bias. We predicted that acute concerns about infection would increase the likelihood of participants reporting on a memory task that they had previously seen an obese target, even if they had not actually seen that target before (conceptually replicating Study 1's findings).

Method

Participants. Fifty-six undergraduate students (age 18–22; 38 women, 18 men) participated for course credit.

Materials and procedure. Participants were told that the purpose of the study was to examine memory for various forms of

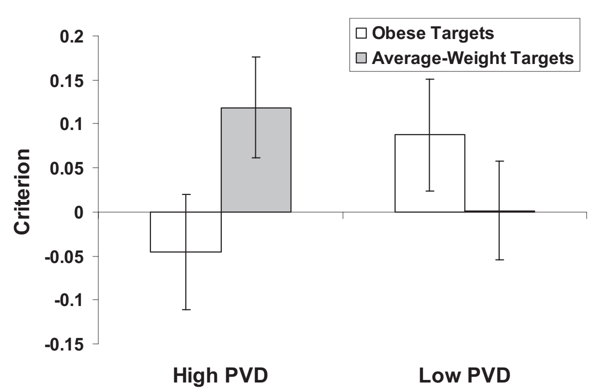

Figure 2. Study 1: High-Perceived Vulnerability to Disease (PVD) participants were more likely to set a lower threshold for indicating that they had previously seen obese targets than average-weight targets on the memory task. Participants' thresholds for obese and average-weight targets did not differ among participants low in PVD. Error bars = standard errors.

information. Participants randomly assigned to the disease prime condition read a fictitious news article about the threat of the H1N1 Swine Flu virus. In the control condition, participants read an article about the threat of winter storms. Both articles provided information about the predicted number of flu- or storm-related deaths and hospitalizations occurring during the upcoming winter season, as well as statements from experts encouraging people to use "common sense measures to prepare for the season." The information contained in the articles was identical except for the type of threat being discussed (flu vs. storm).

Participants then performed the same memory task used in Study 1. In between the encoding and recognition phases, participants completed a recall task that assessed their memory for information contained in the article they read. Participants were given 3 min to answer several questions about the article (e.g., "How many people are predicted to be hospitalized due to flu/storms this upcoming winter season?" "What was the name of the White House Advisor who said that there's going to be great uncertainty about what we're going to see as this develops?"). This recall task produced a distraction between the target-encoding and recognition phases and provided checks on participants' understanding of the priming material.

Results

To ensure that participants read and encoded information from the articles equally across conditions, we compared the average accuracy on the article memory test of the disease-primed participants to the control-primed participants. The average percentage of questions answered correctly by participants did not differ by priming condition, $t(54) = 0.28$, $p = .78$, (disease $M = 65\%$, $SD = 19$; control $M = 66\%$, $SD = 22$). Thus, there was no difference in the degree to which participants understood information in the two articles.

On average, participants' hit and false-alarm rates were 90.9% ($SD = 15.8\%$) and 7.9% ($SD = 11.2\%$), respectively. One participant had an extremely low hit rate, and two participants had extremely high false-alarm rates (i.e., greater than 3 *SD*s below/above the respective means); we excluded those participants' data from subsequent analyses.

We again examined memory biases in terms of criterion (c) and sensitivity (d'). We performed a mixed-model analysis of variance (ANOVA) in which c values were predicted from priming condition (disease vs. control; between subjects), target weight (obese vs. average weight; within subjects), and their interaction. Results revealed the predicted (marginal) interaction between priming condition and target weight, $F(1, 51) = 3.72$, $p = .059$, partial $\eta^2 = .07$. Consistent with our hypothesis, participants primed with disease set a lower threshold for obese targets than average-weight targets, $F(1, 51) = 8.96$, $p = .004$, partial $\eta^2 = .15$. No effect of target weight was observed among participants in the control condition ($F < 1$) (see Figure 3).

Similar analyses of d' revealed only a significant main effect of target weight, $F(1, 51) = 5.78$, $p = .02$, partial $\eta^2 = .10$, such that, regardless of priming condition, participants displayed greater sensitivity to average-weight targets ($M = 2.55$, $SD = 0.43$) than obese targets ($M = 2.37$, $SD = 0.45$). In other words, regardless of priming condition, participants were more accurate in differentiating average-weight targets from foils than they were in differentiating obese targets from foils.

Discussion

Results of Study 2a conceptually replicate and extend those of Study 1. Priming concerns about disease led participants to set a lower threshold (i.e., lower c values) for reporting that they had previously seen obese targets than average-weight targets on a recognition task. This bias in memory did not stem from chronic, dispositional concerns over vulnerability to infection, but rather from acute, situationally activated concerns about disease. Thus, consistent with other behavioral immune system biases (e.g., Park et al., 2007), the overperception of people displaying heuristic disease cues can stem from both acute and chronic concerns about disease threats. Unlike Study 1 results, Study 2a results were specific to c values; the situational prime had no effect on overall sensitivity or accuracy (d' values). To provide further confidence in this finding, we performed a follow-up study (Study 2b) in which we again examined memory biases for obese targets, but used a different manipulation to prime disease concerns.

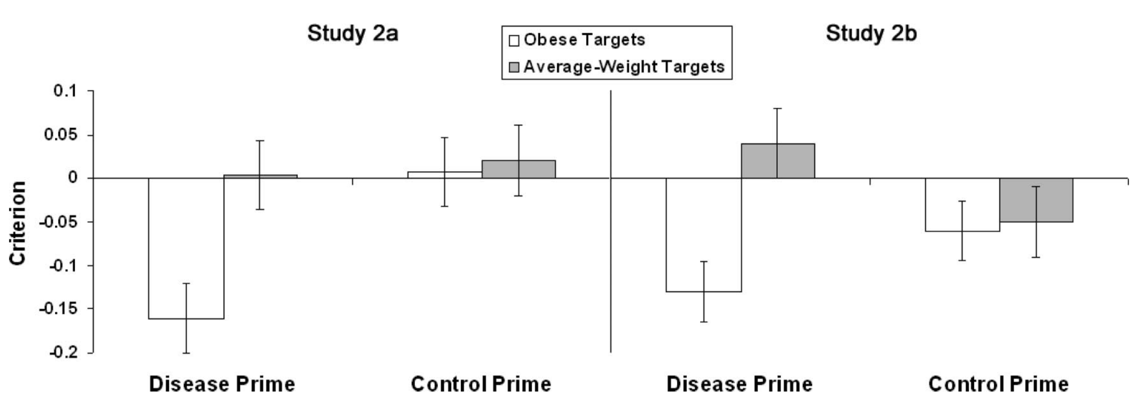

Figure 3. Studies 2a and 2b: Priming thoughts of disease led participants to set a lower threshold for indicating that they had previously seen obese targets than average-weight targets. Participants' thresholds for obese and average-weight targets did not differ after a control prime. Error bars = standard errors.

Study 2b

Method

Participants. Eighty undergraduate students (age 18–26; 56 women, 24 men) participated for course credit.

Materials and procedure. The memory task was identical to one used in Study 1 and Study 2a. However, to assess the generalizability of the effect, different disease and control primes were used (from Park et al., 2007). In the disease condition, participants watched a 3-min slideshow consisting of 10 images that portrayed information about germs, infections, and other diseases. In the control condition, participants watched a slideshow of 10 images portraying information about common accidents and hazards that were nondisease-related threats. Each image was shown for 20 s.

In between the encoding and recognition phases of the memory task, participants rewatched the original disease or control slideshow that they saw previously. This was done both to provide a distraction between encoding and recognition phases and to strengthen the power of the manipulation. All other aspects of the procedure were identical to Study 2a.

Results

On average, participants' hit rate and false-alarm rate were 93.0% (SD = 7.7%) and 7.4% (SD = 7.7%), respectively. One participant had an extremely low hit rate (greater than 3 SDs below the mean); we excluded that participant's data from analyses.

As in Study 2a, c values were predicted from priming condition (disease vs. control), target weight (obese vs. average weight), and their interaction in a mixed model ANOVA. We observed a significant interaction between priming condition and target weight, $F(1, 77) = 4.21$, $p = .04$, partial $\eta^2 = .05$. Consistent with findings from the previous studies, participants primed with disease set a lower threshold for responding that they had seen obese targets than average-weight targets, $F(1, 77) = 9.98$, $p = .002$, partial $\eta^2 = .12$. No effect of target weight was observed among participants in the control condition ($F < 1$) (see Figure 3). Similar analyses of d' revealed no significant effects.

Discussion

In Studies 2a and 2b, priming concerns about disease led participants to set a lower threshold for reporting that they had previously seen obese targets, as compared with average-weight targets. Thus, when the situation signaled a heightened need to protect the self from illness, participants displayed biases in memory consistent with the overperception of disease; participants were more likely to say that they remembered seeing individuals heuristically associated with disease (obese targets) than individuals who did not display heuristic cues of disease. As in Study 2a, the influence of disease primes on memory was specific to c values and did not influence d' values.

It is important to note that in the absence of a disease prime, participants did not display any evidence for overperceiving disease cues, even though those individuals had been primed with other forms of threat (dangerous storms and physical injury). Thus, the biases observed in these studies were quite specific to disease threats, as opposed to physical threats more broadly, suggesting that those biases reflect the operation of the behavioral immune system.

Study 3

Study 1 demonstrated that a disease overperception bias can stem from chronic, dispositional concerns about disease; Study 2 demonstrated that this bias can also stem from acute, situationally activated concerns about disease. The purpose of Study 3 was to examine potential interactive effects of acute and chronic concerns about disease. Participants performed the same categorization task used in Study 1; participants quickly categorized targets on the basis of their weight (obese or average weight). Given that, in Study 1, individuals high in perceived vulnerability to disease displayed a disease overperception bias in the absence of any situational disease prime, we predicted that, regardless of condition, participants high in perceived vulnerability to disease would set a low threshold for categorizing targets as obese, regardless of whether those targets were, in fact, overweight. In contrast, individuals low in perceived vulnerability to disease were expected to display categorization biases associated with disease overperception only when situationally primed with disease.

Method

Participants. Forty undergraduate students (age 18–24; 27 women, 13 men) participated for course credit. Data from one participant were lost due to computer malfunction.

Materials and procedure. As in Study 2b, participants were randomly assigned to watch a slideshow about diseases (disease condition) or common accidents (control condition). Following the slideshow, participants performed the speeded categorization task described in Study 1. Last, participants completed the PVD scale ($M = 3.48$, $SD = 0.92$, $\alpha = .84$). PVD scores did not vary by condition ($F < 1$).

Results

Signal detection analysis (SDA). We again performed an SDA of participants' sensitivity (d') and criterion (c) for categorizing individuals as obese. An analysis of c values revealed a significant interaction between priming condition and PVD, $F(1, 35) = 6.35$, $p = .02$, partial $\eta^2 = .15$. Among participants in the control condition, there was a significant main effect of PVD, $F(1, 35) = 4.28$, $p = .04$, partial $\eta^2 = .11$, such that higher PVD scores were associated with a more lenient threshold for categorizing someone as obese. This conceptually replicates the pattern from Study 1. Among participants primed with disease, there was no effect of PVD, $F(1, 35) = 2.09$, $p = .16$. This was predominantly due to the effect of the disease prime among low-PVD individuals. Low-PVD individuals in the disease prime condition were more likely to set a lenient threshold for categorizing someone as obese than low-PVD participants in the control condition, $F(1, 35) = 5.41$, $p = .03$, partial $\eta^2 = .13$ (disease $M = -.14$, $SE = .04$; control $M = .02$, $SE = .05$). No effect of priming condition was observed among high-PVD individuals, $F(1, 35) = 1.64$, $p = .21$ (disease $M = -.05$, $SE = .05$; control $M = -.13$, $SE = .05$). Analyses of d' revealed no significant effects.

Accuracy. On average, participants correctly categorized the weight of target individuals on 95.0% (SD = 4.7%) of trials. As in Study 1, we used a GEE with a Poisson distribution to analyze the accuracy data.

Error scores (number of targets categorized incorrectly) were predicted from priming condition (disease vs. control; between subjects), target weight (obese vs. average weight; within subjects), individual differences in PVD (a continuous between-subjects variable), and all centered interactions. Results revealed the predicted three-way interaction between priming condition, target weight, and PVD, Wald $\chi^2(1, N = 39) = 8.78, p = .003$.

We subsequently assessed the simple effects of the priming manipulation and target weight among participants high (1 SD above the mean) and low (1 SD below the mean) in PVD. As can be seen in Figure 4, among participants high in PVD, the only significant effect was a main effect of target weight, Wald $\chi^2(1, N = 39) = 11.23, p = .001$, such that high-PVD participants made more categorization mistakes for average-weight targets than obese targets, regardless of priming condition. This replicates the findings from Study 1.

Among low-PVD participants, we observed an interaction between the priming manipulation and target weight, Wald $\chi^2(1, N = 39) = 3.63, p = .05$. Subsequent analyses revealed that low-PVD participants primed with disease were more likely to incorrectly categorize average-weight targets than obese targets, Wald $\chi^2(1, N = 39) = 9.21, p = .002$. No effect of target weight was observed among low-PVD participants in the control condition, Wald $\chi^2(1, N = 39) = 0.23, p = .63$.

Discussion

Study 3 provides further evidence for a disease overperception bias and confirms the interactive effects of acute and chronic concerns about disease threats. Regardless of priming condition, participants high in perceived vulnerability to disease set a relatively lenient threshold for categorizing someone as obese, reflected by a heightened tendency to categorize targets as obese regardless of whether they were obese or average weight (i.e., low c values). This, in turn, led participants to display greater accuracy in identifying obese targets than average-weight targets. Thus, participants who felt chronically vulnerable to infection were biased toward perceiving others as displaying heuristic disease cues. This fits with findings from Study 1 and previous evidence suggesting that high chronic levels of concerns about infection motivate disease-avoidant processes (e.g., Faulkner et al., 2004; Park et al., 2003, 2007; Welling et al., 2007; cf. Duncan & Schaller, 2009).

Individuals low in perceived vulnerability to disease—those who do not feel chronically susceptible to illness—did not display the same overperception bias unless the situation indicated a need to protect against disease. Among those participants, the experimental disease prime increased the tendency to set a low threshold for categorizing someone as obese and to thus mistakenly perceive average-weight targets as obese. These findings again were specific to c values, as there were no effects on d' values. The overall pattern of findings across Studies 1– 3 indicate that people who feel susceptible to illness, either by virtue of their chronic concerns about disease or by their exposure to a situational disease prime, display a disease overperception bias that is reflected in the outcomes of lower order cognitive processes.

Study 4

Study 4 extended the previous studies in several ways. First, it tested the prediction that the interaction between situational primes and individual differences in perceived vulnerability to disease observed for categorization biases (Study 3) would replicate for memory biases. Thus, in the present study, participants performed a memory task similar to the one used in Studies 1 and 2.

Second, the investigation was extended beyond a focus on obesity as a disease cue. As noted in the introduction, several characteristics are heuristically perceived as signaling the presence of possible disease. Two that have been identified by previous research are facial manifestations of aging (Duncan & Schaller, 2009) and foreign nationality (Schaller et al., 2003). Thus, Study 4 was designed to examine whether a disease overperception bias would generalize to older adults and foreigners.

Third, simultaneously examining two heuristic disease cues (old age and foreign nationality) allowed us to evaluate the presence of

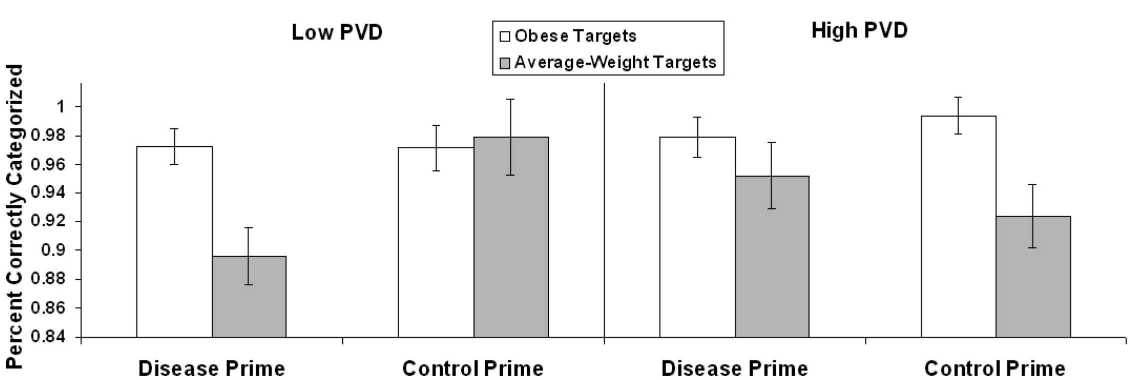

Figure 4. Study 3: Low-Perceived Vulnerability to Disease (PVD) participants primed with disease were less accurate at categorizing average-weight targets than obese targets. Low-PVD participants in the control condition, however, categorized average-weight and obese targets equally well. High-PVD participants were less accurate at categorizing average-weight targets than obese targets, regardless of priming condition. Error bars = standard errors.

synergistic effects in response to targets displaying multiple heuristic disease cues. The previous studies demonstrated that one disease cue (obesity), on its own, can produce behavioral immune system biases. However, people should display the greatest level of self-protective bias when targets display numerous cues indicative of threat. Indeed, threatening characteristics in others tend to produce synergistic effects on self-protective tendencies. For example, in the domain of self-protection from physical aggression, direct gaze (looking directly at someone) is one potential cue of physical threat (Argyle & Cook, 1976). Additionally, in North America, White people tend to perceive Black individuals as a source of physical threat (Cottrell & Neuberg, 2005). In the absence of any variation in target race (i.e., when all targets are of the participants' own race), viewing a target with direct gaze leads to greater threat perception than viewing a target with an averted gaze (Kawashima et al., 1999). However, when both the race and gaze of targets are varied (i.e., when multiple cues indicate levels of threat), the effect of gaze direction on threat perception is greater when the target is Black than when the target is White (i.e., the participants' own race; Richeson, Todd, Trawalter, & Baird, 2008). Thus, when multiple cues of threat are present, people display self-protective processes most strongly toward those individuals displaying multiple indicators of threat (e.g., Ackerman et al., 2006; Miller et al., 2010; see also Shapiro et al., 2009).

In Study 4, we examined whether similar synergistic effects are observed in the domain of disease avoidance. Target age is one factor heuristically associated with disease, so when varied in the absence of other disease-connoting cues, it influences behavioral immune system processes (Duncan & Schaller, 2009). However, we predicted that when target age is varied in conjunction with target race (a cue of foreign nationality, which is another heuristic cue of disease), the effect of target age on disease-avoidance processes would be greater when the targets were of a racial outgroup than a racial ingroup.

In the present study, White participants performed encoding and recognition tasks in which they saw targets that varied in age (older vs. younger adults) and race (White vs. Asian). The locale in which participants lived and went to school was predominantly White (76%). Less than 3% of the local population was a race other than White or Black; therefore, Asians were a relatively foreign racial group. We predicted that, regardless of priming condition, participants high in perceived vulnerability to disease would set a relatively lenient threshold (i.e., low *c* values) for reporting that they had previously seen an older target than a younger target, particularly when that target was Asian; participants low in perceived vulnerability to disease were expected to display this memory bias only after being primed with disease concerns.

Method

Participants. Eighty-one White undergraduate students (age 18–24; 58 women, 23 men) participated for course credit. One participant failed to complete the PVD scale; her data were excluded from analyses.

Materials and procedure. As in Study 2a, participants were randomly assigned to read a fictitious news article about the threat of the H1N1 Swine Flu virus (disease condition) or the threat of winter storms (control condition). After reading the article, participants underwent the encoding phase of the memory task. Participants viewed a slideshow of 16 faces (four White younger adults, four Asian younger adults, four White older adults, four Asian older adults) and seven neutral objects. Each picture was presented in the center of the computer screen for 1,750 ms. Pictures were separated in time by a fixation cross in the center of the screen appearing for 250 ms. The order in which pictures were presented was randomized across participants.

To provide a distraction between encoding and recognition phases, participants completed the same 3-min questionnaire used in Study 2a, which posed questions about the priming article. Participants then performed the target recognition task. Participants saw the 23 targets they saw previously as well as 23 foils (four White younger adults, four Asian younger adults, four White older adults, four Asian older adults, seven neutral objects). For each picture, participants indicated via key press whether they had or had not seen the picture previously. The order in which pictures were presented was randomized. Last, participants completed the PVD scale ($M = 3.41$, $SD = 0.88$, $\alpha = .84$). PVD scores did not vary by condition ($F < 1$).

Results

On average, participants' hit rate and false-alarm rate on the recognition task were 86.0% ($SD = 16.8\%$) and 14.8% ($SD = 12.3\%$), respectively. Four participants had hit rates or false-alarm rates greater than three standard deviations above/below the mean; we excluded those participants' data from analyses.

We again examined memory biases in terms of criterion (*c*) and sensitivity (d'). In a mixed model GLM, *c* values were predicted from priming condition (disease vs. control; between subjects), target age (younger vs. older; within subjects), target race (White vs. Asian; within subjects), individual differences in PVD (continuous, between subjects), and all centered interactions. We observed a significant main effect of target race, $F(1, 72) = 4.12$, $p = .046$. However, this was qualified by the predicted (marginally significant) four-way interaction between target race, target age, priming condition, and PVD, $F(1, 72) = 3.07$, $p = .084$, partial $\eta^2 = .04$; no other effects were significant.

To interpret the four-way interaction, we probed for effects of target race, target age, priming condition, and all interactions among participants high (1 *SD* above the mean) and low (1 *SD* below the mean) in PVD. For participants high in PVD, we observed a (marginal) interaction between target race and target age, $F(1, 72) = 3.82$, $p = .055$, partial $\eta^2 = .05$. This interaction was not affected by priming condition, as no main effects or interactions involving priming condition approached significance (all $ps > .12$). We probed the interaction by testing the simple effects of target age among Asian and White targets separately. As can be seen in Figure 5, regardless of priming condition, high-PVD participants set a lower threshold for responding that they had seen older targets than younger targets when those targets were Asian, $F(1, 72) = 4.07$, $p = .047$, partial $\eta^2 = .05$; there was no effect of target age among high-PVD participants when the targets were White ($F < 1$).

For participants low in PVD, we observed a significant three-way interaction between target race, target age, and priming condition, $F(1, 72) = 4.72$, $p = .033$, partial $\eta^2 = .06$. For low-PVD participants in the disease prime condition, we observed a (mar-

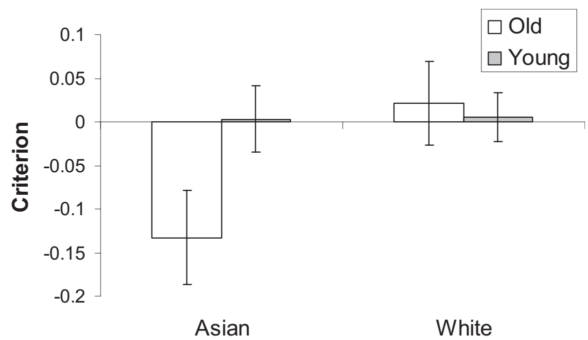

Figure 5. Study 4: Regardless of priming condition, high-Perceived Vulnerability to Disease (PVD) participants set a lower threshold for indicating that they had seen older targets than younger targets when those targets were Asian; there was no effect of target age among high-PVD participants when the targets were White.

ginal) interaction between target age and target race, $F(1, 72) = 3.75$, $p = .057$, partial $\eta^2 = .05$. As can be seen in Figure 6, low-PVD participants primed with disease set a lower threshold for responding that they had seen older targets than younger targets when those targets were Asian, $F(1, 72) = 3.38$, $p = .070$, partial $\eta^2 = .05$; there was no effect of target age among low-PVD participants primed with disease when the targets were White ($F < 1$). For low-PVD participants in the control condition, there were no significant effects involving target age or target race (all ps $> .16$). Thus, responses of low-PVD participants in the disease prime condition (but not in the control condition) closely mirrored responses of high-PVD participants across conditions.

Similar analyses of d' revealed main effects of target race and target age (both ps $< .001$), but these were qualified by an interaction between target race, target age, and PVD, $F(1, 72) = 4.86$, $p = .031$, partial $\eta^2 = .06$; no other effects were significant, and there were no effects of experimental priming. For participants high in PVD, we observed a main effect of target age, $F(1, 72) = 13.32$, $p < .001$, partial $\eta^2 = .16$, indicating that high-PVD participants had a lower sensitivity for older targets ($M = 1.59$, $SE = 0.07$) than younger targets ($M = 1.90$, $SE = 0.07$). This conceptually replicates the pattern from Study 1, in which high-PVD participants displayed lower sensitivity for obese targets than for normal weight targets. For participants low in PVD, we observed an interaction between target race and target age, $F(1, 72) = 4.99$, $p < .029$, partial $\eta^2 = .06$. Follow-up analyses revealed that for Asian targets, low-PVD participants had a significantly lower sensitivity for older targets ($M = 1.33$, $SE = 0.11$) than younger targets ($M = 1.91$, $SE = 0.09$), $F(1, 72) = 18.69$, $p < .001$, partial $\eta^2 = .21$. Low-PVD participants showed a similar but weaker effect of target age when the targets were White, $F(1, 72) = 3.24$, $p = .076$, partial $\eta^2 = .04$ (Older $M = 1.84$, $SE = 0.09$; Younger $M = 2.03$, $SE = 0.07$).

Discussion

Study 4 conceptually replicated the interactive effect of acute and chronic disease concerns observed in Study 3. Participants high in perceived vulnerability to disease set a relatively low threshold for reporting that they had previously seen older Asian targets (targets displaying multiple heuristic disease cues), and this pattern was observed regardless of priming condition. In contrast, participants low in perceived vulnerability to disease set a relatively low threshold for reporting that they had seen older Asian targets only when primed with disease concerns. Thus, combined with the findings from Study 3, these results suggest that feeling vulnerable to infection, whether that feeling stems from aspects of the situation or one's chronic disposition, can lead one to overperceive people in the environment displaying heuristic disease cues.

These findings also demonstrate that concerns about disease shape biases in perceptions of people displaying a range of physical characteristics heuristically associated with disease. Whereas Studies 1–3 demonstrated overperception biases for obese targets, Study 4 revealed similar biases for older members of a foreign racial outgroup. Moreover, Study 4 suggests that the combination of multiple heuristic disease cues produces synergistic effects on disease-avoidance processes. The overperception of disease cues was greatest for targets who were both older and members of a foreign outgroup.

Although we observed the predicted interaction between target age and target race, no main effects of target age or race were observed. Indeed, although participants concerned about disease set a lower threshold for reporting that they had seen older targets

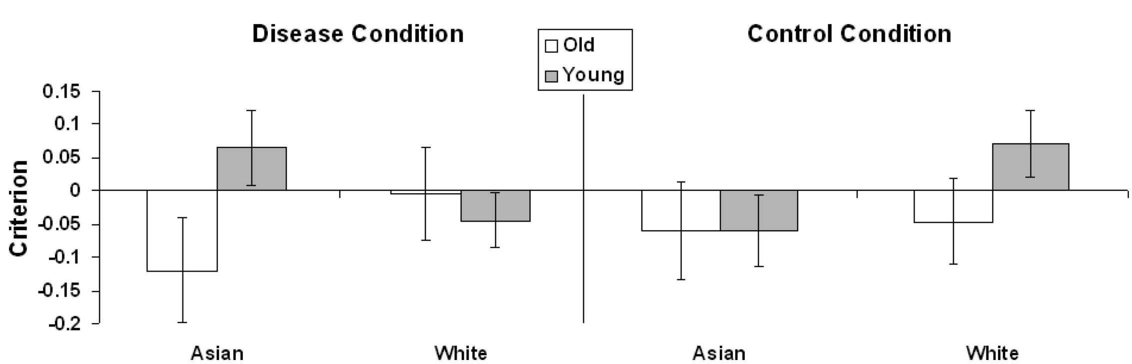

Figure 6. Study 4: Low-Perceived Vulnerability to Disease (PVD) participants primed with disease set a lower threshold for indicating that they had seen older targets than younger targets when those targets were Asian; there was no effect of target age among low-PVD participants primed with disease when the targets were White. There were no significant effects of target age or race among low-PVD participants in the control condition.

than younger targets when those targets were Asian, target age had no effect on c values when those targets were White. This pattern is consistent with research in other self-protective domains. For example, direct gaze is associated with perception of physical threat (Kawashima et al., 1999). However, when gaze is varied in concert with other cues of physical threat (e.g., race), the effect of gaze on perceptions of threat depends on the presence of those other threat cues (whether the target is White or Black; Richeson et al., 2008). Indeed, when gaze direction and target race are varied simultaneously, the effect of gaze direction is only observed when the targets are Black (displaying heuristic racial cues of threat); there is no effect of gaze direction when the targets are White. These findings, along with the present results, are consistent with the idea that people focus their self-protective concerns on the most heuristically threatening individuals in a given environment. That is, when multiple cues can be used to identify potential threats, people engage self-protective processes primarily in response to those individuals displaying combinations of threat cues.

In this study, chronic concerns about disease influenced d' values for targets displaying heuristic disease cues. People high in PVD were less accurate in their memory for older targets and foils compared with younger targets and foils (reflected by lower d' values). This is similar to Study 1's findings in which high-PVD participants displayed lower accuracy in their memory for obese targets/foils compared with average-weight targets/foils. Together, these findings may suggest that individuals with chronic concerns about disease lack the ability to successfully differentiate in memory specific people from one another when those people display heuristic disease cues. This decreased accuracy appears to be specific to memory outcomes and to disease concerns stemming from one's chronic disposition. In no study did we observe effects of situational disease primes on d' values, nor did we observe effects of disease concerns on categorization d' values.

General Discussion

Avoiding the threat of infectious diseases has been a challenge faced by humans and their ancestors for millions of years. As a consequence, people developed a behavioral immune system composed of psychological and behavioral mechanisms designed to promote the detection and avoidance of potential disease carriers. The present research reveals specific cognitive biases reflecting the underlying operation of that system.

Whereas previous studies of the behavioral immune system have provided insight into the types of cues people heuristically associate with disease, the present research provides an understanding of the basic cognitive processes involved in the detection of those cues. Findings from the present studies reveal that concerns about disease promote a disease overperception bias—a tendency to overperceive the prevalence of individuals in the environment displaying heuristic disease cues. Across the present studies, concerns about disease produced a consistent pattern of effects on measures of cognitive bias (c values): Whether stemming from dispositional tendencies or situational primes, concerns about disease led people to set a relatively low threshold for identifying potential health threats.

The disease overperception bias was reflected in the outcomes of two lower order cognitive processes: categorization and memory. Although previous studies of the behavioral immune system have examined consequences of disease concerns for overt attitudes and discriminatory behavior, the present research is one of the first to directly investigate implications for lower order psychological process—those that serve as fundamental building blocks underlying higher order cognition, affect, and behavior. The present findings demonstrate that categorization and memory are shaped by the behavioral immune system so as to overcome the adaptive problem of detecting potential health threats.

Ultimate and Proximate Mechanisms

The overarching hypothesis that disease concerns lead people to overperceive the prevalence of others displaying heuristic disease cues was derived primarily from an evolutionary perspective. Throughout human history, diseases have been commonly transmitted through face-to-face social interaction. Consequently, people display adaptive biases that serve to limit exposure to potentially infected individuals (Neuberg et al., 2011). From this perspective, initially categorizing others as pathogen carriers may reduce the chances of interacting with a contagious individual. Similarly, overremembering disease cues in a situation may reduce the chances of interacting with disease carriers in similar situations in the future. Thus, biases in categorization and memory may reflect adaptations designed to help individuals avoid dangerous health threats.

However, it is also possible that these biases in overperception are not themselves adaptations but rather that they represent byproducts of other underlying disease-avoidance mechanisms. For example, one possible interpretation of these findings is that the categorization and memory biases we observed reflect underlying biases in attention. To the extent that individuals selectively attend to signs of possible infection in others (Ackerman et al., 2009), one might expect those individuals to subsequently overcategorize and overremember others as potential disease carriers. Another possible interpretation of our findings is that categorization biases reflect adaptations for disease avoidance and that memory biases reflect the consequences of initially overcategorizing people as disease carriers. That is, if one were biased toward initially overperceiving others as disease carriers, then one might consequently be more likely to overremember the presence of disease carriers later on.

The present studies were not designed to directly examine the connections between different cognitive processes, nor were they designed to differentiate adaptations from adaptive byproducts. The present studies were designed to identify specific lower order cognitive biases that emerge when the behavioral immune system is activated. In doing so, adopting a functionalist perspective provided a valuable framework from which to derive predictions about the nature of those biases. Nevertheless, directly investigating the functional benefits of such biases and understanding the degree to which downstream cognitive biases (e.g., in memory) are tied to earlier stage biases (e.g., in categorization or attention) is a worthwhile goal for future research.

Implications for Interpersonal Interactions

Although overperceiving threat in the environment may serve important adaptive functions associated with protecting one's health, this bias may also lead to negative consequences for social interactions. Perceiving the social world to be filled with harmful others is likely to stimulate a variety of potentially negative psychological and behavioral responses. For example, perceiving the world to be filled with threatening individuals may decrease people's interest in affiliating with others and engaging in normal face-to-face social interaction. Indeed, recent evidence suggests that disease concerns are associated with low levels of extraversion and increased social avoidance (Mortensen et al., 2010). Such outcomes might be exacerbated by an overperception of people displaying heuristic disease cues.

Perceptions of disease threat have also been linked to prejudicial and antisocial behaviors directed toward members of groups heuristically associated with disease, including the elderly, the obese, and members of foreign nations (Duncan & Schaller, 2009; Park et al., 2003, 2007). The lower order cognitive biases observed in the present studies could partially underlie those downstream forms of prejudice. For example, outgroup prejudice has been linked closely to the process of group categorization (Brewer, 1988; Gramzow & Gaertner, 2005). To the extent that disease concerns increase the likelihood of categorizing someone as a member of a stereotyped group, disease concerns may pave the way for increased prejudice and discrimination. The biases in categorization observed in the present studies may, therefore, serve as a precursor for psychological processes that unfairly favor particular individuals over others. The potential problems are all the more pernicious when one considers that the cues being used to detect disease (e.g., obesity, old age) are, for the most part, not actually indicative of transmittable disease. Thus, although negative perceptions of individuals displaying heuristic disease cues might serve ultimate functions associated with self-protection, they might nevertheless set the stage for unwarranted prejudice and discrimination.

Interactions Between the Situation and the Perceiver

The present findings are consistent with the notion that self-protective tendencies depend on factors within both the person and the situation. Studies 3 and 4 revealed interactions between chronic perceptions of vulnerability to disease and situational disease primes. Those high in perceived vulnerability to disease tended to overperceive disease cues even in the absence of situational disease primes. Those low in perceived vulnerability to disease displayed that tendency only when the situation primed concerns about disease.

Interactions between chronic social schemas and situational primes have been a focus of recent research on self-protective psychological processes. Yet, there is variation across studies in the specific patterns of those interactions. For example, in the domain of physical threat, situational primes of danger increase self-protective tendencies among those relatively high, but not low, in chronic perceptions of vulnerability to physical danger (Miller et al., 2010; Schaller et al., 2003). Similar to the present studies, in the domain of relationship threat, those chronically high in relationship investment engage in mate-guarding behaviors regardless of situational primes, whereas those low in relationship investment do so only when the situation indicates a potential threat to the relationship (Maner, Miller, Leo, & Plant, 2012). Even within a given domain, Person $\times$ Situation interactions can take a variety of forms. For example, although the present research indicated that situational disease primes increased the overperception of disease among those low in perceived vulnerability to disease, other research has reported that situational disease primes increase disease-avoidance processes primarily among those high in perceived vulnerability to disease (Duncan & Schaller, 2009; Mortensen et al., 2010). Indeed, even within a given study, interactions between chronic social schemas and situational primes may be observed for some dependent measures but not others (e.g., Mortensen et al., 2010, Study 1).

Although the present studies were designed to test hypotheses about the relationship between disease concerns and lower order cognitive biases, they were not designed to identify the specific variables leading to particular types of Person $\times$ Situation interactions. Nevertheless, one may speculate as to potential factors underlying particular interactive patterns. For example, one factor might be the strength of the situational prime. Strong primes that are overt and clearly linked with threat might stimulate self-protective processes regardless of individual differences; sitting next to someone on an airplane who is displaying severe flu symptoms and constantly coughing in one's direction is likely to engage disease-avoidance processes even among those who do not chronically feel vulnerable to disease. In contrast, weak primes that are relatively subtle and provide only a slight indication of potential threat might stimulate self-protective processes primarily among those individuals who feel particularly vulnerable to that threat; a small sneeze from a person sitting several rows ahead might capture the attention of only those individuals who are high in perceived vulnerability to disease. Future research would benefit from carefully investigating how and why particular situational primes interact with people's chronic social schemas to influence threat management processes.

The Role of Specific Disease Cues

The present research revealed memory and categorization biases for specific groups of individuals (the obese, the elderly, foreigners) who, in prior research, have been linked with disease concerns (Duncan & Schaller, 2009; Faulkner et al., 2004; Navarrete & Fessler, 2006; Park et al., 2007; Schaller et al., 2003). However, these are not the only groups heuristically associated with disease. Disease concerns also influence how people evaluate others with physical disabilities or asymmetrical faces (Park et al., 2003; Young, Sacco, & Hugenberg, 2012). Consequently, disease concerns may elicit memory and categorization biases for those groups of individuals as well.

Moreover, disease concerns should elicit memory and categorization biases for people displaying "real" indicators of infection (e.g., skin rashes, coughing). To highlight the generalizability of disease-based avoidance processes and to align our work with previous studies in this literature, we focused on heuristic cues of infection—cues that are assumed to signal infection but that may not be true indicators of transmittable disease. However, to be adaptive, concerns about disease should also promote vigilance to disease cues that reliably signal real sources of infection. Indeed, the degree of disease vigilance may vary with the strength of the association between a cue and its probability of reflecting a real health threat. We suspect that, when concerned about potential infection, people may display even stronger biases in response to others displaying physical attributes that historically have served as real sources of disease transmission (e.g., lesions). Future research examining the operation of the behavioral immune system would benefit from taking into account whether targets display disease cues reflecting heuristic versus true indicators of infection.

Theories of disease avoidance should also take into account why specific physical characteristics might be heuristically associated with disease. Some have suggested that because pathogens can produce a range of complex, highly variable physical abnormalities, any deviation from the morphological norm may be perceived as a heuristic indicator of infection (Ackerman et al., 2009; Park et al., 2007; Zebrowitz et al., 2003; Zebrowitz & Rhodes, 2004). For example, older adults display abnormal physical characteristics such as skin discoloration, disproportionate facial features, and abnormal hair distribution and color (Gilchrest, 1996; Gonzalez-Ulloa & Stevens-Flores, 1965; Guthrie, 1976). Foreigners can have different skin tone and facial proportions than the majority of the local population, and engage in behaviors that violate local rituals and norms in disease-relevant domains (e.g., food preparation, personal hygiene; Kurzban & Leary, 2001). Consequently, these groups may elicit affective and behavioral disease-avoidant reactions because they display morphologically abnormal characteristics and behaviors.

Others have argued that some groups are heuristically associated with disease, not because of atypical physical characteristics suggesting current infection, but because of characteristics suggesting the potential transmission of *novel* diseases—diseases that one's immune system may not be sufficiently prepared to fight off. For example, throughout evolutionary history, members of foreign groups may have carried novel pathogens to which one had not yet developed immunity (Fincher & Thornhill, in press; Letendre, Fincher, & Thornhill, 2010). Consequently, some groups, such as foreigners, may be perceived as a disease threat not because of deviations from the morphological norm, but because of an evolved tendency to perceive unfamiliar individuals as outgroup members and outgroup members as potential health threats.

Although our findings provide insight into how people cognitively process others who display heuristic disease cues, the present findings do not address why specific people are heuristically associated with disease. The overperception of disease cues may have different implications depending on why targets are heuristically associated with disease. For example, if illness cues reflect outgroup membership or a lack of familiarity, then overperceiving those cues may facilitate specific behaviors aimed at reducing outgroup threats (e.g., violent intergroup conflict), while also increasing a desire to affiliate with members of one's ingroup (Letendre et al., 2010). In contrast, if illness cues reflect abnormal morphologies, then an overperception of those cues may promote more general forms of social avoidance (Mortensen et al., 2010). Future research would benefit from testing these speculations directly.

Limitations and Future Directions

Additional limitations of the present studies provide valuable opportunities for further research. One limitation pertains to potential biases displayed by perceivers who themselves display heuristic disease cues. It is unclear whether belonging to a group heuristically associated with disease would influence the way individuals perceive members of their own group or other groups linked to disease. For example, it is unclear whether an obese individual would respond to disease concerns by displaying biases in their perceptions of other obese people or elderly people. To the extent that people are more familiar with characteristics that they themselves possess, one might at least expect to observe less bias in their perception of similar others (cf. Shapiro & Neuberg, 2008). This remains an interesting empirical question for future studies.

Another limitation is that our investigation was conducted within a relatively static and artificial laboratory environment. The goal of our studies was to provide rigorous and tightly controlled experimental tests of our hypotheses. Yet, social cognition is designed to help individuals navigate dynamic social environments. Examining the extent to which behavioral immune system processes occur outside laboratory settings is an important goal for future research.

Conclusion

The physiological and behavioral immune systems have been central to human survival for millions of years. Although decades of research have provided insight into the operation of the physiological immune system, only recently have researchers begun to examine the behavioral immune system. The present research provides important insight into the basic operation of that system. Disease concerns promoted systematic biases in the cognitive processing of the social environment, leading to an overperception of people displaying heuristic disease cues. Although such biases may serve to protect the self from potential health threats, they may also have implications for destructive social processes such as prejudice and discrimination. The present investigation provides a useful springboard for investigating those implications.

At a broader theoretical level, these findings contribute to a burgeoning literature aimed at understanding the way lower order cognitive processes help solve adaptive social challenges. From an evolutionary perspective, the errors and biases observed in social perception can be understood through the lens of adaptationist thinking. Such errors and biases may reflect solutions to the recurrent adaptive challenges faced by humans throughout history (Kenrick, Griskevicius, Neurberg, & Schaller, 2010). By applying an evolutionary perspective to social cognition, the present research demonstrates one way in which psychological mechanisms may have been shaped to deal with recurrent forms of social peril.

References

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

Ackerman, J. M., Shapiro, J. R., Neuberg, S. L., Kenrick, D. T., Becker, D. V., Griskevicius, V., . . . Schaller, M. (2006). They all look the same to me (unless they're angry). *Psychological Science, 17,* 836–840. doi:10.1111/j.1467-9280.2006.01790.x

Argyle, M., & Cook, M. (1976). *Gaze and mutual gaze.* Cambridge, UK: Cambridge University Press.

Becker, D. V., Kenrick, D. T., Guerin, S., & Maner, J. K. (2005). Concentrating on beauty: Sexual selection and sociospatial memory. *Personality and Social Psychology Bulletin, 31,* 1643–1652. doi:10.1177/0146167205279583

Bodenhausen, G. V., & Macrae, C. N. (1998). Stereotype activation and inhibition. In R. S. Wyer Jr. (Ed.), *Advances in social cognition* (Vol. 11, pp. 1–52). Mahwah, NJ: Erlbaum.

Brewer, M. B. (1988). A dual-process model of impression formation. In R. S. Wyer Jr., & T. K. Srull (Eds.), *Advances in social cognition* (Vol. 1, pp. 1–36). Hillsdale, NJ: Erlbaum.

Cottrell, C. A., & Neuberg, S. L. (2005). Different emotional reactions to different groups: A sociofunctional threat-based approach to "prejudice." *Journal of Personality and Social Psychology, 88,* 770–789. doi:10.1037/0022-3514.88.5.770

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

Crandall, C. S., Nierman, A., & Hebl, M. (2009). Anti-fat prejudice. In T. D. Nelson (Ed.), *Handbook of prejudice, stereotyping, and discrimination* (pp. 469–487). New York, NY: Psychology Press.

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

Deaux, K., & Lewis, L. L. (1984). Structure of gender stereotypes: Interrelationships among components and gender label. *Journal of Personality and Social Psychology, 46,* 991–1004. doi:10.1037/0022-3514.46.5.991

Devine, P. G. (1989). Stereotypes and prejudice: Their automatic and controlled components. *Journal of Personality and Social Psychology, 56,* 5–18. doi:10.1037/0022-3514.56.1.5

Dougal, S., & Rotello, C. M. (2007). "Remembering" emotional words is based on response bias, not recollection. *Psychonomic Bulletin & Review, 14,* 423–429. doi:10.3758/BF03194083

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

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

Faulkner, J., Schaller, M., Park, J. H., & Duncan, L. A. (2004). Evolved disease-avoidance mechanisms and contemporary xenophobic attitudes. *Group Processes and Intergroup Relations, 7,* 333–353. doi:10.1177/1368430204046142

Fincher, C. L., & Thornhill, R. (in press). Parasite-stress promotes in-group assortative sociality: The cases of strong family ties and heightened religiosity. *Behavioral and Brain Sciences.*

Fiske, S. T., & Neuberg, S. L. (1990). A continuum model of impression formation from category-based to individuated processes: Influences of information and motivation to attention and interpretation. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 3, pp. 1–74). New York, NY: Academic Press.

Gilchrest, B. A. (1996). A review of skin ageing and its medical therapy. *British Journal of Dermatology, 135,* 867–875. doi:10.1046/j.1365-2133.1996.d01–1088.x

Gonzalez-Ulloa, M., & Stevens-Flores, E. (1965). Senility of the face: Basic study to understand its causes and effects. *Plastic and Reconstructive Surgery, 36,* 239–246. doi:10.1097/00006534-196508000-00013

Gramzow, R. H., & Gaertner, L. (2005). Self-esteem and favoritism toward novel in-groups: The self as an evaluative base. *Journal of Personality and Social Psychology, 88,* 801–815. doi:10.1037/0022-3514.88.5.801

Green, D. M., & Swets, J. A. (1966). Signal detection theory and psychophysics. New York, NY: Wiley. (Reprinted 1974 by Krieger, Huntington, NY)

Guthrie, R. D. (1976). *Body hot spots.* New York, NY: Van Nostrand Reinhold.

Harvey, T., Troop, N. A., Treasure, J. L., & Murphy, T. (2002). Fear, disgust, and abnormal eating attitudes: A preliminary study. *International Journal of Eating Disorders, 32,* 213–218. doi:10.1002/eat.10069

Haselton, M. G., & Nettle, D. (2006). The paranoid optimist: An integrative evolutionary model of cognitive biases. *Personality and Social Psychology Bulletin, 10,* 47–66. doi:10.1207/s15327957pspr1001_3

Kawashima, R., Sugiura, M., Kato, T., Nakamura, A., Hatano, K., Ito, K., . . . Nakamura, K. (1999). The human amygdala plays an important role in gaze monitoring: A PET study. *Brain, 122,* 779–783. doi:10.1093/brain/122.4.779

Kenrick, D. T., Griskevicius, V., Neurberg, S. L., & Schaller, M. (2010). Renovating the pyramid of needs: Contemporary extensions built upon ancient foundations. *Perspective on Psychological Science, 5,* 292–314. doi:10.1177/1745691610369469

Klein, S. B., Cosmides, L., Tooby, J., & Chance, S. (2002). Decisions and the evolution of memory: Multiple systems, multiple functions. *Psychological Review, 109,* 306–329. doi:10.1037/0033-295X.109.2.306

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

Kurzban, R., Tooby, J., & Cosmides, J. (2001). Can race be erased? Coalition computation and social categorization. *Proceedings of the National Academy of Sciences, 98,* 15387–15392. doi:10.1073/pnas.251541498

Letendre, K., Fincher, C. L., & Thornhill, R. (2010). Does infectious disease cause global variation in the frequency of intrastate armed conflict and civil war? *Biological Reviews, 85,* 669–683.

MacMillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide.* Cambridge, England: Cambridge University Press.

Macrae, C. N., & Bodenhausen, G. V. (2000). Social cognition: Thinking categorically about others. *Annual Review of Psychology, 51,* 93–120. doi:10.1146/annurev.psych.51.1.93

Macrae, C. N., & Bodenhausen, G. V. (2001). Social cognition: Categorical person perception. *British Journal of Psychology, 92,* 239–255. doi:10.1348/000712601162059

Maner, J. K., Kenrick, D. T., Becker, D. V., Delton, A. W., Hofer, B., Wilbur, C. J., & Neuberg, S. L. (2003). Sexually selective cognition: Beauty captures the mind of the beholder. *Journal of Personality and Social Psychology, 85,* 1107–1120. doi:10.1037/0022-3514.85.6.1107

Maner, J. K., Kenrick, D. T., Becker, D. V., Robertson, T., Hofer, B., Neuberg, S. L., . . . Schaller, M. (2005). Functional projection: How fundamental social motives can bias interpersonal perception. *Journal of Personality and Social Psychology, 88,* 63–78. doi:10.1037/0022-3514.88.1.63

Maner, J. K., Miller, S. L., Leo, J., & Plant, E. A. (2012). *Motivated social categorization: Fundamental motives enhance people's sensitivity to basic social categories*. Manuscript submitted for publication.

Maner, J. K., Miller, S. L., Rouby, D. A., & Gailliot, M. T. (2009). Intrasexual vigilance: The implicit cognition of romantic rivalry. *Journal of Personality and Social Psychology, 97,* 74–87. doi:10.1037/a0014055

Miller, S. L., & Maner, J. K. (2011). Sick body, vigilant mind. The biological immune system activates the behavioral immune system. *Psychological Science, 22*, 1467–1471.

Miller, S. L., Maner, J. K., & Becker, D. V. (2010). Self-protective biases in group categorization: Threat cues shape the psychological boundary between "us" and "them." *Journal of Personality and Social Psychology, 99,* 62–77. doi:10.1037/a0018086

Mortensen, C. R., Becker, D. V., Ackerman, J. A., Neuberg, S. L., & Kenrick, D. T. (2010). Infection breeds reticence: The effects of disease salience on self-perceptions of personality and behavioral avoidance tendencies. *Psychological Science, 21,* 440–447. doi:10.1177/0956797610361706

Navarrete, C. D., & Fessler, D. M. T. (2006). Disease avoidance and ethnocentrism: The effects of disease vulnerability and disgust sensitivity on intergroup attitudes. *Evolution and Human Behavior, 27,* 270–282. doi:10.1016/j.evolhumbehav.2005.12.001

Nesse, R. M. (2005). Natural selection and the regulation of defenses: A signal detection analysis of the smoke detector principle. *Evolution and Human Behavior, 26,* 88–105. doi:10.1016/j.evolhumbehav.2004.08.002

Neuberg, S. L., Kenrick, D. T., & Schaller, M. (2011). Human threat management systems: Self-protection and disease avoidance. *Neuroscience and Biobehavioral Reviews, 35,* 1042–1051. doi:10.1016/j.neubiorev.2010.08.011

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

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

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

Richeson, J. A., Todd, A. R., Trawalter, S., & Baird, A. A. (2008). Eye-gaze direction modulates race-related amygdala activity. *Group Processes and Intergroup Relations, 11,* 233–246. doi:10.1177/1368430207088040

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

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

Schaller, M., Park, J. H., & Faulkner, J. (2003). Prehistoric dangers and contemporary prejudices. *European Review of Social Psychology, 14,* 105–137. doi:10.1080/10463280340000036

Shapiro, J., Ackerman, J., Neuberg, S. L., Maner, J. K., Becker, D. V., & Kenrick, D. T. (2009). Following in the wake of anger: When not discriminating is discriminating. *Personality and Social Psychology Bulletin, 35,* 1356–1367. doi:10.1177/0146167209339627

Shapiro, J. R., & Neuberg, S. L. (2008). When do the stigmatized stigmatize? The ironic effects of being accountable to (perceived) majority group prejudice-expression norms. *Journal of Personality and Social Psychology, 95,* 877–898. doi:10.1037/a0011617

Stangor, C., Lynch, L., Duan, C., & Glass, B. (1992). Categorization of individuals on the basis of multiple social features. *Journal of Personality and Social Psychology, 62,* 207–218. doi:10.1037/0022-3514.62.2.207

Tajfel, H. (1978). The achievement of group differentiation. In H. Tajfel (Ed.), *Differentiation between social groups* (pp. 77–98). London, England: Academic Press.

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

Welling, L. L., Conway, C. A., DeBruine, L. M., & Jones, B. C. (2007). Perceived vulnerability to disease predicts variation in preferences for apparent health in faces. *Journal of Evolutionary Psychology, 5,* 131–139. doi:10.1556/JEP.2007.1012

Young, S. G., Sacco, D. F., & Hugenberg, K. (2012). *Vulnerability to disease is associated with a domain-specific preference for symmetrical faces relative to symmetrical non-face stimuli*. Manuscript submitted for publication.

Zebrowitz, L. A., Fellous, J. M., Mignault, A., & Andreoletti, C. (2003). Trait impressions as overgeneralized responses to adaptively significant facial qualities: Evidence from connectionist modeling. *Personality and Social Psychology Review, 7,* 194–215. doi:10.1207/S15327957PSPR0703_01

Zebrowitz, L. A., & Rhodes, G. (2004). Sensitivity to "bad genes" and the anomalous face overgeneralization effect: Cues validity, cue utilization, and accuracy in judging intelligent and health. *Journal of Nonverbal Behavior, 28,* 167–185. doi:10.1023/B:JONB.0000039648.30935.1b

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