THE DEVELOPMENT OF DISEASE-AVOIDANT BEHAVIOR

by

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ABSTRACT OF THE DISSERTATION

The Development of Disease-Avoidant Behavior

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Understanding how children and adults behave in situations in which they might become ill is critical for preventing the spread of infectious disease. Avoiding individuals who show signs of infectious disease would have been beneficial over evolutionary history, so such behavior may appear early in development and persist throughout adulthood (Boyer & Bergstrom, 2011; Neuberg, Kenrick & Schaller, 2011; Schaller & Park, 2011; Rottman, 2014). However, little has examined whether adults and children actually exhibit behavioral avoidance of contagion, (i.e., sick individuals, and contaminated objects). In addition, psychological mechanisms underlying the development of behavioral avoidance, such as the role of causal knowledge of illness transmission, have not been investigated empirically. In Study 1, we investigated whether adults exhibit behavioral avoidance of illness, and found that they do. In Studies 2, 3, and 4, we explored whether and at what age children show avoidance behavior of sick individuals and contaminated objects. In Studies 2 and 3, we found that preschoolers did not avoid contaminated objects, and that their causal knowledge was unrelated to their behavior. In Study 4, we included older children, and measured whether they avoid contagion, or

people who have a contagious illness. We found that children as a group did not avoid contagious individuals until around the age of six, but that avoidance behavior was best predicted by their causal knowledge of contagious illness rather than age. In fact, even 4-year-old children who were able to make predictions about illness transmission in our sample avoided contagious individuals. Finally, in Study 5 we investigated whether prompting preschool aged children to generate explanations about illness would increase their causal knowledge about illness and their avoidance of contagion. Although we did not find an increase in knowledge and avoidance behavior as a result of providing causal explanations, children who were prompted to talk about the point of illness transmission in the story were more likely to avoid. Together, these studies constitute the first developmental investigation of avoidance behavior towards sick individuals and contaminated objects, and our results suggest that avoidance of illness is not early developing and depends on causal knowledge of illness transmission.

Preface

This dissertation is submitted for the degree of Doctor of Philosophy at Rutgers University, Newark. The research described herein was conducted under the supervision of Dr. Vanessa LoBue in the Department of Psychology, Rutgers University, Newark between January 2013 and May 2016.

The work is an original intellectual product of the author, K. Blacker, except where acknowledgements and references are made to previous work. Neither this, nor any substantially similar dissertation has been or is being submitted for any other degree, diploma, or other qualification at any other university.

Part of this work has been presented in the following conference formats and journal publications:

Blacker, K. & LoBue, V. (2016). Behavioral Avoidance of Contagion in Childhood. *Journal of Experimental Child Psychology,* 143, 162-170.

Blacker, K. Bonawitz, E., & LoBue, V. (2015, October). "Why is she sick? Prompting preschoolers to provide explanations during storybook reading increases causal learning about illness." Poster presented at the biennial meeting for the Cognitive Development Society, Columbus, OH.

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Blacker, K. & LoBue, V. (2013, October). "Children's knowledge and avoidance of contagious illness." Poster presented at the biennial meeting of the Cognitive Development Society, Memphis, TN.

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The Development of Disease-Avoidant Behavior

Children are especially risky carriers of infection, not only because they are more likely to catch diseases themselves, but also by enabling greater transmission of infection to others (Bryant & McDonald, 2009; Lambe, et al., 2012; de Lencastre & Tomasz, 2002). Thus, it is critical that we understand how children behave when confronted with contagion and whether children can effectively learn behaviors that limit the spread of disease throughout the population. Although there is a body of research examining children's conceptual understanding of illness transmission, only a handful of studies have examined how children *behave* when presented with contaminated objects (e.g., Rozin & Fallon, 1987; DeJesus, Shutts, & Kinzler, 2015), and no research has examined how children's behavior is affected by being confronted by a sick or contagious person. The lack of data on this topic is problematic, as contact with or exposure to sick people is what causes contagious illnesses to spread. Thus, studying children's behavior when faced with the threat of getting sick has practical applications for preventing children from becoming ill and spreading illness to others.

In addition to having practical benefits for preventing the spread of illness, studying children's illness avoidance is of theoretical importance. Behavioral immune system theory proposes that humans have a system of psychological mechanisms that protect against infectious disease, and predicts that behaviors leading to the avoidance of harmful pathogens should appear early in childhood and persist into adulthood (Rottman 2014; Schaller & Park 2011; Neuberg, Kenrick & Schaller, 2011). Evidence suggests that adults engage in behaviors that limit contact with pathogens (Ryan, Oaten, Stevenson & Case, 2012; Park, Van Leeuwen & Chochorelou 2013). However, due to the lack of data on children's behavior, the developmental trajectory of these behaviors and the mechanisms underlying them remain unexplored. Examining children's behavior can shed light on whether avoidance of illness appears early in development and whether other factors, such as knowledge about illness, influence the development of avoidance behavior.

Avoidance Behaviors in Adults

According to behavioral immune system theory, a system of psychological mechanisms evolved to protect against contracting infectious disease (Schaller & Park, 2011; Neuberg, Kenrick & Schaller, 2011). These mechanisms detect cues in the environment that signal the presence of an infectious disease and then initiate cognitive and emotional responses that lead to avoidance behavior. These mechanisms of disease avoidance are thought to be so robust that people exhibit avoidance behavior in cases where an infectious disease is not present, such as in the presence of people with disabilities or non-contagious illnesses, erring in favor of minimizing costly false-negative errors (Duncan & Schaller, 2009; Park, Faulkner & Schaller, 2003; Mortensen et al., 2010; Park, Schaller & Crandall, 2007; Schaller & Neuberg, 2012).

Indeed, adults believe that contagious illnesses are more likely to be transmitted to others than non-contagious illnesses, and have a greater desire to avoid individuals with contagious illnesses than non-contagious illnesses (Kouznetsova et al., 2012). Similarly, adults are less comfortable making physical contact than nonphysical contact with individuals who have contagious diseases (Park, Van Leeuwin and Chochoelou, 2013).

Further, adults have negative attitudes about individuals with noncontagious illnesses. Using the Perceived Vulnerability to Disease (PVD) scale, which measures individual differences in how likely people think they are to get sick as well as well as their aversion to germs, and the Implicit Associations Test (IAT), which measures whether people associate negative words or words from a particular category (i.e., disease) with members of certain groups of people (i.e., people with chronic illnesses and disabilities that are not contagious), researchers have reported an association between high PVD and negative attitudes toward the disabled and obese on the IAT (Park et al., 2003; Park et al., 2007). This has been interpreted as evidence that the behavioral immune system is so robust that it overgeneralizes to people with non-contagious illnesses and disabilities.

Although these studies demonstrate that adults report a desire avoid individuals with a variety of contagious and non-contagious illnesses and feel uncomfortable making physical contact with them, it is possible that ratings of discomfort do not reflect whether an adult would actually exhibit avoidance behavior. Since the purported function of the behavioral immune system is to produce behavior that reduces exposure to harmful pathogens, it is important to evaluate whether or not adults exhibit actual avoidance of individuals with infectious diseases and contaminated objects in a way that would reduce contact with these pathogens.

Little empirical research has examined adults' avoidance behavior in response to an individual with an infectious disease. Ryan, Oaten, Stevenson and Case (2012) asked participants to imitate an action with a group of objects after watching someone perform those same actions on a video. Participants were told that the object they were using was the same one used in the video, and that the videos had been recorded that same day. Importantly, depending on the trial, the person in the video had an infectious illness (influenza), a non-contagious facial birthmark, or neither (control). Participants were far less likely to make oral contact with the objects if the person had influenza or a facial birthmark compared to the control condition, but there was no difference in their willingness to touch the objects with their hands, head, or face. This suggests that adults avoid oral contact with an object previously used by someone with a common infectious illness. However, participants were still willing to touch the objects, and even bring the objects up to their faces if touched by someone with the flu. Therefore, it remains unclear whether adults avoid contagious individuals and contaminated objects in a more natural setting.

Avoidance Behaviors in Children

Although existing work on behavioral immune system theory focuses on adults, the theory predicts that young children from around the age of weaning (two years of age), should avoid individuals with contagious illnesses, just as adults do (Rottman 2014). To date, little work has measured children’s responses to infectious disease. A thorough investigation of children’s avoidance of infectious disease and the mechanisms underlying the development of these behaviors could provide support for behavioral immune system theory if these behaviors are shown to be early developing.

Only one study has measured children’s avoidance behavior in a situation where they could become sick. DeJesus, Shutts and Kinzler (2015) presented 3- to 8-year-old children with a video depicting two actors each sitting behind a bowl of applesauce. Both actors consumed some of the applesauce with a spoon, but one actor sneezed into the bowl. The actor who sneezed put her spoon into the bowl of applesauce, while the other actor put a new, unused spoon into her bowl. After viewing the video, children were allowed to try food from either of the bowls. Three- and 4-year-old children consumed equal amounts of applesauce from each bowl, but 5- to 8-year-olds consumed significantly more applesauce from the clean bowl than from the bowl that had been "contaminated" by the sneeze. However, even the older children in the sample consumed *some* of the applesauce, which still could have led to the transmission of illness.

These findings possibly contradict the predictions of behavioral immune system theory—which hypothesizes that avoidance of contaminated substances should appear quite early in development—since the youngest children in their sample did not avoid the contaminated applesauce and even the older children consumed some of it. However, it may simply be that the youngest children found it more difficult than older children to connect the bowls they saw in the video with the real bowls with which they were presented at test. Another possibility is that these results accurately reflect the developmental trajectory of illness avoidance, and that such behaviors are still developing between the ages of three and five.

If avoidance behavior does develop in this age range, the avoidance of infectious disease may be a learned behavior, and its development may depend in part on children's causal understanding of how infectious diseases are transmitted. This is one potential reason why the youngest children in DeJesus, Shutts & Kinzler (2015) did not avoid the contaminated applesauce: If causal knowledge of illness is developing in this age range, the youngest children in the sample may not have avoided the contaminated applesauce because they lacked the appropriate knowledge of how illnesses are transmitted, and thus failed to understand that consuming contaminated food might result in getting sick. Causal knowledge may make the signs of illness more salient to children and inform their response to such cues (Siegal, Fadda, & Overton, 2011).

In contrast to behavioral immune system theory, a learning account makes different predictions about the conditions under which children should exhibit avoidance behavior. If causal reasoning about how contagious illnesses are transmitted underlies children's avoidance behavior, then children who have not yet acquired this knowledge should fail to avoid sick individuals. In other words, children should only avoid contagious individuals and contaminated objects in contexts in which they know that that a person has an infectious disease, and understand that the infectious disease can be transmitted to them through contact or proximity.

Children's Knowledge of Illness Transmission

Unlike children's behavior towards sick individuals and contaminated objects, children's understanding of illness transmission (i.e., the transmission of illness caused by microbes through contagion and contamination) has been particularly well-researched in studies of causal learning in early childhood, as it sheds light on children's acquisition of biological knowledge as well as their more general ability to reason about non-obvious properties and mechanisms (e.g., Au, Sidle & Rollins, 1993; Kalish 1996; Keil, Levin, Gutheil, & Richman, 1999). Germs play a causal role in the transmission of illness, but although the term "germ," is generally introduced to children early in life, it refers to something that children cannot see or touch. Thus, researchers have taken an avid interest in how children develop concepts of illness and how illness is transmitted from one person to another.

Children's reasoning about illness begins to develop in the preschool years and continues throughout middle childhood. First, children acquire a basic understanding of *contamination*—that people can become sick by ingesting harmful substances such as poison and consuming food that has been contaminated by someone else's bodily fluids, such as saliva (Legare, Wellman & Gelman, 2009). When asked to explain why someone became ill, they can use their knowledge of contamination to select relevant explanations for why someone has become sick (e.g., from consuming contaminated food). However, although children show an understanding that ingesting contaminated food can make them sick, it is unknown whether they reason similarly about how contact with contaminated surfaces and objects can also lead to the spread of illness.

Reasoning about *contagion*—the transmission of illness from person to person—also begins to develop in early childhood (Kalish, 1999). Five- and 7-year-old children judge colds to be contagious (Bares & Gelman, 2008; Myant & Williams 2005), and preschoolers infer that illnesses that last for a short time are contagious, while those that persist over the course of a lifetime are not (Raman & Gelman, 2005). Even though preschoolers reason about the transmission of illness from person to person, it is still unclear whether they have any knowledge about particular situations and risk behaviors that can lead to such transmission. For example, a 5-year-old may judge colds to be contagious, but they may not know that risk behaviors such as contact with and proximity to someone who is sick are what lead to illness transmission. Thus, children may not reason about the causes of contagion in a way that allows them to infer whether or not illness transmission can occur in novel situations; such knowledge is critical in order to engage in behavioral avoidance.

Only one study to date has measured both children's knowledge about illness transmission and their subsequent behavior in contexts in which pathogen transmission can occur. Au et al. (2008) found that interventions designed to teach 8-year-olds about the conditions under which germs live and die effectively improved children's ability to identify specific scenarios in which illness transmission would be likely to occur. Importantly, children in the intervention were also more likely to wash their hands before handling food for other people to consume, even though they were not taught about that specific behavior in the intervention. This provides evidence that older children's causal knowledge about illness transmission influences their engagement in preventative behaviors. However, it is unclear whether having this kind of knowledge would increase avoidance behavior, or whether avoidance of illness develops separately, or whether such interventions would work with younger children.

The Current Research

In summary, children's understanding of illness transmission begins to develop in the preschool years. Despite a heavy focus on children's conceptual knowledge of illness in the developmental literature, the degree to which this knowledge influences children's behavior has not yet been investigated. Examining whether conceptual knowledge of illness underlies children's avoidance behavior is of theoretical importance, as it is a learning mechanism that behavioral immune system theory has not considered. Further, this potential relationship is of practical significance, as it can address whether interventions should aim to increase illness avoidant behaviors by increasing children's causal knowledge of how contagious illnesses are transmitted.

To date, there has been no empirical investigation of how avoidance of people with contagious illnesses develops or whether adults avoid contagious individuals in a natural setting. Furthermore, the mechanisms underlying avoidance behavior in childhood have not been examined empirically. Although behavioral immune system theory predicts that even the youngest children should avoid sick individuals (see Rottman 2014, *for review*), it is unknown whether they actually do, and whether children's causal knowledge underlies their avoidance behavior. Most importantly, in order to design more effective interventions that promote healthy habits, it is important to investigate whether causal learning mechanisms known to be present in early childhood can be exploited to teach children more adaptive behavior.

In the current research, we aim to address these issues. In Study 1, we examine whether adults exhibit behavioral avoidance of sick individuals in a naturalistic setting. In Studies 2 and 3, we examine whether 4- to 5-year-old children avoid playing with objects that have been contaminated by someone with a contagious illness, and whether their behavior is related to their knowledge of illness transmission. In Study 4, we measure whether 4- to 7-year-old children avoid contagiously sick people and whether their behavior is related to their knowledge. Finally, in Study 5 we explore a potential way to increase preschooler's conceptual knowledge of illness transmission in a way that in turn increases avoidance behavior.

If avoidance behavior develops early, unaided by the acquisition of causal knowledge about illness, even the youngest children in our studies should avoid the contaminated toys and sick individuals, providing the strongest support for behavioral immune system theory. However, children may not avoid the contaminated toys or sick people until later in childhood. If this is the case, behavioral immune system theory would have to account for why avoidance does not appear at the point in development at which it is hypothesized to have been evolutionarily adaptive, around two years of age (Rottman, 2014). Alternatively, causal knowledge of illness transmission may play a key role in the development of avoidance behavior. If this is the case, children's avoidance should relate to their knowledge, suggesting that causal knowledge is a potential mechanism underlying the acquisition of avoidance behavior.

Study 1

Study 1 aims to establish whether adults avoid contagious illness, with the goal of characterizing the "end state" of illness avoidance so that we can then examine its developmental trajectory. Although behavioral immune system theory predicts that adults should avoid people who show signs of infectious disease, research on behavioral avoidance in adulthood is limited. One study to date (Ryan et al., 2012) has measured adults' behavior when confronted with the threat of contracting a contagious illness. In this study, participants were instructed to imitate what an actor in a video was doing to a group of objects. These actions included touching the object, bringing the object up to the face, and making oral contact with the object. Although participants showed reduced oral contact with the objects if the actor was visibly ill, they still made some contact and even brought the objects up to their face, which are actions that could have led to the transmission of illness. In addition, participants showed reduced oral contact if the actor had a facial birthmark and did not show signs of a contagious illness. However, it is possible that participants' behavior was based on a desire to comply with the experimenter's requests. Thus, participants' behavior may not have reflected how they would behave in a more natural, everyday setting.

In Study 1, we address this issue by measuring whether the presence of visible signs of a contagious illness (e.g. coughing, sneezing, sniffling) leads to avoidance behavior in a more natural setting. In addition, it examines whether adults also avoid people with an injury, as behavioral immune system theory predicts that people may overgeneralize avoidance behavior to anyone with a perceptible physical abnormality.

Method

Participants

Participants were 61 undergraduate students from Rutgers-Newark (M_{age} = 22 years; 41 female). They received course credit for their participation. An additional 4 participants (3 in the contagion condition and 1 in the injury condition) were run in the study, but their data was excluded for failure to notice the target confederate.

Procedure and Design

Participants were assigned to one of three conditions—the contagion condition, the injury condition, and a control condition. In all three conditions, participants were made aware of a "live" video feed to the testing room down the hall. Upon arriving at the lab, participants sat on a couch to fill out paperwork, near a 19-inch television playing a "live feed" of a testing room. The screen showed two people sitting at two different workstations, each at a laptop computer. The experimenter gestured toward the video playing on the television, apologized and told the participants that someone else was using the room for a different study, and that the people using the room should be done in a few minutes. In the contagion condition, one of the confederates coughed, sneezed, and sniffled repeatedly while typing on her computer. In the injury condition, one of the confederates wore an orthopedic boot and used crutches. In the control condition, the confederates did not display any symptoms or signs of an injury.

Once the video depicted the women on screen leaving the room, the experimenter brought the participant down the hall to the same room that the videos were filmed in. The room was set up exactly as it was in the videos. The experimenter told the participant to take a seat at either computer. While the participants chose their seat, the experimenter walked into the back room to “grab a few things” so that she would not be present to bias the participant’s seat choice in any way. The main dependent measure was where the participants chose to sit. Participant’s seat choice was coded as avoidant if they sat in the seat that was not previously inhabited by the sick or injured confederate or by the same confederate in the control condition.

Once the participant was seated, the experimenter returned from the back room, opened the laptop and set up a survey for the participant on Qualtrics. The survey included the Perceived Vulnerability to Disease (PVD) scale and a measure of general risk taking behavior (described below).

As a manipulation check, once the participants completed the surveys, the experimenter asked participants what they thought the study was about, if someone previously in the room was sick (contagious condition) or injured (injury condition), and where the sick/injured person sat. If the participants spontaneously mentioned the true purpose of the study or they could not report accurately that someone in the room was sick or injured and where they sat, they were excluded from the analyses.

Video Stimuli

The stimuli were three videos, one for each condition (contagion, injury, control), and each approximately seven minutes long. The videos featured two women seated and using laptops at separate tables that faced away from each other. When the video began, the women were sitting at the desks, typing on their computers. In the contagion condition, after about a minute, the target confederate began to show symptoms of the cold or flu. Throughout the remainder of the video, the “sick” woman coughed, sneezed, and blew her nose, depositing the used tissue onto the keyboard of the computer. After about four minutes, one of the women stood, closed her laptop, pushed in her chair, and exited the room. The second woman followed about 30 seconds later. The video continued for an additional two minutes with the room empty. In the injury condition, the target confederate sat with her leg splayed out in front of the table. She wore an orthopedic boot, and her crutches leaned up against the table. When she exited the room, she used her crutches to walk. In the control condition, neither woman displayed symptoms of illness. Instead, the target confederate in the control condition stretched periodically throughout the video. The location of the target confederate in each condition was counterbalanced, and the actors who played the confederates were consistent across the three videos.

Outcome Measures

Our main dependent variable was avoidance of the target confederate’s seat. Participant’s seat choice was coded as avoidant if they sat in the seat that was not previously inhabited by the target confederate. We also assessed perceived vulnerability to contracting an infectious disease (PVD) using a validated 15-item perceived vulnerability to disease scale by Duncan, Schaller, and Park (2009). Seven of the questions provided a measure of perceived infectability, or how susceptible they thought they were to infectious illness. The remaining eight items provided a measure of Germ Aversion, or aversive affective responses to certain scenarios, such as touching dirty money (See Appendix A). Each item was scored on a scale of 1 through 7; the mean of the scores on the scale and subscales was used in the analyses.

Finally, we assessed individual differences in risk susceptibility, using a task designed by Holt and Laury (2002). In the task, participants were presented with a table of 10 choices, each of which required them to decide between one of two options—Option A or Option B (see Appendix B). Each option resulted in a monetary reward with a high or low payoff. The probability of the highest payoff was initially low (1/10), but gradually increased as participants moved down the table. In previous research using this method, most participants begin by choosing Option A, but at some point, cross over to choosing Option B. This task has been shown to produce individual differences in risk proneness as measured by when an individual switches to Option B. For example, risk averse individuals generally select Option A for the first 6-10 choices before moving to Option B, while risk prone individuals move to Option B after only 1-3 decisions. This measure was included to assess whether variability in risk susceptibility could provide a more general explanation for avoidance behavior than the PVD scale.

Results

A chi-square revealed that whether participants avoided the target confederate differed by condition, X^2 (2, N = 61) = 9.46, p = .009. Participants were more likely to avoid the target confederate in the contagious condition than in the control condition, X^2 (1, N = 40) = 8.46, p = .003. Participants were also more likely to avoid the target confederate in the injury condition than in the control condition, X^2 (1, N = 41) = 4.11, p = .043. Participants were no more likely to avoid the contagious confederate than the injured confederate, X^2 (1, N = 41) = 1.1, p = .294 (see Figure 1).

Avoidance in the contagious condition was greater than would be expected by chance, exact binomial p = .001, one-tailed. Avoidance in the injury condition was marginally different from chance, exact binomial p = .06, one-tailed. Avoidance in the control condition was no different from chance, exact binomial p = .5, two-tailed.

Risk aversion did not significantly predict avoidance in the contagious condition, β = .569, p = .141 or in the injury condition, β = .011, p = .953. Likewise, PVD scores did not significantly predict avoidance in the contagious condition, β = 1.6, p = .129 or in the injury condition, β = .075, p = .909, nor did either of its subscales (See Table 1).

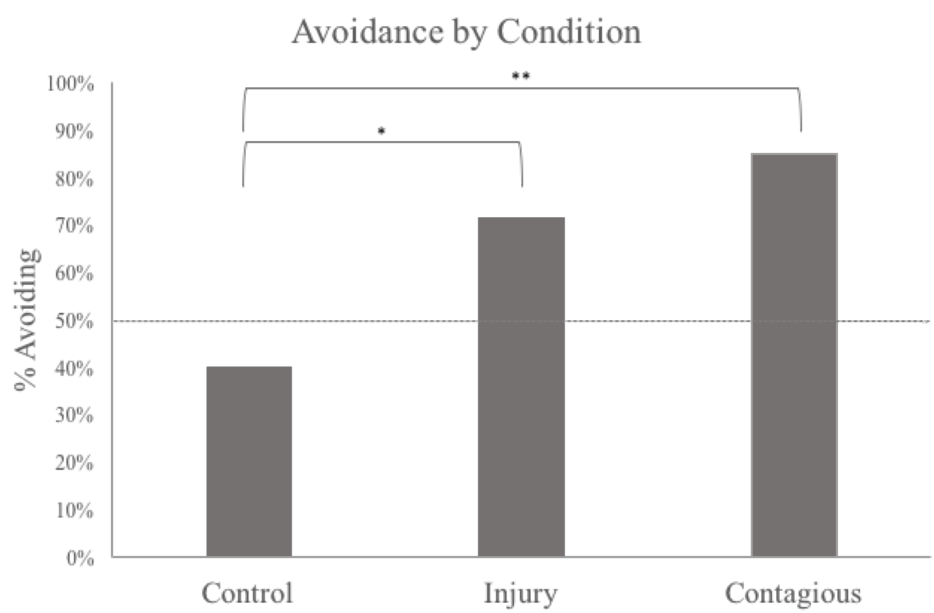


Figure 1. Percentage of participants who avoided in each condition in Study 1.

Avoidance	Contagion		Injury	
Predictor	*β*	*Sig.*	*β*	*Sig.*
PVD	1.602	0.129	.075	0.909
Germ Aversion	2.1	0.138	0.288	0.617
Perceived Infectability	.665	0.263	-.179	0.689
Risk Aversion	0.569	0.141	.011	0.953

Table 1. Summary of regression analyses predicting avoidance behavior in the contagion and injury conditions in Study 1.

Discussion

Our primary objective in Study 1 was to examine whether adults show behavioral avoidance of illness in a naturalistic setting. We found that participants avoided both the sick and injured confederates. Individual differences in risk aversion and PVD did not predict avoidance behavior.

Based on the number of studies that have used PVD, it is somewhat surprising that we did not find a relation between PVD and avoidance behavior. One possible reason for the null result is our small sample size, especially in the contagious condition where we see non-significant trends ($p < .2$) for PVD predicting avoidance behavior. We saw no such trends in the injury condition, suggesting that with a larger sample, we might find that PVD predicts avoidance behavior in the contagious condition but not in the injury condition. This result would have important implications for behavioral immune system theory, as PVD is often used as a stand-in for behavioral avoidance in studies where researchers are primarily interested in generalization of avoidance and negative attitudes toward people with non-transmissible illnesses and disabilities. According to that theory, PVD should predict avoidance in the injury condition as well. If future research shows that PVD predicts avoidance of contagious illness but does not generalize to non-contagious illnesses, injuries, and disabilities, this would suggest that different psychological mechanisms underlie avoidance in those circumstances.

In addition, we found a similar pattern with the risk aversion score, where $p < .2$ in the contagious condition, but $p > .9$ in the injury condition. This suggests that people's aversion to risk in general may play a role in their avoidance behavior; people who are risk averse in general may evaluate proximity to a contagion person or contact with contaminated objects as risky and then avoid, but people who are risk averse may not evaluate proximity to an injured person as risky, and so do not avoid. This suggests that more general factors, such as general risk aversion, may play a role in avoidance behavior. Using a larger sample size, future work should examine the independent contributions of risk aversion and PVD to avoidance of contagion and overgeneralization of avoidance to non-contagious illnesses, injuries, and disabilities. In addition, in future work it may be worth presenting participants with a choice between a workspace associated with and potentially contaminated by a contagiously ill confederate and a workspace associated with an injured person. This would allow us to assess whether, all things being equal, people treat these ailments different, preferring to avoid a contagiously sick person than an injured person.

Although results of this study cannot directly determine whether avoidance in the contagious and the injury conditions are both due to the same underlying psychological mechanisms, they show that adults do avoid situations in which they might become sick from a transmissible illness. Given this result, we can investigate the trajectory of contagious illness avoidance and examine how avoidance of contagious illness develops.

Study 2

The aim of Study 2 was to explore children's avoidance behavior in contexts similar to Study 1 in order to examine the developmental trajectory of disease-avoidant behavior. We chose to study preschool-aged children for two main reasons. First, preschoolers are past the point in development (weaning) at which illness avoidance is theorized to become adaptive (Rottman, 2014). Thus, if the behavioral immune system is a set of psychological mechanisms that evolved because they conferred an adaptive advantage to survival, children in this age range should exhibit avoidance behavior. Second, preschoolers have been shown to have some causal knowledge of how illnesses are transmitted (Kalish 1999), so we can explore whether that knowledge is related to their avoidance behavior and is thus a potential way through which avoidance behavior is learned.

Preschool-aged children were shown a video depicting two confederates interacting with objects, just as adults were in Study 1. One of the confederates displayed visible symptoms of a contagious illness, such as coughing and sneezing and wiping their nose while playing with their set of toys, while the other confederate did not. After watching the video, children were allowed to play with the same two sets of toys. If avoidance behavior in early childhood relies on cues such as visible symptoms, the 4- and 5-year-old children should avoid playing with the set of toys that the sick confederate coughed and sneezed on.

Method

Participants

Participants were 20 4- and 5-year-olds children (12 female; M_{age} = 4;8; range: 4;0 to 5;5) recruited from local preschools. An additional two children were excluded from analyses, one because the child did not remember who was sick in the video, and one because of equipment failure.

Materials and Apparatus

Children were seated on the floor in front of a laptop computer between two covered boxes. One box was covered in green cardboard stars, while the other was covered in yellow stars. The green box was always placed on the left, and the yellow box was always on the right. Each box contained an identical set of four toys, chosen because they were appropriate for preschool children, and they afford touching and in some cases breathing on the toys: bubbles, Mr. Potato Head, pin art, and a slinky.

The child was shown a video on the laptop depicting the same boxes in the same spatial configuration placed in front of two confederates who were wearing t-shirts that matched the boxes. The video was approximately two minutes long, and depicted the confederates taking turns removing the identical toys from their corresponding box and playing with them. For each set of toys, the confederates either displayed a physical symptom of illness (sick confederate) or performed a neutral action (neutral confederate) before removing each toy from the box and performing an action with it. The symptoms were sneezing, coughing, and wiping her nose with her hand. The neutral actions were sighing, yawning, and stretching her arms. Each symptom was repeated twice over the course of the video.

The video began with the two confederates sitting directly behind the two closed boxes. Each confederate took turns waving at the camera, and then opening her box. When the sick confederate opened her box, she leaned forward and sneezed directly into the box. When the healthy confederate opened her box, she sighed as she looked into it. The confederates then took turns taking the toys out of the box in the following order: bubbles, pin art, Potato Head, and slinky. For the bubbles, the sick confederate opened the container, held up the bubble wand, coughed on it, and then blew the bubbles. The healthy confederate did the same thing, except she yawned instead of coughing. For the pin art, the sick confederate removed the pin art from the box, placed it in her lap, sniffed and wiped her nose with the back of her hand, and then picked up the pin art and pressed the back of her hand into it. The healthy confederate picked up the pin art, placed it in her lap, stretched her arms out in front of her, and then pressed the back of her hand into the pin art. For Mr. Potato Head, the sick confederate sneezed directly onto the toy, and then switched its ears around; the healthy confederate sighed before switching its ears around. For the slinky, the sick confederate again wiped her nose, and then put her hand through the slinky. The healthy confederate stretched on this trial before putting her hand through the slinky. Finally, both confederates put the toys back into their corresponding boxes in unison. Before closing her box, the sick confederate coughed into it, and the healthy confederate yawned into hers. They then put the lids back onto the boxes, and the video ended with both of confederates facing forward with neutral expressions.

Procedure

The child was invited to sit on the floor directly in front of the laptop, which displayed the paused video in full screen. The experimenter then informed the child about the video and the toys in the boxes, "We're going to watch a video that my friends made for you right before I came here this morning! They put toys in these boxes here for you to play with, and they made the video to show you the toys in the boxes." Then, the experimenter pointed to each confederate on the screen, then at the box on the screen, and then at the corresponding box next to the computer, "See this girl here in the yellow/green shirt? This morning, she put toys in this box right here with the yellow/green stars [points to box on screen] and then I brought it here [points to real box next to computer]." This was repeated for the other confederate and box. The order of introduction was counterbalanced, with the yellow confederate introduced first for half of the participants, and the green confederate introduced first for the other half of the participants.

Next, the experimenter pressed play, and then took a seat next to, but slightly behind, the child. When the video began to play, the experimenter drew the child's attention to the video, "Look! They're waving! Let's see what they have in the boxes." The experimenter then remained silent for the remainder of the video, unless the child looked away, in which case the experimenter drew the child's attention back to the video, "Let's see what they do next!"

Once the video was finished, the experimenter told the child that they could play with the toys. The experimenter then went to sit at a table facing away from the child to reduce bias. The child was allowed to play with the toys in the boxes for two minutes.

After the play session, the experimenter returned and asked the child whether someone in the video was sick. If they said yes, the child was asked to point to which person was sick. If they said no or did not respond, they were asked which experimenter sneezed during the video. If the child could not correctly answer either of these questions, their data were excluded from the analyses. Following this memory check question, the experimenter pointed to each box, and asked the child to point to which confederate played with the toys in that box. The order for this memory check question was also counterbalanced. Any child who could not answer these questions correctly was excluded from the analyses. As mentioned above, only one child was eliminated from our analyses for not remembering who was sick in the video.

Following these memory check questions, children's knowledge of contagion was assessed in an interview (See Appendix C). During the interview, the children were presented with a series of pictures of children's faces from the Child Affective Face (CAFE) Set (LoBue & Thrasher, 2015) and asked questions about them. Children were presented with four vignettes — two about common contagious illnesses (the cold and the flu) and two about non-contagious ailments (toothache and broken arm). The vignettes were presented in one of two orders. In each vignette, the participant was shown a picture of a child and told that the child had a cold/flu/toothache/broken arm. Participants were then prompted to provide an explanation as to how the child became sick or injured, e.g., "How did they get a broken arm"? Then, the experimenter told the participants that someone else played with the child, and asked participants to make a prediction about whether that person would get the child's ailment from playing with them, e.g., "Will their friend get the flu from playing with them?"

Behavioral Coding

Contact with each toy was coded off-line by a trained coder. Contact began when a child touched a toy, and ended when the child put it down. Contact with the toys that came from the box the symptomatic person interacted with were coded as “sick”, and contact with toys from the other box were coded as “healthy”. Each child received an avoidance score that reflected the percentage of the two-minute play session that they did *not* spend in contact with the symptomatic person’s toys. The child’s first toy choice was also coded as either “sick” or “healthy.”

Verbal Coding

Children’s explanations were coded as follows:

Risk Behaviors: Any mention of engaging in a risk behavior (touching something dirty, falling down, etc.) was coded.

Proximity: Risk behaviors were further coded for whether they mentioned proximity to someone who was sick or person-to-person contact.

Preventative Measures: Explanations were also coded for whether they mentioned failure to engage in a preventative measure (wearing a coat, washing their hands, etc.).

Biological: Explanations were coded for whether they explicitly mentioned germs.

Other: “I don’t know” and all other responses were coded as “other”.

Contagion-relevant/irrelevant: Explanations were grouped as to whether or not they fell into two broad categories—contagion-relevant or contagion-irrelevant. Explanations that were initially coded as mentioning a risk behavior, as mentioning a failure to engage in a preventative measure, as biological, or as including person-to-person contact or proximity (cold only) were categorized as “contagion-relevant”. Explanations that fell under “other” or “I don’t know” were combined to form the “contagion-irrelevant” category.

Children's responses to the prediction questions about person-to-person transmission were coded as 1 for a correct response (yes for cold/flu and no for broken arm/toothache) and as 0 for an incorrect response (no for cold/flu and yes for broken arm/toothache). A coder blind to condition coded the responses on all measures for all children, and a second coder coded a random 25% of the responses. Coder agreement was above 90% for these measures (all Cohen's $k > .8$). Differences were resolved through discussion.

Results

Preliminary analyses revealed no effects of gender, box color/position, confederate preference, introduction order, or order of actions in the video, so they were dropped from subsequent analyses. A paired-samples t-test revealed no difference in the amount of time

children spent in contact with the healthy confederate's toys (M = 58.59%, SE = 10.3) and the sick confederate's toys (M = 37.34%, SE = 10.0), $t(19) = 1.06$, $p = .151$ (one-tailed). One sample t-tests revealed that the amount of time children spent in contact with the healthy confederate's toys was not different from chance (50%), $t(19) = .866$, p = .199 (one-tailed), nor was their contact with the sick confederate's toys, $t(19) = -1.255$, p = .128 (one-tailed).

Regressions were run to examine whether children's answers to the knowledge interview questions were predictive of the amount of time children spent in contact with the sick confederate's toys. None of questions in the knowledge interview were predictive of children's behavior, nor were composite scores of their answers to the questions about contagious illness (cold and flu) (see Table 2).

	Contact with Sick Confederate's Toys		
Predictor	β	*t*	*Sig.*
Cold Prediction	.044	.185	.855
Cold Explanation	.143	.613	.584
Flu Prediction	-.116	-.493	.628
Flu Explanation	.079	.336	.741
Contagion Prediction	.047	-.199	.845
Toothache Prediction	.367	1.675	.111
Toothache Explanation	.064	.274	.787
Broken Arm Prediction	-.053	-.225	.825
Broken Arm Explanation	.207	.039	.969

Table 2. Summary of regression analyses predicting avoidance in Study 2.

Discussion

Children responded at chance on the avoidance task, with only 10 out of 20 children avoiding the sick experimenter. In addition, we found no relation between children's causal knowledge and their avoidance behavior. Although all of the children included in the analyses were able to indicate which confederate in the video was sick, it is possible that symptoms are ambiguous for young children. Thus, children may only spontaneously avoid contaminated toys if they are provided with unambiguous verbal information indicating that the confederate in the video has a contagious illness.

Study 3

Study 3 investigates whether children would avoid a set of contaminated toys in the video-based paradigm if they were also provided with unambiguous verbal information about the presence of a contagious illness. Study 3 was identical to Study 2 except that just before children viewed the video, they were provided with verbal descriptions of the illnesses of the confederates in the video.

Method

Participants

Participants were 20 4- and 5-year-olds children (9 female; M_{age} = 4;8; range: 4;0 to 5;6) recruited from local preschools. An additional three children were excluded from analyses, one because the child did not remember who was sick in the video, one because of equipment failure, and one because of experimenter error.

Procedure

The procedure was identical to that of Study 2, except when the children sat down to watch the video, the main experimenter described the symptomatic confederate as having “the flu, so they have a fever, a headache, and a sore throat” and the asymptomatic confederate as having “a toothache, so their tooth hurts a lot when they try to eat or drink anything.” This provided the children with less ambiguous information about whether the symptomatic confederate was suffering from a contagious illness. The introduction order was counterbalanced, so that half of the children heard the sick experimenter described first, and the other half heard her described second.

Results

Preliminary analyses revealed no effects of gender, box color/position, confederate preference, introduction order, or order of actions in the video, so they were dropped from subsequent analyses. A paired-samples t-test revealed no difference in the amount of time children spent in contact with the healthy confederate's toys (M = 51.87%, SE = 9.6) and the sick confederate's toys (M = 48.66%, SE = 9.8), $t(19) = .170$, p = .434 (one-tailed). None of questions in the knowledge interview were predictive of children's behavior, nor were composite scores of their answers to the questions about contagious illness (cold and flu) (See Table 3).

Table 3. Summary of regression analyses predicting avoidance in Study 3.

	Contact with Sick Confederate's Toys		
Predictor	β	t	*Sig.*
Cold Prediction	.125	.533	.600
Cold Explanation	-.121	-.515	.613
Flu Prediction	.036	-.153	.880
Flu Explanation	.286	1.267	.221
Contagion Prediction	.083	.354	.728
Toothache Prediction	-.065	-.278	.785
Toothache Explanation	-.225	-.978	.341
Broken Arm Prediction	.052	.220	.829
Broken Arm Explanation	-.020	-.086	.933

Discussion

As in Study 2, the children in Study 3 did not avoid contact with the sick confederate's toys, even though they were provided with verbal descriptions of the illness of each confederate. In addition, none of the measures of causal knowledge was related to the amount of contact they had with the sick confederate's toys.

Children may have failed to avoid the sick experimenter's toys in Studies 2 and 3 for several reasons. First, the task itself may be difficult for young children; they may not have made the connection between the boxes in the video and the boxes they were playing with, and so they did not avoid the toys because they did not understand that someone who was sick had previously touched them. Another possibility is that the children did not avoid the contaminated toys because they inferred that a time delay would make transmission impossible, making it okay to play with the previously contaminated toys. It is also possible that children failed to avoid in this task because the neutral confederate's actions, such as yawning and sighing, may have led the children to believe that the neutral confederate's toys were less interesting than the sick confederate's toys. A final possibility is that children would only avoid the toys in the presence of the sick confederate, not understanding that germs can be transmitted from people to objects. Study 4 addresses these issues by measuring contact with contaminated toys in the presence of a sick confederate.

Study 4

In Study 4, children from the ages of four to seven were invited to play with two confederates—one who was "sick" and one who was not—for a period of five minutes, and we measured children's proximity to and contact with the sick/healthy confederates and their toys. Following the play session, children were given a vignette task to assess their verbal knowledge of contagious illness, just as in Studies 2 and 3. We asked whether children avoid contagious individuals by playing further away from the sick confederate and by spending less time touching her toys. Further, we asked whether children's conceptual knowledge of illness transmission—specifically their ability to provide explanations for illness and predict illness outcomes—relates to their avoidance behavior.

We chose to expand the age range in Study 4 to include 6- and 7-year-old children in order to observe potential age-related changes in avoidance behavior. Behavioral immune system theory predicts that children should avoid sick individuals from as early as we can test. If this is the case, across all ages, children should avoid the sick confederate at above chance levels, and variability in the knowledge measures should not be predictive of their avoidance behavior. A second possibility is that avoidance behavior will emerge later in development than verbal knowledge. If this is the case, avoidance may not be related to conceptual knowledge of illness transmission as measured by our vignette task, and increasing age will be the best predictor of avoidance behavior. This pattern would provide evidence against early emergence accounts of illness avoidance such as behavioral immune system theory. It would also suggest that children's causal knowledge about illness transmission does not necessarily influence their behavior, and that a mechanism other than causal knowledge underlies avoidance.

A third and final possibility is that avoidance behavior and conceptual knowledge of contagious illness will be tightly linked, such that children who avoid the sick experimenter will also score highly on our measure of conceptual knowledge of illness transmission. If the data show this pattern, avoidance behavior should be best predicted by scores on our conceptual measures of illness knowledge, even when controlling for age, and would suggest that an explicit and causal understanding of illness transmission may be a potential mechanism underlying avoidance behavior in early childhood.

Method

Participants

Twenty-five 4- and 5-year-olds (13 female; M_{age} = 4;10; range: 4;0 to 5;9) and 20 6- and 7-year-olds (14 female; M_{age} = 7;0; range: 6;3 to 7;9) participated in the study. A total of 10 additional children (5 from the older age group and 5 from the younger age group) were excluded from analyses: 2 for refusing to complete the study, 2 due to experimental error, 2 for parental interference, 2 for failing to remember which experimenter was sick, and 1 for exhibiting a response bias in the interview.

Procedure

Behavioral Task. At the beginning of the study, an experimenter introduced each child to a large playroom. In the playroom, two confederates (C1 and C2) were seated on the floor, one on either side of a large black box, the contents of which were not visible. The experimenter then introduced C1 (healthy) and C2 (sick), using three facts to describe each: “Thanks for coming to play with us today! We have a bunch of toys to show you. [C1] and [C2] want to play with you too! That is [C1]; she has brown hair and brown eyes and is wearing a [green/yellow] shirt. That is [C2]; she has a cold, she has a fever, a headache, and a sore throat. Let’s go in and play!” Each confederate wore a different color shirt (green or yellow), and the color and location of each confederate along with the order of their introduction (sick or healthy first) were counterbalanced.

The confederates were not aware of whether or not they were “sick”, as they wore headphones playing loud music while their traits were described to the child.

After the experimenter described the two confederates, she signaled to the confederates to remove their headphones to begin the free play task. Next, the confederates removed identical toys out of the box one by one—a ball, a set of toy cars, crayons and paper, and Mr. Potato Head—and placed them on the floor. The toys were chosen because they were suitable for the wide age range in our study. The experimenter then encouraged the children to play with whatever toys they wished. After 5 minutes, the experimenter told the children that the play session was over, and invited them to sit at a small table for the verbal knowledge task. After the play session, the confederates put their headphones back on while child was interviewed.

Verbal Knowledge Task. Following the behavioral task, the child was interviewed to assess their knowledge about illness transmission (See Appendix D). First, they were asked about the free play session. As a memory check, children were asked if they remembered which confederate [C1 or C2] was sick (the 2 children who failed to answer this question correctly were eliminated from data analyses). During the main portion of the interview, adapted from Myant & Williams (2005), the children were read vignettes about a child with a cold and a child with a broken arm. For the cold vignette, they were shown a picture of a child and were told, "This is Sal. Sal has a cold, so Sal has a runny nose, a headache, and sore throat." For the broken arm vignette, they were shown a picture of a different child, and were told, "This is Danny. Danny has a broken arm, so his arm is swollen and really hurts when he tries to move it." The children were then prompted to provide an open-ended explanation for how the child got a cold or broken arm, "How did Sal/Danny get a cold/broken arm?" Afterward, they were asked to make a prediction about whether they and another child would get a cold or broken arm after playing with the child in the vignette, "If Sal/Danny's friend plays with her while Sal/Danny has a cold/broken arm, will Sal/Danny's friend get a cold/broken arm, too? What if you played with Sal/Danny? Would you get a cold/broken arm?"

Behavioral Coding. *Contact* was defined as whenever a part of the child's body was in direct contact with a toy or with a confederate. The duration of contact with each confederate and her toys was coded. Each instance of contact was categorized as either "sick contact" if the child made contact with the sick confederate or her toys, and "healthy contact" if the child made contact with the other confederate or her toys. If a child made contact with both confederates' toys simultaneously, contact was coded as both "sick" and "healthy", since the child was making contact with each confederate's toys at the same time. The percentage of free play spent in contact with each confederate and her toys was then calculated.

Proximity to the sick confederate was coded on two dimensions. First, the horizontal location (left/right) of the child was coded as either being on the side of the sick confederate or on the side of the healthy confederate. Second, how close the child sat to each confederate was coded as either sitting directly in front of the confederate (close proximity) or approximately three feet or more away from the confederate (far). A location code was given if the child remained in the same area for at least two seconds. The percentage of the play session that each child spent in each of these areas was calculated. Further, the percentage of time children spent playing in close proximity to the sick confederate was calculated. This yielded two key scores for each child—one based on how long they spent on the same side of the play area as the sick confederate, which provides a broad measure for how long they spent in proximity to the sick experimenter; and one based on how long they played directly in front of the sick confederate, which provides information about how much time they spent in close proximity to the sick confederate.

Verbal Knowledge Coding. Children's explanations and predictions were coded the same way they were coded in Studies 2 and 3. A coder blind to condition coded the responses on all measures for all children, and a second coder coded a random 25% of the responses. Coder agreement was above 90% for all measures (all Cohen's $k > .8$). Differences were resolved through discussion. Preliminary analyses did not yield any effects of gender, shirt color, or target side, so these variables were not included in the main analyses.

Results

Contact. First we examined the percentage of time children spent in contact with the sick versus healthy confederates' toys. The results of a 2 × 2 repeated measures ANOVA with confederate type (sick or healthy) as a within subjects variable and age (4- and 5-year-olds versus 6- and 7-year-olds) as a between subjects variable revealed only a main effect of confederate type, with children spending a greater percentage of time with the healthy confederate (M = .64, SD = .45) than the sick confederate (M = .36, SD = .46), $F(1,43) = 4.71$, $p = .04$, $\eta^2 = .10$. To examine whether children's avoidance behaviors differed significantly from chance (50%), we ran follow-up one-sample t-tests on the percentage of time children in each age group spent in contact with each of the confederate's toys. The percentage of time that 4- and 5-year-olds spent with the sick confederate's toys (*M* = .43, *SD* = .47) did not differ from chance, *t*(24) = -.73, *p* = .47, nor did the percentage of time they spent with the healthy (*M* = .57, *SD* = .47) confederate's toys, *t*(24) = .79, *p* = .44. Conversely, the 6- and 7-year-olds spent more time with the healthy confederate's toys (*M* = .72, *SD* = .44), *t*(19) = 2.23, *p* = .04, and less time with the sick confederate's toys (*M* = .27, *SD* = .44), *t*(19) = -2.36, *p* = .03 than would be expected by chance (see Figure 2). It is important to note that *none* of the children ever made physical contact with either of the confederates themselves, so these data could not be analyzed.

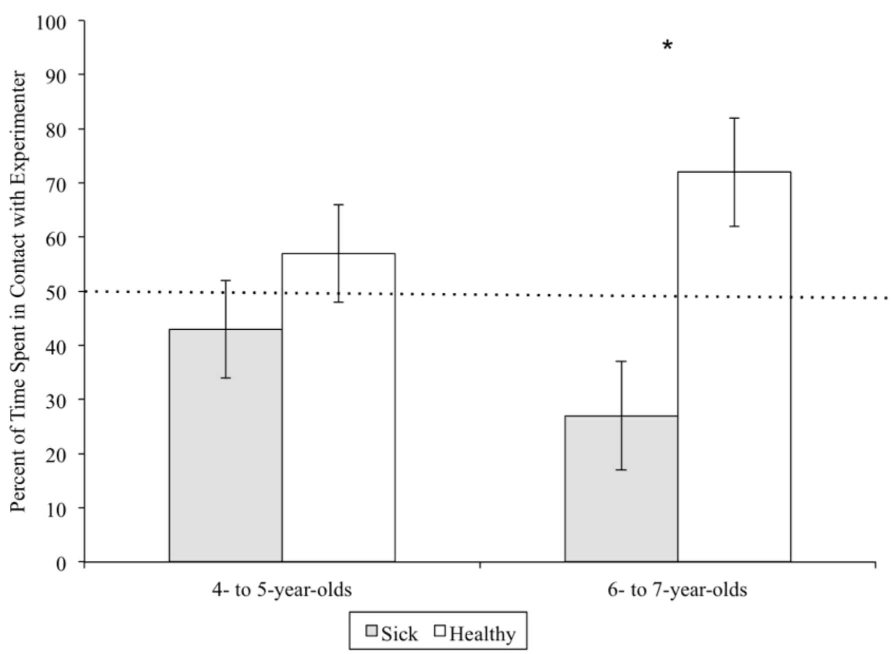


Figure 2. Contact with each confederate's toys in Study 4.

Proximity. Next we examined proximity to the sick versus healthy confederates in terms of their horizontal proximity (sick side versus healthy side) to each of the confederates. The results of a 2 × 2 repeated measures ANOVA with horizontal location (sick versus healthy side) as a within subjects variable and age (4- and 5-year-olds versus 6- and 7-year-olds) as a between subjects variable revealed a marginally significant main effect of location, with children spending more time on the side of the healthy confederate (M = 60.95 SD = 45.07) than the sick confederate (M = 35.85 SD = 44.94), $F(1,41) = 3.721$, $p = .06$, $\eta^2 = .08$. Comparisons to chance revealed that the amount of time 4- and 5-year-olds spent on the same side as the sick confederate was not significantly different from chance, $t(23) = -.972$, $p = .17$, but the 6- and 7-year-olds spent significantly less time on the sick confederate's side than would be expected by chance, $t(18) = -2.01$, $p = .03$.

We then examined the amount of time children spent in *close* proximity to the sick experimenter. A 2 × 2 repeated measures ANOVA with age group as a between subjects variable and location (close proximity to sick vs. healthy confederate) revealed a main effect of location, with children spending less time in close proximity to the sick confederate (M = 27.72, SD = 42.39) than the healthy confederate (M = 60.98, SD = 45.07), $F(1, 41) = 7.45$, $p = .009$ (See Figure 3).

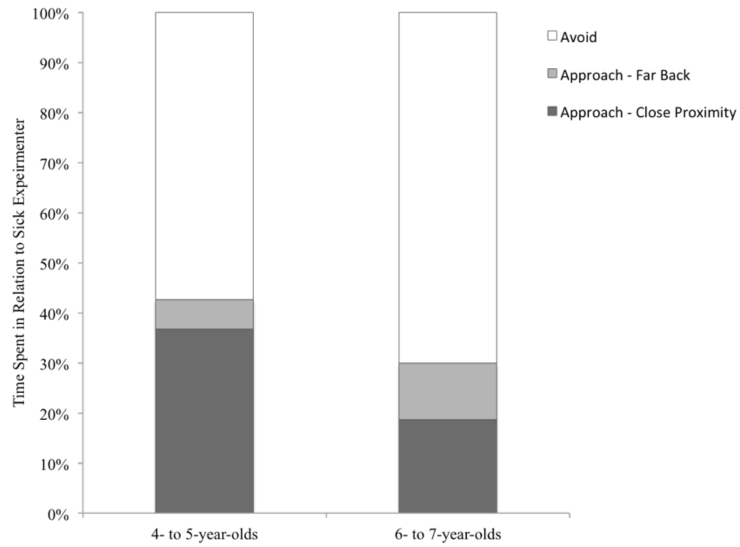


Figure 3. Proximity to the sick confederate in Study 4.

Verbal Knowledge. Two chi-square tests of independence were performed to examine the relation between age and verbal knowledge of colds—one between age and responses on the cold prediction question, and one between age and explanation type for colds (contagion-relevant vs. irrelevant). The relation between age and performance on the cold prediction question was significant, $\chi^2(1, 45) = 7.49$, $p = .006$. Younger children were less likely to correctly answer the cold prediction question than were older children. There was no significant relation between age and explanation type, $\chi^2(1, 45) = 2.21$, $p = .14$.

Two additional chi-square tests of independence were performed to examine the relation between age and verbal knowledge of broken arms—one between age and responses to the broken arm prediction question, and one between age and explanation type for broken arms (contagion-relevant vs. irrelevant). The relation between age and performance was not significant, χ^2 (1, 44) = 1.35, *p* = .25; younger children were just as likely to correctly answer the broken arm prediction question as were older children. There was a significant relation between age and explanation type for broken arms, χ^2(1, 44) = 6.73, *p* =.009, such that older children were more likely to provide correct explanations for a broken arm than younger children.

Verbal Knowledge and Avoidance. Finally, we ran two regressions to examine whether knowledge (as indexed by responses to the cold prediction and cold explanation questions respectively) and age predicted avoidance behavior (as indexed by contact with the sick confederate's toys and proximity to the sick confederate) in the free play task. In addition, we included children's responses on the broken arm prediction question and broken arm explanation type (contagion-relevant vs. irrelevant), hypothesizing that broken arm knowledge should not be related to avoidance behavior.

Responses to the cold prediction question significantly predicted the percentage of time children spent touching the sick confederate's toys, β = -.311, *t*(44) = -2.22, *p* = .03. Conversely, age, cold explanation type, and responses to the broken arm questions did not predict the percentage of time children spent in contact with the sick confederate's toys. Children's responses on the cold prediction question in the knowledge task was also the sole predictor of their avoidance of close proximity to the sick experimenter, β = -.31, *t*(44) =-2.05, *p* = .05 (See Table 4).

Predictor	Contact			Proximity		
	β	*t*	*Sig.*	β	*t*	*Sig.*
Age	.07	.46	.65	-.05	-.29	.77
Cold Prediction	-.31*	-2.22	.03	-.31*	-2.05	.05
Cold Explanation	-.05	-.326	.75	-.2	-1.29	.20
Broken Arm Prediction	-.08	-.59	.56	.09	.61	.98
Broken Arm Explanation	-.03	-.22	.83	-.004	-.03	.98

*$p < .05$

Table 4. Summary of regression analyses predicting contact with and proximity to sick confederate in Study 4.

When analyzing data from only the younger age group, this relation between cold predictions and avoidance of contact was still significant, $\beta = -.31$, $t(24) = -2.20$, $p = .02$, as was proximity to the sick confederate, $\beta = -.31$, $t(24) = -2.07$, $p = .05$.

Discussion

As in Studies 2 and 3, 4- and 5-year-old children in the younger age group did not perform differently from chance in the avoidance task. However, 6- and 7-year-old children avoided the sick confederate and her toys. When age was analyzed as a continuous linear variable, age was not predictive of children's avoidance. Instead, the best predictor of children's avoidance behavior was their ability to make predictions about cold transmission. In contrast, knowledge about injuries was not related to children's behavior during free play. In other words, it was children's specific knowledge of contagious illness that was related to their behavior, not their knowledge of injuries. These findings are consistent with the hypothesis that children's causal knowledge of contagion underlies their avoidance behavior and provides evidence that children's developing causal representations of illness transmission are a potential mechanism underlying their behavior.

Although we found a relation between children's predictions about cold transmission and their behavior, we did not find a relation between cold explanations and avoidance behavior. This might be because children's causal knowledge must be sophisticated enough for them to use it to make predictions about the future. Prior research suggests that the ability to reason backward about causes and hone in on relevant explanations for outcomes develops before the ability to reason forward from a cause to predict its effects (Legare et al., 2009). This highlights an important difference between explaining an outcome in terms of known potential causes and predicting an outcome based on whether or not a particular cause is present in that deciding whether or not to approach a sick person or a contaminated object involves making a prediction about whether or not doing so will lead to contracting an illness.

One possible alternative explanation for children's performance in the avoidance task is that the children were simply avoiding negative valence; essentialist views propose that children might intuitively know that being sick is negative or undesirable without having specific knowledge about illness transmission (e.g., Gelman, 2004; Nemeroff & Rozin, 1994). However, if this were the case, it is unlikely that we would have found a relationship between children's knowledge of illness and their avoidance behavior. If children were simply responding to negative valence, the children in the younger age group should have avoided it at above chance levels given that even infants avoid objects previously associated with a negative valence (e.g., Mumme & Fernald, 2003). Another alternative possibility is that children who are more verbal also happen to exhibit more avoidance behavior. However, if children who are more verbal just happened to perform better on the avoidance task, we would expect to see a relation between children's answers to the questions about injuries and their avoidance behavior in addition to their answers on the cold questions. However, we did not see this pattern of results; the relationship between knowledge and avoidance held only for the questions about contagious illness.

It is important to note that the results from this study are correlational. Future work must investigate this relation further to determine whether it is causal. However, the results we present here constitute the very first investigation of the developmental trajectory of children's avoidance of sick individuals and provide the first evidence of a relation between their knowledge and avoidance behavior. These findings can be used to motivate future research to determine whether the nature of this relationship is causal and how to bring about adaptive behavioral change in young children by increasing their causal knowledge of contagion. Future research should also examine the role of both verbal and physical signs of illness on children's behavior. It is possible that visible symptoms would lead to different patterns of avoidance behavior across development.

Study 5

Study 4 demonstrated that in general, children do not avoid sick individuals or contaminated objects until around the age of six, but that children younger than six do avoid if they recognize the causal connection between interacting with someone who is sick and later becoming ill. This raises the possibility that increasing children's causal knowledge about how illnesses are spread can in turn increase their avoidance behavior.

Of particular interest, then, is how to provide young children with this causal information in a manner that most effectively promotes avoidance behavior.

The majority of previous research on children's conceptual knowledge of illness has focused on characterizing what children know; few studies have examined how preschool-aged children acquire this knowledge. Schulz, Bonawitz, and Griffiths (2007) showed that preschoolers can use statistical information to learn about novel risk behaviors that lead to illness, even if these risk behaviors conflict with their prior beliefs about how illnesses are transmitted. Other research has shown that children may also consider causal explanations from their caregivers when learning about illness (Callanan & Oaks, 1992; Hickling & Wellman, 2001; Toyama, 2015). Likewise, research with older children shows that providing them with causal-explanatory information about germs leads to an increase in knowledge of illness transmission (Au et al., 2008).

Although these studies demonstrate ways in which knowledge about illness transmission can be learned, only one study to date has measured whether increases in causal knowledge also lead to behavioral change. Au et al. (2008) provides evidence that knowledge-based interventions can be effective at getting children to engage in preventative behaviors if they present information about illness transmission in a rich causal context that affords generalization to novel scenarios. They designed an intervention for use with children aged eight and older called "Think Biology", which teaches children about the biological properties of germs. Children in this intervention showed an increase in their causal knowledge of how illness is transmitted along with an increase in hand washing behavior before handling food, even though they were never taught about that behavior specifically in the intervention. They outperformed children in control knowledge-based interventions that explicitly taught children a list of risk behaviors to avoid and preventative measures to engage in. Despite being specifically told about hand washing, children in this control condition did not show an increase in causal knowledge or hand washing behavior. Thus, it appears that knowledge interventions that improve older children's causal knowledge support adaptive behavioral change. However, it is currently unclear whether such interventions would also lead to behavioral avoidance of sick individuals, or whether such methods would lead to conceptual and behavioral change in early childhood.

Importantly, current knowledge-based interventions that aim to modify children's behavior in early childhood ignore several critical factors that may influence the effectiveness of their methods—children's prior conceptions about illness as well as alternative conceptions they may have, how increasing young children's causal knowledge of illness can promote transfer of knowledge to the real world leading to more adaptive behavior, and how to exploit the wa y children learn about causal relationships in their natural environment to teach them about risk behaviors and illness transmission from an early age. Currently, there is no work on using causal knowledge interventions to improve children's behavior in early childhood. Educational interventions could potentially benefit from exploiting these learning mechanisms to lead to conceptual and behavioral change in preschool aged children.

Although children may learn about illness transmission by receiving causal explanations from caregivers (Toyama, 2015) and at school (Myant & Williams, 2008), recent work on learning in other domains with both children and adults suggests that having learners themselves generate explanations can more effectively lead to category learning and causal learning (Lombrozo, 2009; Williams & Lombrozo, 2010; Williams & Lombrozo, 2013; Williams, Lombrozo & Rehder, 2013; Legare & Lombrozo, 2014; Walker, Lombrozo, Legare & Gopnik, 2014; Lombrozo & Gwynne, 2014, Walker et al., in press). This may be because providing explanations is tied to causal reasoning, as generating an explanation involves considering potential causes and selecting which one is most likely (Lombrozo & Vasilyeva, in press). Thus, prompting people to provide explanations during a learning task can lead them to focus on causally-relevant properties and events (Walker, Lombozo, Legare & Gopnik, 2014).

In studies on explanation generation with children, preschoolers were presented with a complex novel toy, and their task was to learn how the toy worked. Children were either prompted to think about non-obvious causes by being asked to "explain" how the toy worked, or they were simply asked to describe what the toy was doing. Children who generated explanations showed more causal learning and better memory for causally relevant properties of objects than did children who were prompted to provide descriptions (Legare & Lombrozo, 2014). They also led children to hone in on non-obvious, inductively rich properties of objects during categorization as opposed to causally-irrelevant perceptual features (Walker, Lombrozo, Legare & Gopnik, 2014). Children in these studies also exhibited poorer memory for perceptual features of the objects, suggesting that explaining does not simply increase children's general attention during the task, and that explanation instead leads children to focus on causally-relevant properties specifically. In these studies, prompting children to explain the events more effectively promoted causal learning than having the children simply observe the events or prompting them to describe the events verbally. Thus, the researchers argue that prompting children to provide explanations makes children consider the underlying causes of what they are observing.

To date, this line of research has focused on how children learn about novel objects with which they have no prior experience. Of interest, then, is whether this learning mechanism also works in domains, such as illness, where children have rich prior knowledge. Prompting children to generate explanations for events related to illness could facilitate causal learning in this domain as well. If such learning improves children's causal reasoning about illness to the extent that it enables them to generalize to new situations, it could also lead children to modify their behavior. Study 5 therefore examines the role of generating explanations on learning about illness in early childhood. Specifically, it investigates whether prompting children to generate explanations for what caused a particular illness leads to better learning outcomes compared to having children simply generate descriptions of the same events.

In addition, Study 5 explores whether focusing young children on risk behaviors can be effective for promoting behavior change. Teaching children about risk behaviors has received some criticism, as such interventions have been shown to be ineffective ways to get children to engage in appropriate preventative measures such as hand washing (Au et al., 2008). However, these risk behavior-focused interventions typically focus on rote memorization of behaviors. It is possible that teaching children about risk behaviors can be effective if embedded in a context that allows children to learn about the causal link between engaging in those behaviors and later becoming sick. Thus, in Study 5, we also compare how generating explanations for risk behaviors compares to generating explanations for illness outcomes. It is possible that having children generate explanations for such behaviors will allow them to link those behaviors to the consequences of those behaviors, i.e., getting sick, and therefore lead to an increase in avoidance behavior.

In the current study, children were read a storybook about two characters—one who plays with someone who has the flu, and one who plays with someone who has a toothache. At the end of the story, the character that played with the person with the flu gets sick, but the other character does not. Children were prompted to either explain or describe what was happening at one of two points in the story—either when the character engaged in a risk behavior by playing with the sick child, or when the character became sick at the end of the story. Immediately after the storybook reading, children completed an illness prediction task, in which they were asked questions that assessed their causal knowledge of illness, and an avoidance task.

We predicted that children who provided explanations would show increased causal learning from the story, as evidenced by better performance on the illness prediction task, than those who provided descriptions. In turn, we predicted that children who provided explanations would be more likely to avoid the sick confederate in the avoidance task. Finally, if focusing on risk behaviors is effective for increasing avoidance behavior if done so in a causal context, we should see that children providing explanations about risk behaviors do just as well, if not better, than those providing explanations about illness outcomes.

Method

Participants

Participants were 100 4- and 5-year-old children (45 female, M_{age} = 4;9; range = 4;0 to 5;9) recruited from local preschools. Data from an additional 4 participants were excluded for inattentiveness.

Materials

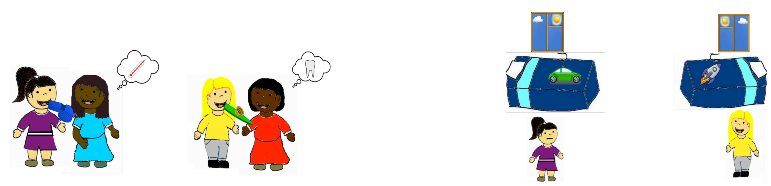
Storybook. The storybook tells a story about two girls—Alex and Jayme—who go to the park. When they get there, they see two other girls they've never seen before. One of the girls has a toothache, which is obvious to them because she keeps rubbing her mouth and saying that her tooth hurts. The other girl has the flu, which is obvious to them because she keeps coughing and sneezing, and she looks like she has a fever. Alex goes to play with the girl who has the flu, and they take turns blowing a whistle. Jayme goes to play with the girl who has a toothache, and they take turns playing a kazoo. Then Alex and Jayme go back to their houses to go to sleep. When they wake up the next morning, Alex has the flu, but Jayme feels healthy. Then, Alex goes to the doctor, who gives her medicine. Alex takes the medicine and feels a lot better. (See Appendix E)

Design

Participants were randomly assigned to one of four experimental storybook conditions or a fifth control condition. The four experimental conditions are as follows: behavior explanation, outcome explanation, behavior description, and outcome description. Children in the *explanation* conditions were prompted to generate explanations about one of two events in the story—either when the character played with the sick child at the park (behavior explanation) or when the character became sick at the end of the story (outcome explanation). In the behavior explanation condition, children were prompted to provide an explanation for the characters' choice in playmates when they are at the park, e.g., "Why did Jayme play with her and not the other girl?" In the outcome explanation condition, children were prompted to provide an explanation for why one character got the flu at the end of the story but the other did not, "Why does Alex feel sick, but Jayme feels healthy?" Children in the *description* conditions were prompted to provide descriptions of the same events in the storybooks (behavior description or outcome description).

(See Figure 4 below).

Figure 4. Prompts for each experimental condition in Study 5.



	Behavior	Outcome
Explanation	Why did Jayme play with Taylor instead of Riley? Why did Alex play with Riley instead of Taylor?	Why does Alex feel sick, but not Jayme? Why does Jayme feel healthy, but not Alex?
Description	What did Jayme and Taylor do when they played together? What did Alex and Riley do when they played together?	How did Alex feel when she woke up in the morning? How did Jayme feel when she woke up in the morning?

Procedure

Following the storybook reading, children were asked two sets of questions—memory questions and prediction questions. The memory questions consisted of nine questions about details from the storybook itself. The prediction questions assessed children's causal knowledge of illness, and asked them to predict playmate choices and illness outcomes for novel illness scenarios. Finally, children participated in a behavioral avoidance task.

Memory Check Questions. Participants were asked nine memory check questions about details from the story, such as the character's shirt colors, bedspread patterns, and who they chose to play with (See Appendix F). Participants received a score of 0 through 9 based on how many questions they got correct.

Prediction Questions. Next, children participated in a prediction task consisting of four questions (See Appendix F). In two of the questions, they were told that someone could invite one person over to play with them—either someone with a contagious illness (flu or cold) or non-contagious ailment (bruised knee or burnt tongue). The child indicated which person should be invited over. Participants got the question correct if they chose the child with a non-contagious illness or injury. In the other two questions, they were told about two pairs of children who played together. In one set, one of the children had a contagious illness (cold or flu) and in the other set, one of the children had a non-contagious ailment (scratched arm or toothache). Then, they were told that the next day, one of the two other children from each pair became sick. Participants had to predict which of these two children got sick the next day. Participants received a score ranging from 0 to 4 based on how many questions they correctly answered.

Avoidance Task. Finally, participants completed an avoidance task. At the end of the prediction task, the experimenter called in two confederates (C1 and C2) who were unfamiliar to the child. C1 and C2 sat approximately three feet apart from each other facing forward, each an equal distance from the child. As C1 and C2 were sitting down, they each exhibited a symptom—C1 coughed, a symptom of the flu, and C2 groaned and rubbed their jaw, a sign of a toothache.

Next, the main experimenter introduced the child to the confederates by saying, “These are my friends, and they’re here to show you how some toys work. They’re really shy, so they don’t talk very much.” The experimenter then introduced each confederate, pointing and saying, “See that girl in the green shirt? She has the flu, so she had a fever a headache and a sore throat. She also coughs a lot too because of it. And see that girl in the yellow shirt? She has a toothache, so her tooth really hurts when she tries to eat or drink anything, and she grabs her mouth a lot because her tooth hurts.”

Following the introduction, the confederates offered identical toys to the child (pin art). The confederates demonstrated how to use the toy, placing their hands in their pin art and forming a handprint. The confederates then reset the pins and placed the pin art in front of them an equal distance from the participant. After the experimenter asked the confederates to leave the room to grab the next set of toys, she prompted the participant to demonstrate how to use the toy, “Can you show me what they did with the pin art?” If the child played with the toy the non-contagious confederate played with, their choice was coded as avoidance behavior.

Explanation/Description Prompt Coding. Children’s responses to the storybook prompts were coded as a manipulation check to make sure that children in the control and description conditions did not spontaneously provide causal explanations and that the children in the explanation conditions did provide causal explanations. Further, the content of children’s explanations was coded for whether the explanation provided a “correct” response to the explanation prompt. In the behavior explanation condition, a "correct" explanation was coded if the child indicated that Jamie avoided the person with the flu because she was sick. In the outcome explanation condition, an explanation was coded as "correct" if the child indicated that Alex became sick because she played with the girl with the flu. A second coder coded 25% of the responses. Coder agreement was above 90% for these measures (all Cohen's $k > .8$). Differences were resolved through discussion

Results

Preliminary analyses yielded no effects of age, gender, question order, confederate introduction order, or location of the sick confederate (left or right), so these variables were excluded from the main analyses.

Explanations. None of the children in the control or description conditions spontaneously provided causal explanations during storybook reading. Children's responses in each of the description conditions did not vary. In the behavior description condition, children provided no verbal response and the remaining 17 children talked about the play behavior the children were engaging in. 16 of these children specifically talked about the girls passing the kazoo and the whistle back and forth, "they played with the whistle, they played with the kazoo". 2 children spontaneously mentioned that playing with the sick child could make Alex sick. In the outcome description condition, 2 the children provided no verbal response, but the remaining 17 all described Alex's and Jayme's health status, "she feels sick, she feels healthy". In this condition, 1 child spontaneously mentioned germs, "it passes germs" (in reference to Alex).

85% of the children in the explanation conditions provided causal explanations. Of these causal explanations, very few (17.5%) were correct explanations pertaining to illness transmission.[1] In general, children's responses to the explanation prompts were more varied than their responses to the description prompts. In the behavior explanation condition, 3 children provided no verbal response. 3 children cited friendship or liking as the reason for playmate choice, "they were friends" or "she liked her better". 2 children cited a common favorite color based on the character's shirt colors. Only 2 children explicitly cited a desire to avoid the sick confederate as a reason underlying playmate choice. The remaining 10 children produced even more variable responses that could not be categorized, e.g. "because they needed to go home", "because she was happy", "because they are different". In the outcome explanation condition, responses were slightly less variable. 2 children provided no response. 5 children cited sleeping as the reason Alex got sick. 3 children provided circular explanations for illness, "because she is sneezing". 2 children cited Jayme's resilience as her reason for being healthy, e.g. "because Jayme eats a lot and she's strong". 3 children provided responses that could not be classified. 7 children cited engaging in risk behaviors as the reason why Alex got sick. Of these 7 explanations, 2 explicitly mentioned germs.

Memory Check Questions. Across all conditions, participants scored higher on the memory check questions than would be expected by chance, all p's $< .001$. However, participant's memory check scores did not differ with respect to condition, $F(4, 95) = 1.703$, $p = .156$.

Prediction Questions. Across all conditions, participants scored higher on the prediction task than would be expected by chance were significantly different than

[1] The analyses include the 15% of children in the explanation conditions who did not provide explanations. The analyses were repeated with those children excluded, and the results were the same.

chance, $t(99) = 3.178$, p = .003. However, participants' prediction scores did not differ with respect to condition, $F(4, 95) = .9$, $p = .467$.

Avoidance Task. Of the 100 participants who completed the memory check and prediction tasks, a subset (N = 79) completed the avoidance task. Overall across all conditions, 47% of children avoided the sick confederate, which was not different from chance, exact binomial p (two-tailed) = .653. A chi-square revealed a marginally significant effect of condition on avoidance, X^2 (4, N = 79) = 8.635, $p = .071$. Follow up analyses revealed that avoidance of the sick confederate was not related to whether participants were in the explanation or description conditions, X^2(1, N = 64) = .064, p = .8. However, children were more likely to avoid the sick confederate in the behavior conditions than in the outcome conditions, X^2(1, N = 64) = 5.189, $p = .042$. (See Figure 5).

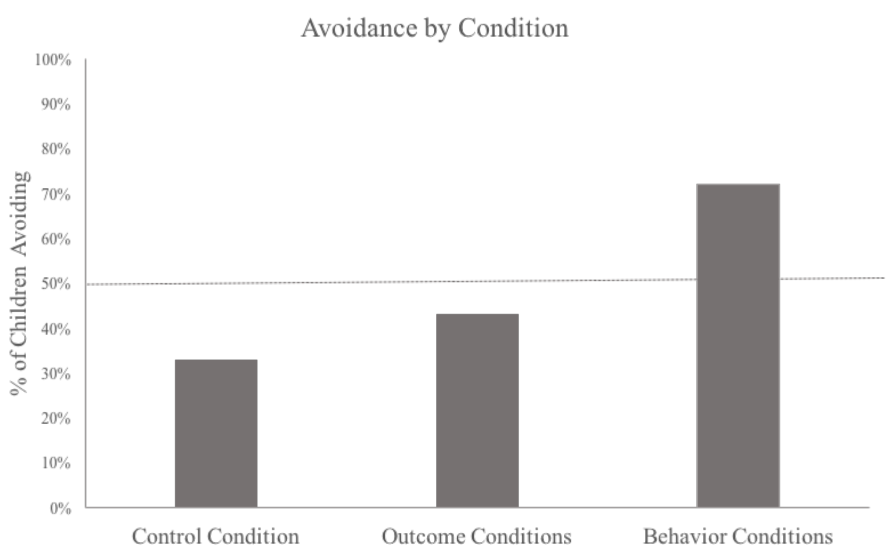


Figure 5. *Percentage of children who avoided in the control, outcome, and behavior conditions in Study 5.*

Discussion

We predicted that children in the explanation conditions would have higher scores on the prediction task and avoidance task and have lower scores on the memory check questions compared to children in the description conditions. In addition, we predicted that children in the behavior explanation condition would exhibit the most avoidance behavior compared to all the other conditions. Our results did not support these predictions. There were no differences between children in the explanation conditions and description conditions on any of these measures.

Children did not differ on their prediction scores in the explanation and description conditions. Although children in the explanation conditions tended to provide explanations, very few of them (seven in total) provided illness-relevant explanations for the characters' playmate choices in the behavior conditions or explanations citing sharing a contaminated toy or playing with someone who was sick in the outcome condition as a cause for illness. Thus, it is possible that prompting children to provide explanations during learning only works if it leads children to hone in on causally relevant properties and details. Although children's poor performance on the explanation prompts may seem to contradict results from previous studies that have shown that children in this age range do show an ability to provide explanations for illness, in those studies children are typically provided with forced-choice responses for possible causes of illness; they were not asked to spontaneously provide causal explanations, as they were here.

We did not find the predicted difference in avoidance between the explanation conditions and the description conditions. It is worth noting that we may have found larger differences between conditions on the avoidance measure if children had to choose between contact with a sick confederate's toy and a neutral confederate's toy. In this task, children had to choose between a sick confederate's toy and the toy of someone with a non-contagious ailment (a toothache). Children may have also found a toothache to be negative, leading some of the children to approach the sick confederate's toys. Although our task provides a more stringent test of avoidance by having children choose between two confederate's both associated with a negative ailment, we may have found different affects had one of the confederates been truly neutral.

Although children in the explanation conditions were no more likely to avoid the sick confederate than those in the description conditions, children in the two behavior conditions were more likely than children in the two outcome conditions to avoid the sick confederate. It is possible that we found an increase in the behavior conditions because prompting children at the point in the story where the characters themselves engaged in approach or avoidance behaviors led the children to keep track of the outcomes later in the story, and set them up to identify a causal connection between playing with someone who is sick and later becoming ill. In addition, it may have been easier for children to generalize the story characters' behavioral choices and their associated outcomes to the avoidance task in which they were prompted to make a similar behavioral choice (*i.e.*, deciding who or what to play with). In contrast, children in the outcome conditions may have focused less on the relation between characters' original playmate choices and illness and may thus have been less likely to reason backward to identify potential causes of illness.

One alternative explanation for this finding is that participants in the behavior conditions were simply prompted earlier than those in the outcome conditions, increasing children's attention early enough for those in the behavior conditions to learn more from the storybook reading than those in the outcome conditions. If this is the case, *any* prompt earlier on in the story would have lead to an increase in avoidance behavior; focusing on risk behaviors during storybook reading specifically would have conferred no unique benefit. This possibility, however, seems unlikely because even though the behavior prompts came before the outcome prompts, the prompts were only two pages apart; the only event that occurred between the avoidance behavior in the story and the illness outcomes later on was that the two characters went home and went to sleep. Instead, it seems more plausible that focusing children's attention on the characters' playmate choices and, albeit only implicitly on the cause of one character's subsequent illness, namely, exposure to germs, may have influenced participants own behavioral choices. Clearly, this hypothesis would require further empirical support. If verified, it would have important practical implications for reducing children's actual illness-related risk behaviors.

While we initially anticipated that prompting children to provide explanations about risk behaviors would lead to an increase in avoidance compared to other kinds of prompts such as descriptions, it is possible that the storybook provided enough causal information about risk behaviors (in this case, covariation information between playing with a sick person and becoming sick later on) as long as children's attention was drawn to it. Prompting children to provide any sort of information about children's playmate choice may have been sufficient to focus their attention on the importance of those kinds of choices or the outcomes of those choices. Future work should therefore examine whether and how providing young children with causal information about risk increases engagement in preventative behaviors. Although one study with much older children has suggested that interventions based on risk behaviors are less effective than those that focus on biological causal knowledge, such as learning about germs (e.g., Au et al., 2008), no studies have directly examined whether information about risk behaviors can effectively be communicated to young children by making connections between those risk behaviors and children's developing biological knowledge about germs. Future work should examine this in preschool-aged children, given our findings that focusing on playmate choice increased their avoidance behavior.

General Discussion

Across these developmental studies, we found that avoidance behavior did not appear until later in development than behavioral immune system theory would predict. In Studies 2 and 3, we found that preschool aged children did not avoid contact with contaminated objects. In Study 4, which expanded our age range, children did not avoid the sick confederate or her toys until around the age of six. However, when in the presence of someone with a contagious illness, even the youngest children were more likely to avoid contact with toys contaminated by that person if they knew that proximity to someone who was sick could lead to illness transmission. Additionally, in Study 5, we found that focusing children on the point of contagious illness transmission during storybook reading increased their avoidance behavior. This work provides the first evidence of a potential relation between children's developing causal knowledge of illness and avoidance behavior. Together, these findings suggest that avoidance of illness is a learned behavior potentially supported by causal knowledge about illness transmission.

Our findings converge with those of Dejesus et al. (2015), who found that children began to show avoidance of contaminated food around the age of six, but that younger children did not do so. Likewise, the 4- and 5-year-old children in Studies 2 and 3 did not avoid the contaminated objects. Although these studies used a video methodology that could have led younger children to fail on the task, work using a similar method suggests that even infants can use information from a video to guide their approach or avoidance behavior (Mumme & Fernald, 2013). Further, children in these studies had no problem identifying that one of the video confederates was sick. Thus, it could be that the results of these studies accurately reflect the developmental trajectory of contamination avoidance. However, future work should investigate whether using a live avoidance paradigm leads to similar results.

Although we found a relation between causal knowledge and avoidance behavior in Study 4, this was not the case in Studies 2 and 3. This could be because of the way causal knowledge was measured. The causal knowledge prediction questions in Studies 2, 3, and 4 involved *contagion* events specifically—they asked children whether they could get the cold or the flu from someone else. Thus, we may not have found the relation in Studies 2 and 3 which involved *contamination* avoidance. Questions that measure children's intuitions about the contamination of objects by bodily fluids or germs should be developed for future work investigating the development of contamination avoidance.

Currently, behavioral immune system theory has not accounted for the possibility of knowledge playing a role in avoidance behavior. Instead, it defines the behavioral immune system as a system of psychological mechanisms that detect visible physical abnormalities which initiate an emotional response followed by avoidance behavior (Schaller & Park, 2011). The developmental findings reported here suggest these responses may be learned and that cognition plays a more prominent role in avoidance behavior, which are possibilities not previously considered by proponents of behavioral immune system theory. However, it is important to note that the children in Study 4 were not presented with visual cues (i.e., symptoms) of contagious illness. It is still possible that young children would avoid if they were presented with a live confederate who displayed visible symptoms of illness. Future work should investigate whether avoidance of contagion appears earlier in development if symptoms are salient in a live confederate.

In addition to predicting that avoidance of illness should emerge early in development, behavioral immune system theory attempts to explain avoidance and stigmatization of people with chronic non-contagious illnesses and disabilities as resulting from overgeneralization of the same psychological disease-avoidance mechanisms (Neuberg, Kenrick & Schaller, 2011). Therefore, one critical outstanding question regarding the development of avoidance behavior is how children behave toward people with chronic illnesses, disabilities, or other physical abnormalities. Very little work has examined how children's behavior toward people who are disabled or chronically ill. One study found that when questioned, preschoolers report a preference for other children who are typically developing than those in a wheelchair (Huckstadt & Shutts, 2014). Another study found that children prefer drinks made by children of a typical weight over drinks created by an obese child (Klaczynski, 2008). However, no studies to date have examined whether children exhibit behavioral avoidance of these groups and how it develops in relation to avoidance of contagious illnesses.

It is also unknown whether overgeneralization of avoidance develops piecemeal, with children avoiding only particular non-contagious illnesses and disabilities, or all at once, with children avoiding in all situations in which someone has a physical abnormality once avoidance behavior emerges. If this overgeneralization results from one system of psychological mechanisms as behavioral immune system theory states, then we should see the same pattern in development, with children who avoid people with contagious illnesses also avoiding all people who exhibit abnormalities. Although this pattern of evidence would not prove without a doubt that these behaviors result from the same mechanisms put forth by behavioral immune system theory, this developmental pattern would be consistent with it. If, however, overgeneralization of avoidance results from separate mechanisms or processes, we should see avoidance develop in a piecemeal fashion, with children avoiding specific illnesses but not others. If it does develop piecemeal, this would provide a challenge for behavioral immune system theory, and suggest that separate mechanisms underlie avoidance of people with chronic illnesses and disabilities.

Another issue concerning overgeneralization is whether and under what circumstances children erroneously judge non-contagious illnesses to be contagious and whether these explicit judgments relate to their avoidance behavior. Previous research on children's judgments of contagion has resulted in conflicting findings, with children sometimes overgeneralizing contagion to non-contagious illnesses and sometimes not. Myant & Williams (2005) found that children's knowledge is often specific to particular illnesses; although a child may know about the causes of a specific illness, such as a cold, they do not spontaneously generalize contagion to other ailments, such as asthma or a toothache. In contrast, Bares & Gelman (2008) found that children judge cancer to be contagious. Although it has not been explored directly in the existing literature, this contradictory evidence is consistent with the possibility that children only overgeneralize contagion to illnesses such as cancer that they are unfamiliar with. It is currently unknown whether these intuitions about contagion reflect how children would actually behave toward people with unfamiliar, non-contagious illnesses. Future work should investigate whether children's judgments of contagion are reflected in their avoidance behavior. If so, this again would provide a challenge for behavioral immune system theory, as it would provide additional evidence that causal reasoning influences avoidance behavior.

An additional issue concerning children's causal knowledge is what role children's developing biological conceptions about germs plays in their avoidance behavior and engagement in preventative measures. In the studies reported here, we did not measure children's knowledge of the role germs play in the transmission of illness. However, some work with older children and teenagers suggests that causal reasoning about germs plays a role in the identification of risk and subsequent engagement in healthy behaviors to reduce risk. Au et al. (2008) found that 8-year-old children were better able to identify risk behaviors and engage in hand-washing to prevent food contamination after an intervention that taught them biological knowledge about germs, such as the conditions under which germs live and die and how they transmit illness and result in infection. Likewise, Zamora, Romo & Au (2006) found similar results with adolescents when teaching them about STI transmission. Thus, biological knowledge about germs may help children determine whether illness transmission is likely to occur in novel situations. However, it is unclear how sophisticated such biological knowledge is in early childhood (Solomon & Cassimatis, 1999; Kalish 1999), and whether it is possible to teach preschoolers this knowledge effectively in a way that increases risk behavior identification and engagement in healthy behaviors. Thus, future work should investigate whether increasing young children's biological knowledge of germs leads to an improvement in the identification of risk behaviors, especially in novel situations, and whether this could in turn lead to more engagement in avoidance behavior and preventative measures. This kind of knowledge may be especially critical for avoidance and prevention of contamination, which was shown to be difficult for preschoolers in Studies 2 and 3 and in DeJesus, Shutts & Kinzler (2015).

In summary, the research presented here constitutes the first investigation of the development of avoidance behavior. These findings present several challenges for behavioral immune system theory. First, the theory states that the same system of psychological mechanisms underlie avoidance of people with contagious illnesses and avoidance of people with injuries, disabilities, chronic illnesses, and disfigurements (Duncan & Schaller, 2009; Park, Faulkner & Schaller, 2003; Mortensen et al., 2010; Park, Schaller & Crandall, 2007; Schaller & Neuberg, 2012). The studies that support this use a self-report scale to assess Perceived Vulnerability to Disease (PVD), and show that individuals who score higher on PVD are related to cognitions about contagious disease as well as negative attitudes toward stigmatized groups of people without contagious illnesses (Park et al., 2003; Park et al., 2007). However, when we measured avoidance behavior in adults, we did not find a relationship between PVD and avoidance of the contagious or injured confederate. Although with a larger sample size, we might have found a relationship in the contagious condition, this was not the case in the injury condition. This suggests that the PVD scale may not actually be a valid measure of behavioral avoidance of people with non-contagious ailments. In addition, we found a similar pattern of results when measuring risk aversion, suggesting that only the contagious condition was evaluated as risky by risk-averse individuals. Taken together, these findings with adults call into question whether the same system of psychological mechanisms are responsible for both behavioral avoidance of contagion and stigmatization of marginalized groups of people.

Another challenge to behavioral immune system theory is that we did not find avoidance in early childhood and avoidance behavior was predicted by knowledge. Thus, avoidance of illness does not appear around the time of weaning, when such behavior is theorized to become adaptive (Rottman, 2014). Instead, illness avoidance may be supported by children's knowledge about illness, suggesting that contagion avoidance is learned. If contagion avoidance is learned, it is possible that overgeneralization is also learned through other means. Thus, it may be that overgeneralization of avoidance develops separately from contagion avoidance. If this is the case, this again suggests that avoidance of contagious illness and of people from marginalized groups develop separately, and consequently result from different sets of psychological mechanisms rather than one.

To examine this possibility, future work should examine whether the PVD scale is related to actual behavioral avoidance of contagious individuals as well as those with injuries and disabilities. If PVD only relates to the avoidance of contagious illness, this would suggest that separate psychological mechanisms are responsible for avoidance of other marginalized groups of people. In addition, work should examine the developmental trajectory of the avoidance of people with injuries, disabilities, chronic non-contagious ailments, etc. If they develop separately instead of all at once, this would again suggest that separate mechanisms underlie avoidance behavior.

In addition to examining the developmental trajectory of avoidance behavior, we found evidence of a relation between children's causal knowledge of illness and avoidance of contagion. This initial work is correlational in nature, so future work should experimentally manipulate children's causal knowledge of illness transmission and measure its effect on avoidance behavior. Future work should also examine at a finer level of detail how causal knowledge relates to avoidance of both contamination and contagion by measuring children's biological knowledge about germs and their intuitions about how contamination occurs. If knowledge really does influence children's avoidance behavior, this work would have important practical applications for educating young children about preventative behaviors. If children's causal knowledge is critical for promoting healthy behaviors, schools could focus on providing children with relevant causal knowledge about illness transmission rather than rote learning of preventative behaviors in a conceptual vacuum. In order to be effective, health workers should embed the information they present about prevention in a culturally sensitive causal framework that relates preventative and risk behaviors to how such behaviors either prevent or result in the transmission of disease.

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Appendix A
Perceived Vulnerability to Disease (PVD) Scale

Perceived Infectability

1. In general, I am very susceptible to colds, flu, and other / infectious diseases.
2. I am unlikely to catch a cold, flu, or other illness, even if it is / 'going around.'
3. If an illness is 'going around', I will get it.
4. My immune system protects me from most illnesses that other people / get.
5. I am more likely than the people around me to catch an infectious / disease.
6. My past experiences make me believe I am not likely to get sick / even when my friends are sick.
7. I have a history of susceptibility to infectious disease.

Germ Aversion

1. I prefer to wash my hands pretty soon after shaking someone's hand.
2. I avoid using public telephones because of the risk that I may / catch something from the previous person.
3. I do not like to write with a pencil someone else has obviously / chewed on.
4. I dislike wearing used clothes because you do not know what the / last person who wore it was like.
5. I am comfortable sharing a water bottle with a friend.
6. It really bothers me when people sneeze without covering their / mouths.
7. It does not make me anxious to be around sick people.
8. My hands do not feel dirty after touching money.

Appendix B
Risk Aversion Scale

Instructions: Below are 10 choices. For each, you will have to select either Option A or Option B. Each option presents you with the probability of winning a larger versus a smaller amount of money. Please choose the option you would prefer for each of the 10 choices.

	Option A	Option B
1.	10% chance of winning \$2.00 90% chance of winning \$1.60	10% chance of winning \$3.85 90% chance of winning \$0.10
2.	20% chance of winning \$2.00 80% chance of winning \$1.60	20% chance of winning \$3.85 80% chance of winning \$0.10
3.	30% chance of winning \$2.00 70% chance of winning \$1.60	30% chance of winning \$3.85 70% chance of winning \$0.10
4.	40% chance of winning \$2.00 60% chance of winning \$1.60	40% chance of winning \$3.85 60% chance of winning \$0.10
5.	50% chance of winning \$2.00 50% chance of winning \$1.60	50% chance of winning \$3.85 50% chance of winning \$0.10
6.	60% chance of winning \$2.00 40% chance of winning \$1.60	60% chance of winning \$3.85 40% chance of winning \$0.10
7.	70% chance of winning \$2.00 30% chance of winning \$1.60	70% chance of winning \$3.85 30% chance of winning \$0.10
8.	80% chance of winning \$2.00 20% chance of winning \$1.60	80% chance of winning \$3.85 20% chance of winning \$0.10
9.	90% chance of winning \$2.00 10% chance of winning \$1.60	90% chance of winning \$3.85 10% chance of winning \$0.10
10.	100% chance of winning \$2.00 0% chance of winning \$1.60	100% chance of winning \$3.85 0% chance of winning \$0.10

Appendix C
Explanation/Prediction Task from Study 2 and Study 3

1. This is Sal. Sal has a cold, so he has a stuffy nose, a headache, and a sore throat. How did did that happen? How did Judd get a cold?

Sal still has the cold. Sal’s friend comes over to play with him for a little while. Will Sal’s friend get a cold from playing with him while he has a cold?

2. This is Chris. Chris has a toothache, so now her tooth really hurts when she tries to eat or drink anything. How did that happen? How did Chris get a toothache?

Chris still has a toothache. Chris’s friend comes over to play with her for a little while. Will her friend get a toothache from playing with her while she has a toothache?

3. This is Danny. Danny has a broken arm, so his arm really hurts when he touches it or tries to move it. How did that happen? How did Danny get a broken arm?

Danny still has a broken arm. Danny’s friend comes over to play with him for a little while. Will Danny’s friend get a broken arm from playing with Danny while he has a broken arm?

4. This is Alex. Alex has the flu, so she has a fever, a headache, and a sore throat. How did that happen? How did Alex get the flu?

Alex still has the flu. Alex’s friend comes over to play with her for a little while. Will Alex’s friend get the flu from playing with Alex while she has the flu?

Appendix D
Explanation/Prediction Task from Study 4

1. This is Sal. Sal has a cold, so he has a stuffy nose, a headache, and a sore throat. How did did that happen? How did Judd get a cold?

Sal still has the cold. Sal’s friend comes over to play with him for a little while. Will Sal’s friend get a cold from playing with him while he has a cold?

2. This is Danny. Danny has a broken arm, so his arm really hurts when he touches it or tries to move it. How did that happen? How did Danny get a broken arm?

Danny still has a broken arm. Danny’s friend comes over to play with him for a little while. Will Danny’s friend get a broken arm from playing with Danny while he has a broken arm?

Appendix E
Storybook Script from Study 5

1. This is Alex. See Alex? (pointing) Alex is wearing a purple shirt, and her favorite color is purple. And this is Jayme. See Jayme? (pointing) Jayme is wearing a yellow shirt, and her favorite color is yellow. Alex and Jayme want to play!

2. Alex and Jayme go to the playground. When they get there, they see two other little girls who they've never seen before. They see this girl (pointing), in the blue shirt, who has the flu, and they can tell that she has the flu because she keeps coughing and sneezing, and she looks like she has a fever. And they see this girl (pointing), in the read shirt, who has a toothache, and they can tell that she has a toothache because she keeps grabbing her mouth and saying that her tooth hurts.

3. Alex goes to play with the girl in the blue shirt who has the flu (pointing). The girl in the blue dress has a whistle with her, and she puts the whistle in her mouth and blows on it, and then gives it to Alex, and Alex puts the whistle in her mouth and blows on it. And the whole time they're playing together, the little girl in the blue dress keeps coughing and sneezing because she has the flu. Jayme goes to play with the girl in the red dress (pointing) who has a toothache. The girl in the red dress has a kazoo with her, and she puts the kazoo in her mouth and blows on it, and then gives it to Jayme, and Jayme puts the kazoo in her mouth and blows on it. And the whole time they're playing together, the little girl in the red dress keeps saying that her tooth hurts because she has a toothache.

Explanation Prompt (Behavior Explanation): Why did Jayme play with this girl (pointing to girl in red dress) instead of that one? Why did Alex play this with girl (pointing to girl in blue dress) instead of that one?
Description prompt (Behavior Description): What did Jayme and this little girl do when they played together? What did Alex and this little girl do when they played together?

4. That night, they Alex and Jayme each went back to their houses to go to sleep. Alex went to sleep in her bed, which had a picture of a car on it. And Jayme went to sleep in her bed, which had a picture of a rocketship on it.

5. The next morning, when Alex wakes up she feels sick! Alex has the flu now, so she has a fever, a runny nose, and is coughing a lot. But when Jayme wakes up, she feels healthy. Jayme does not have the flu, she does not have a fever or runny nose and is not coughing a lot.

Explanation Prompt (Outcome Explanation): Why does Alex feel sick? Why does Jayme feel healthy?
Description prompt (Outcome Description): How did Alex feel the next morning when she woke up? How did Jayme feel the next morning when she woke up?

6. Okay, later that same day, Alex went to the doctor. The doctor gave her some medicine. Alex took the medicine, and then she felt a lot better!

Appendix F
Memory Check and Prediction Task Questions from Study 5

Memory Check Questions

1. What color was Alex's shirt?
2. What color was Jayme's shirt?
3. Which girl did Alex play with?
4. Did the girl who Alex played with have the flu or a toothache?
5. Which girl did Jayme play with?
6. Did the girl who Jayme played with have the flu or a toothache?
7. What picture was on Alex's bed?
8. What picture was on Jayme's bed?
9. Who got sick and had to go to the doctor?

Prediction Task Questions

Behavior Prediction

1. See this boy? His mom says he can invite one person over to play with him. He can either invite this boy, who has the flu and has a fever, a headache, and a sore throat, or he can invite this boy, who has a bruised knee, so his knee hurts when he touches it. Who should he invite over to play with him?
2. See this girl? Her mom says she can invite one person over to play with her. She can either invite this girl, who has a toothache, so her tooth really hurts when she eats or drinks anything, or she can invite this girl who has a cold, so she keeps sneezing and blowing her nose. Who should she invite over to play with her?

Outcome Prediction

1. See this girl here? She went to play with this little girl, who has a scratch on her arm, so her arm really hurt if she touches the scratch. See this other girl? She went to play with this girl who has the flu, so she has a fever, a headache and a sore throat. The next morning, when the two little girls who went to play wake up, one of them feels sick. Which little girl feels sick?
2. See this boy here? He went to play with this little boy who has a cold, so he keeps sneezing and blowing his nose. See this other boy? He went to play with this little boy who has a burnt tongue, so his tongue really hurts if he drinks anything. The next morning, when the two little boys who went to play wake up, one of them feels sick. Which little boy feels sick?