Contagious or Not Contagious: Is that the Question? Evaluating the Effects of Disease Contagion on Memory

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Researchers have suggested that individuals possess a disease-avoidance system designed to detect and remember potential sources of harmful pathogens, a system termed the behavioral immune system. Consistent with this system, evidence has shown an increase in memory for objects that are physically touched by individuals who are contaminated with a contagious disease versus individuals with a non-contagious disease or who are healthy. We further extend these findings by examining correct and false memory using the Deese/Roediger-McDermott (DRM) paradigm in which individuals study lists of associates (e.g., bed, rest, tired, etc.) that converge upon a single critical lure (e.g., sleep), which is often falsely recalled and/or recognized at a later test. Participants studied associative lists that were presented auditorily by an individual described as either infected with a contagious disease (influenza), infected with a noncontagious disease (cancer), or healthy. On final recall and recognition tests, neither correct nor false memory were found to differ across disease groups, suggesting that disease-related information may not affect memory processes for words presented auditorily, and that have not been physically contacted by an infected individual.

Exposure to potential sources of disease is common. Fortunately, disease exposure is rarely fatal, which is partially attributable to well-tuned biological processes designed to eliminate threats that can harm the body. Specifically, the biological immune system has evolved over time to retaliate against pathogens that enter internally to stave off illness (Schaller & Park, 2011). While the immune system is generally effective at thwarting pathogenic threats, its operation is not cost free. In response to pathogens, for instance, individuals may show an increase in mucus production and develop a cough to quarantine and clear the respiratory system of foreign particles. Furthermore, individuals often develop a fever to create an inhospitable environment for infectious pathogens. In these cases, symptoms are uncomfortable and require considerable energy to rid the body of pathogens.

Given the cost of the biological immune system, researchers have suggested that individuals may have evolved another way to detect and avoid pathogenic sources through the behavioral immune system (BIS; Schaller, 2006; Schaller & Duncan, 2007). An effective BIS requires a high-functioning cognitive system to encode, store, and retrieve stimuli associated with a diseased source that may be harmful to the self. The purpose of this study is to provide an additional test of whether memory processes are indeed more sensitive to information across different sensory domains associated with potential pathogens, consistent with the BIS. To this end, the present experiment will examine memory performance for lists of words when audibly presented by individuals who are described as infected by a contagious or non-contagious disease versus a healthy individual.

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Disease-Avoidant Effects on Memory

Disease-avoidant behaviors have been well documented in humans and other animals. For example, animals have been shown to avoid other members of their own species who are perceived as contaminated with pathogens (Behringeret al., 2006; Loehle, 1995), and engage in grooming behaviors to remove potential pathogens from themselves and others (Eckstein & Hart, 2000; Zhukovskaya et al., 2013). Humans show similar avoidant behaviors. For example, individuals have shown greater repelling arm movements towards faces when primed with disease-related information (Mortensen et al., 2010), and exhibit disgust responses towards infectious sources (Schaller & Duncan, 2007; Schaller & Park, 2011). Disgust responses are triggered by a variety of stimuli including bodily functions that are often a byproduct of illness (e.g., sneezing, itching, coughing, etc.), foods that have spoiled, and animals that may be carriers of pathogens (e.g., ticks, fleas, mosquitos, etc.; Tybur et al., 2009; Tybur et al., 2013). Therefore disgust may reflect activation of the BIS which would encourage individuals to avoid pathogenic sources.

Consistent with behavioral-avoidance systems, accumulating evidence suggests that cognitive systems have adapted to process and retain information relevant to genetic longevity. For instance, females show greater memory for male faces in a long-term dating context versus a long-term worker context with whom they would establish a "long-term contract," such as by creating a team to develop important projects (Pandeirada et al., 2017). Furthermore, there is evidence that processing information based on its perceived relevance towards survival improves memory relative to information that has not been processed based on survival relevance. This memory improvement has been termed the survival-processing effect (Nairne et al., 2007; Nairne & Pandeirada, 2016) and has been suggested to be the result of an evolutionary process in which the cognitive system has been selectively "tuned" to remember information that can benefit survival and increase the likelihood of reproduction—consistent with the natural selection process.

To evaluate whether cognitive processes are sensitive to survival-related information, Nairne et al. (2007) asked participants to study lists of words using a survival-processing task. In this task, participants were asked to imagine that they were stranded in the grasslands of a foreign land and would need to sustain their own survival. Participants then rated words based on their relevance to the survival scenario. When tested, processing words based on survival relevance increased correct memory relative to a control task in which participants imagined that they were moving to a new city and rated the words based on their relevance for thriving in a new location. Importantly, this control task mimicked many of the elements of the survival task but lacked the survival component.

Subsequent experiments have revealed that the survival-processing effect is robust. It holds relative to powerful deep study tasks such as pleasantness ratings and self-referential encoding (Craik & Lockhart, 1972; Kang et al., 2008), and under survival scenarios outside of the grasslands scene (e.g. surviving a zombie apocalypse; Soderstrom & McCabe, 2011; Nairne & Pandeirada, 2010), and being socially isolated or around potential attackers (Kostic et al., 2012). Given the broad and reliable benefits for processing information based on survival relevance, an important question is whether information that could potentially compromise survival, such as sources of disease, may also be highly memorable to avoid contamination, potentially through activation of the BIS.

To evaluate the effects of diseased sources on memory, Fernandes et al. (2017) presented participants with pictures of objects that were paired with a face of an individual who presumably interacted with the object. Critically, the faces were either paired with a description of the individual that communicated the presence of disease (e.g., "constant cough") or did not communicate disease information (e.g., "green eyes"). According to the law of contagion, disease-connoting objects transfer pathogens to individuals who encounter these objects, thereby inflicting harm (Frazer, 1922). Therefore, if individuals perceive objects as infectious, they will be more likely to remember them later. Consistent with this possibility, object recall was found to be greater when objects were paired with faces with a disease-related description than with a non-disease description. Thus, sources associated with disease may be processed more deeply and thus

better remembered than non-threatening sources due to BIS activation.

An important factor for whether disease knowledge will affect memory processes may be whether the disease is perceived as contagious and consequently threatening. In a separate study, Gretz and Huff (2019) examined whether association with disease alone is sufficient for enhancing memory, or if the disease needs to be perceived as contagious. Participants viewed a set of household videos in which a single actor interacted with a series of objects. Prior to viewing, participants were informed that the actor was either diagnosed with influenza (an infectious disease), cancer (a noninfectious disease), or that the actor was healthy. In addition, the influenza actor (but not the cancer or healthy actors) sneezed prior to touching objects in the videos to enhance the salience of the disease to viewers. Following the presentation of the videos, participants recalled objects presented in the videos with instructions to identify both touched and non-touched objects, followed by a source-recognition test. In the source-recognition test, participants were presented with a list of objects and were asked to classify each object as being one that was touched, not touched, or not presented in the videos. Correct recall and source recognition were found to be greater for items that were touched versus not; however, source recognition was particularly high for touched items in the influenza videos, but not for the cancer or healthy videos. Thus, knowledge of the actor having an infectious disease appears to facilitate contextual memory for objects that have been touched, presumably because participants can avoid these objects later and be less likely to contract a potential illness.

False Memory Errors and the Effects of Distinctiveness

In addition to examining correct memory, researchers have also been interested in memory errors which could negatively affect overall accuracy. Memory errors have generally been classified into two broad types: errors of omission and errors of commission. Omission errors refer to a retrieval failure, possibly due to a failure in encoding memory initially. Commission errors refer to remembering events that did not happen or remembering them differently than how they originally occurred (Roediger & McDermott,1995; Schacter, 1999). Given that commission errors are common and highly problematic due to their introduction of false details, it is important to determine whether methods that facilitate correct memory also enhance false memory. In particular, the present study examines whether disease salience may operate to improve memory accuracy by increasing correct memory while reducing memory errors.

A powerful method for inducing commission errors in a laboratory setting is the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In this paradigm, participants study lists of strongly related words that are presented auditorily (e.g., bed, rest, tired, dream, etc.) that all converge upon a single non-presented critical lure (e.g., sleep). This critical lure is an item that is related to the presented list of associates but does not appear in the initial study list. After studying the list, participants then complete a memory test in which false recall and recognition of critical lures often meet or even exceed correct memory rates for presented items. The robust pattern of false recall and recognition is termed the DRM illusion. Given the power of the DRM illusion, researchers have explored several ways to reduce it. The DRM illusion has been reduced (but not eliminated) when participants had been warned about it, especially before studying (Gallo et al., 1997; Gallo et al., 2001), and when participants had been given more time to study list words (McDermott & Watson, 2001). Relevant to our study, the DRM illusion has also been reduced following distinctive item-specific encoding, occurring when participants focus on unique characteristics of list items. Item-specific encoding increases correct recognition while producing a concomitant reduction in false recognition—a pattern termed a mirror effect since correct and false are inversely correlated (Glanzer & Adams, 1990; Gunter et al., 2007; Huff et al., 2015; McCabe et al., 2004). Given Gretz and Huff's (2019) findings that pathogenic concerns associated with influenza facilitate memory for item-specific source details, it was expected that influenza pathogenicity would produce a reduction in the DRM illusion.

In the present study, participants studied a set of DRM lists presented auditorily by a female speaker. An auditory rather than visual modality was chosen to be consistent with the standard DRM paradigm (Roediger & McDermott, 1995), and to test whether disease-related

effects on memory could be detected with non-visual stimuli. Critically, prior to the presentation of each study list, participants were informed that the speaker had either influenza (a contagious disease), cancer (a non-contagious disease), or was healthy and not afflicted with ailments (based on Gretz & Huff, 2019). Following study of each list, participants completed a free-recall test for the list of words followed by a final recognition test. Disease conditions were manipulated using a between-subject design.

According to the BIS account, correct memory should be enhanced for the influenza group over the cancer and healthy groups. Avoidance of this contagious influenza source should be associated with an increase in the likelihood of survival, therefore facilitating correct memory. False memory was expected to decrease when correct memory increases, if consistent with mirror effect patterns reported in the literature following item-specific encoding (e.g., Huff & Bodner, 2013).

To more effectively characterize the effects of the BIS on memory accuracy, participants in both experiments further completed the Perceived Vulnerability to Disease Scale (PVD; Duncan et al., 2009). The PVD is a dispositional rating scale that assesses an individual's concerns towards pathogens. The scale is composed of two subscales: one that assesses participants' beliefs concerning their susceptibility to infectious diseases, termed perceived infectability, and another that assesses emotional discomfort concerning pathogen transmission, termed germ aversion. Based on responses to this scale, it is possible that individuals who show greater concerns towards their own infectability and/or are more averse to germs may possess a more sensitive BIS and, therefore, more exaggerated memory effects. If so, then responses on the PVD and the two subscales will be positively correlated with correct memory but negatively correlated with false memory across conditions.

Method

Participants

Sixty-seven University of Southern Mississippi Psychology undergraduates participated for partial fulfillment of course credit. Six were removed for failure to follow experimental instructions, with the remaining participants randomly assigned to the influenza (N = 21), cancer (N = 18), or healthy (N = 22) groups. Participants ranged in age from 18 to 59, with a mean age of 22.77 (8.1) years. Most participants were female (68%) and of those who reported ethnicity, 54% of participants were Caucasian, 38% were African American, and less than 1% were Asian. All were proficient English speakers and reported normal or corrected-to-normal vision.

Materials

Twenty DRM lists containing the highest levels of mean backward associative strength (BAS) from the list items to the critical lure were taken from Roediger et al. (2001). BAS refers to the magnitude of association between the list items and the critical lure and has a strong positive correlation with false recall and recognition of critical lures (e.g., Roediger et al.). These DRM lists were divided into two sets of 10 lists to create two versions which were counterbalanced across participants. Each list contained 15 items that were presented in descending order of BAS. Due to experimenter error, two lists (the "Car" and "Chair" lists) were presented in a random BAS order instead. Lists were presented via audio recordings featuring two female speakers. Both speakers spoke in a plain, controlled manner, lacking any distinctive indicators of illness. Each word was read aloud at an approximate rate of one word every two seconds.

An 80-item recognition memory test was constructed and consisted of 30 items from study lists (from list positions 1, 8, and 10 in each list), 30 non-studied items from the lists in the non-studied version (from the same list positions), 10 critical lures from studied lists, and 10 critical lures from the lists in the non-studied version. The recognition test was randomized once and presented in the same order across participants.

The 15-item PVD scale (Duncan et al., 2009) was also administered. The PVD contains two subscales: perceived infectability and germ aversion, which correspond to separate dispositional responses. The perceived infectability subscale contains seven items to assess susceptibility to diseases (e.g., "I have a history of susceptibility to diseases."), whereas the germ aversion subscale consists of eight items to assess an individual's aversion to pathogenic threats (e.g., "It really bothers me

when people sneeze without covering their mouths."). A 7-point Likert scale was used to make responses ranging from strongly disagree (1) to strongly agree (7). Higher scores indicate greater perceptions of disease vulnerability. Six items were reverse scored. The overall PVD (M = 3.73; range = 1.87-5.80; α = .79), the germ aversion subscale (M = 4.23; range = 1.50-6.50; α = .74), and the perceived infectability subscale (M = 3.16; range = 1.57-6.71; α =.71) had acceptable reliabilities.

Procedure

Following informed consent, participants were tested individually via a computer using Microsoft PowerPoint and were instructed that they would be presented with lists of words auditorily and that their memory for these words would be tested. At this time, participants were presented with one of the condition-specific disease instructions. The influenza group was informed that "the individual reading this list has recently been diagnosed with influenza, a highly contagious disease that can result in fever, sore throat, and muscle or body aches." The cancer group was informed that "the individual reading the list has recently been diagnosed with cancer, a non-contagious disease that can result in anemia, the development of tumors, and changes in digestive movements." The healthy group was informed that "the individual reading this list is healthy and not afflicted with ailments." Additionally, each group was presented with a photograph of a female who visually matched the description presented in each disease group to better portray the disease status of the speaker reading the word lists. Specifically, the photograph in the influenza group depicted a female who was blowing her nose next to bottles of medicine. The photograph in the cancer group depicted a female with no hair. The photograph in the healthy group depicted a female who was smiling at the camera (Appendix).

After listening to each list, participants then completed a one minute arithmetic filler task followed by a one minute free-recall test. Using a filler task is a standard procedure for testing the DRM paradigm (e.g., Huff et al., 2011; Roediger & McDermott, 1995). The free-recall test instructed participants to write down as many words as possible from the list in any order on a provided sheet of paper. Immediately following the free-recall test, participants then completed another study/recall cycle until all 10 lists were tested. Disease information was repeated prior to each study list to ensure participants were aware of the disease status of the speaker.

After the final study/recall cycle, participants then completed an old/new recognition test. They were presented with a sheet of paper with 80 words and were instructed to determine whether each word was "old" and studied on a previous list, or "new" and not studied on a previous list by placing a checkmark into the old or the new column. The recognition test was untimed, and participants were required to make a response for every item. Following the recognition test, participants completed the PVD, a brief demographics questionnaire, and were then debriefed regarding the purpose of the study. The experimental session lasted approximately 60 minutes.

Results

All data were analyzed using SPSS statistics software. Table 1 reports recall and recognition performance as a function of disease group. For recognition analyses, a signal-detection measure of discriminability (d') was computed. False alarm rates of 0 and hit rates of 1 were adjusted using Macmillan and Creelman's (1991) 1/2n correction. For correct recognition, d' was computed by taking the z-score for the list item hit rate minus the z-score for the false alarm rate for list item controls. Similarly, for false recognition, d' was computed by taking the z-score for "hit" rates to critical lures minus the z-score for false alarms to critical lure controls1[1] (see Huff & Bodner, 2013; Schacter et al., 1999, for an identical application of signal detection to critical lures).

An alpha level of .05 was used for all results reported unless otherwise noted. All non-significant effects were further tested using a Bayesian estimate of evidence supporting the null hypothesis (Masson, 2011; Wagenmakers, 2007).

1 1For completeness, we include adjusted correct and adjusted false recognition scores in Table 1. Adjusted scores were taken by subtracting raw false alarm rates to control items from the respective raw recognition rates for studied list items and critical lures. Analyses using adjusted recognition scores showed identical statistical patterns as the d' analysis and are therefore not discussed further.

Table 1

Mean (SE) Recall and Recognition Proportions for Studied List Items, Critical Lures, and Extra-List Intrusions per List as a Function of Influenza, Cancer, and Healthy Disease Groups

Disease Group/ Test Type	Influenza	Cancer	Healthy
N	21	18	22
Recall Test			
List Items	.50 (.02)	.47 (.02)	.45 (.02)
Critical Lures	.48 (.04)	.59 (.05)	.50 (.05)
Extra-List Intrusions	.76 (.13)	.73 (.13)	.67 (.12)
Recognition Test			
List Items	.81 (.02)	.85 (.02)	.83 (.02)
List Item Controls	.09 (.02)	.12 (.02)	.11 (.02)
List Item *d'*	**2.45 (.16)**	**2.55 (.18)**	**2.40 (.13)**
Adjusted List Items	.72 (.03)	.74 (.04)	.72 (.03)
Critical Lures	.79 (.04)	.74 (.04)	.72 (.03)
Critical Lure Controls	.19 (.03)	.21 (.05)	.13 (.03)
Critical Lure *d'*	**1.87 (.19)**	**2.09 (.19)**	**2.39 (.12)**
Adjusted Critical Lures	.60 (.06)	.66 (.05)	.76 (.03)

Note. Boldface indicates *d'* values included in the reported analyses. Adjusted recognition proportions reflect corrected scores (i.e., List Items and Critical Lures minus Control Items) and analyses are included in Footnote 1.

The Bayesian analysis compares the probabilities for two models: one that assumes an effect and one that assumes no effect, given the observed data. For this Bayesian analysis, we assumed that the two models had equal prior probabilities. This analysis yields a probability estimate that the null effect is retained, a p-value termed pBIC (the posterior probability given the Bayesian Information Criterion). Thus, for all null effects reported, we include a pBIC analysis which improves our confidence that the null effect is reliable. Additionally, a pBIC analysis is highly sensitive to sample size and can therefore serve as a proxy for a power analysis.

Free Recall

The three disease groups (healthy vs. cancer vs. influenza) were compared using a one-way ANOVA. Correct recall, false recall, and mean number of extra-list intrusions were not found to differ across disease groups, $F(2, 58) = 1.20$, $MSE = .01$, $p = .31$, $pBIC = .95$; $F(2, 58) = 0.80$, $MSE = .05$, $p = .45$, $pBIC = .96$; and $F(2, 58) = 0.30$, $MSE = .34$, $p = .74$, $pBIC = .98$, respectively. Therefore, disease status of the individual presenting auditory word lists produced no effect on any of the recall measures.

Recognition

Recognition analyses were conducted on d′ values as reported above. For correct recognition of studied list items, the one-way ANOVA yielded no effect of disease group on d′ , $F(2, 58) = .24$, $MSE = .50$, $p = .79$, $pBIC = .98$. For false recognition d′, a marginal difference was found across groups based on a standard null-hypothesis significance testing, but, importantly, evidence from the Bayesian analysis indicated fairly strong evidence in support of the null effects, $F(2, 58) = 2.50$, $MSE = .59$, $p = .09$, $pBIC = .81$. Given strong support of the null, we did not further analyze individual groups. Thus, consistent with correct and false recall, disease conditions appear to affect neither correct recognition for studied list items nor false recognition for critical lures[2].

Table 2

Perceived Vulnerability to Disease Scale Correlations

	1	2	3	4	5	6	7
1. Correct Recall	-						
2. False Recall	-.09	-					
3. Correct RGN	.71**	-.01	-				
4. False RGN	.07	.34**	.39**	-			
5. PVD	-.11	-.06	.05	-.04	-		
6. Infectability	-.07	.08	-.09	-.12	.71**	-	
7. Germ Aversion	-.09	-.14	.13	.03	.85**	.23^	-

Notes. ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). ^ Correlation is marginal ($p = .05$-$.10$). RGN = recognition.

Correlations with the PVD Scale

Correlation analyses were then conducted to examine the relationship between memory responses and the PVD. These correlations, including the two subscales (infectability and germ aversion) are reported in Table 2. Given the relatively low number of participants in each disease group, correlation analyses collapsed across groups in order to maximize sensitivity and reliability. No significant relationships were found between the overall PVD scale and subscales, and correct or false recall and recognition, $rs < .14$, $p > .29$. Therefore, responses on the PVD were not related to memory performance on either

2 Analyses were similarly conducted on criterion c, a response bias estimate that often accompanies signal-detection analyses. Although we did not have any a priori reason to expect bias to differ as a function of disease condition, we conducted a separate analysis on c estimates. No difference was found across groups for c for studied list items, $F(2, 58) = 1.04$, $MSE = .12$, $p = .36$, $pBIC = .96$, nor for critical lures, $F(2, 58) = 0.53$, $MSE = .16$, $p = .59$, $pBIC = .97$. Thus, response biases were similarly unaffected by disease instructions.

the recall or recognition tests.

Discussion

The experimental findings failed to mimic patterns found in prior literature. Correct and false recall were equivalent across the disease groups and the healthy control, and this pattern was echoed on correct and false recognition. Disease-related effects on memory were similarly absent when correlations were computed between recall and recognition performance and the PVD scale. Here, no relationships were found, suggesting that individual dispositional responses towards disease vulnerability were not related to memory performance when diseased sources provided memory information auditorily.

A possible reason for these null effects may be a lack of direct physical contact between the diseased source and memory items. As mentioned above, an auditory modality was chosen in part to be consistent with the standard DRM paradigm; however, this presentation type has not been used in past literature and may have limited disease-related effects on memory.

For instance, in Fernandes et al. (2017), participants were explicitly told that memory objects were touched by individuals with characteristics consistent with diseases, thereby producing a physical "vector" allowing disease to infect studied objects which may have been perceived as threatening to participants. Similarly, in Gretz and Huff (2019), videos included actors who physically interacted with objects which also established a disease vector. In the present experiment, participants were auditorily provided with word lists and descriptions of the speakers' disease states, but a direct vector between the disease state and the studied item was not created. Physical interaction between the diseased speaker and the memory item might therefore be critical for demonstrating disease-related effects on memory.

Additionally, another reason why this study failed to find disease-related effects on memory could have been that participants did not believe or were not heavily affected by the disease manipulation. According to Nairne et al. (2007), only information that is relevant to an individual's survival chances will enhance retention. In this experiment, participants may not have perceived the disease state of the speaker as threatening to their well-being. Indeed, word lists were presented through computer speakers, and the speakers spoke with clear voices that were likely incongruent with the expectations of a diseased state. The information provided about influenza and cancer disease states may therefore have been rendered ineffective. Future research could examine this possibility by presenting word lists read aloud by speakers who better match the appropriate disease condition. For example, a healthy person would have the control voice used in this experiment, while the cancer or influenza speakers would be frail or nasally to better emulate illness auditorily.

Disease potency could also have been a key player. In Fernandes et al. (2017), the diseases presented to participants were not specified. Without this detail, subjects may have perceived the disease characteristics to be extremely potent. Our experiments clearly stated the disease state of each presenter, leaving little room for imagination. Influenza was used as the contagious disease state due to its common occurrence in the population and would therefore have been experienced by most participants. While symptoms associated with influenza may be easily recognizable, the actual term of the illness might not have been, as the word "flu" is more readily recognized and used in the common vernacular. Disease-related effects of memory may have occurred if the disease was more severe, such as Ebola, measles, or coronavirus—possibilities that are currently being explored.

As mentioned above, future studies could examine different contagious illnesses with varying degrees of severity. A reasonable extension of this study could also study a different population (e.g., older population), as the participants used in this study were college students. In summary, the present study further tested the role of adaptive memory and how it may be moderated by the effects of the BIS when individuals are faced with potential disease-related threats. In an experiment modeled after prior work from Fernandes et al. (2017) and Gretz and Huff (2019), participants were presented with word lists read by healthy individuals or those with an infectious or non-infectious disease. Memory for these word lists showed no differences as a function of disease state, and the use of Bayesian analyses indicated strong support for the null effect. This study suggests that findings reported

previously for the visual modality do not generalize to the auditory modality. The discrepancy with prior literature could be due to a variety of the methodological differences discussed above; however, the present study demonstrates that disease-related effects on memory may not always occur consistently.

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Appendix

Photographs of Disease States

Cancer

Healthy

Influenza