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# OC Washing and Checking: Examining the Selective Impairments in Evolved Disease Avoidance and Safety Management Mechanisms

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UNIVERSITY OF MIAMI

OC WASHING AND CHECKING: EXAMINING THE SELECTIVE IMPAIRMENTS  
IN EVOLVED DISEASE AVOIDANCE AND SAFETY MANAGEMENT  
MECHANISMS

By

Alison G. Aylward

A DISSERTATION

Submitted to the Faculty  
of the University of Miami  
in partial fulfillment of the requirements for  
the degree of Doctor of Philosophy

Coral Gables, Florida  
August 2013

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Three studies were conducted to examine the possibility that the expression of obsessive-compulsive (OC) washing and checking symptoms reflect impairments in cognitive mechanisms underlying adaptations for disease avoidance and physical harm avoidance, respectively. Studies provided initial evidence that specialized attention, memory and reasoning processes exist depending on whether adaptations for disease avoidance or physical harm avoidance are activated. The data provided no support for the hypothesis that individuals expressing OC contamination and physical harm concerns evince concern-related attention, memory, and reasoning biases.

## TABLE OF CONTENTS

	Page
LIST OF FIGURES.....	iv
LIST OF TABLES .....	v
Chapter	
1 INTRODUCTION.....	1
2 GENERAL METHODS .....	31
3 CREATION AND VALIDATION OF STUDY MEASURES.....	37
4 STUDY 1: ATTENTION TASK, STIMULI DEVELOPMENT.....	41
5 STUDY 1: ATTENTION AND OCS.....	47
6 STUDY 2: MEMORY TASK, STIMULI DEVELOPMENT .....	57
7 STUDY 2: MEMORY AND OCS .....	62
8 STUDY 3: REASONING TASK, STIMULI DEVELOPMENT .....	70
9 STUDY 3: ATTENTION AND OCS.....	75
10 GENERAL DISCUSSION.....	83
REFERENCES .....	92
FIGURES .....	104
TABLES.....	113

## LIST OF FIGURES

Figure 1.....	104
Figure 2.....	105
Figure 3.....	106
Figure 4.....	107
Figure 5.....	108
Figure 6.....	109
Figure 7.....	110
Figure 8.....	111
Figure 9.....	112

## LIST OF TABLES

Table 1 .....	113
Table 2 .....	114
Table 3 .....	115
Table 4 .....	116
Table 5 .....	117
Table 6 .....	118
Table 7 .....	119
Table 8 .....	120
Table 9 .....	121
Table 10 .....	122
Table 11 .....	123
Table 12 .....	124
Table 13 .....	125
Table 14 .....	126
Table 15 .....	127
Table 16 .....	128
Table 17 .....	129
Table 18 .....	130

## **Chapter 1. Introduction**

Obsessive-compulsive disorder (OCD) is a multifaceted condition that has been characterized in many different ways. A common feature of most characterizations is that there are different sets of co-occurring symptoms (American Psychiatric Association, 2004; Foa Kozak, Salkovskis, Coles, & Nader 1998; Foa et al., 2002; Mataix-Cols, Rauch, Manzo, Jenike, & Baer, 1999; Mataix-Cols et al., 2003, 2004; Mataix-Cols, do Rosario-Campos, & Leckman, 2005). This has led to the identification of various subtypes or dimensions of OCD based on the compulsive behavior and obsession experienced. For example, some people with OCD show anxiety about the possibility of harming others and, in response, compulsively check their environment to ensure it is safe. Others show anxiety over possible contamination and implement ritualized cleaning behaviors to protect against the threat of infection. Some researchers have proposed that OCD symptoms, across all dimensions, are due to deficits in general cognitive abilities, for instance, the general misappraisal of intrusive thoughts or general deficits in inhibition (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Rachman & De Silva, 1978; Salkovskis, 1985). In contrast, others have proposed that symptoms associated with different OCD dimensions are due to the impairment of functionally distinct psychological mechanisms (Mataix-Cols et al., 2004; McKay et al., 2004).

The program of research presented herein uses an evolutionary framework to investigate the functional specificity of different symptoms of OCD. Specifically, this research focuses on symptoms associated with contamination (“washing symptoms”) and

symptoms associated with physical safety (“checking symptoms”). A prediction stemming from an evolutionary framework is that these symptoms reflect the impairment of different evolved psychological adaptations – those for avoiding pathogens and those for avoiding physical harm, respectively. Across a series of studies, individuals displaying washing and/or checking tendencies were tested on various cognitive abilities to better understand whether these dimensions of OCD stem from more general or distinct evolved psychological adaptations.

### **Obsessive-Compulsive Disorder: An Overview**

From a clinical perspective, obsessive-compulsive disorder is defined as the experience of frequent, unsettling intrusive thoughts (i.e., obsessions) that are often experienced as inappropriate and can induce concern and anxiety (e.g., “I might accidentally stab my child with this knife”). These obsessions typically lead to avoidance of the associated stimuli and generate specific precautionary behaviors to protect against the particular danger (e.g., check that the knife is not by the child).

According to most models of OCD, symptoms cluster into distinct factors—or dimensions, as they are also termed in the literature. The number and content of factors varies between studies, ranging from three to seven. One of the earlier models of OCD proposed that symptoms could be clustered into the factors of washing, checking, slowness, and doubting (Hodgson & Rachman, 1977). Sanavio (1988) suggested a similar set of four factors: contamination, checking, loss of control of actions, and impaired mental control. Baer (1994) condensed symptoms into three dimensions: one that indexes symmetry and hoarding, another that indexes contamination and checking, and one that indexes pure obsessions. Foa et al. (1998, 2002) found seven dimensions after factor

analyzing a questionnaire of commonly experienced symptoms: checking, washing, obsessing (e.g., the experience of intrusive thoughts), mental neutralizing (e.g., praying), ordering, hoarding, and doubting (e.g., reassurance seeking). Other researchers have found the four dimensions of contamination/washing, aggressiveness/checking, hoarding, order/symmetry to be stable (Leckman et al., 1997; Mataix-Cols et al., 1999, 2003, 2004, 2005; Summerfeldt, Richter, Antony, & Swinson, 1999).

This overview of OCD models highlights two main points. First, there has been wide variation in how scientists have characterized the thoughts and behaviors associated with OCD. For instance, there is currently a debate as to whether hoarding behaviors even belong within the scope of OCD or represent a separate disorder (Mataix-Cols et al., 2010; Pertusa et al., 2008). Second, and most pertinent for the research presented herein, for most models of OCD, the washing/contamination and checking dimensions are two consistent dimensions that explain different subsets of behaviors and thoughts. Indeed, these are also the two most commonly expressed subtypes (e.g., Mataix-Cols et al., 1999; Rachman, 2002; Omori et al., 2007).

### **Traditional Explanations of OCD**

There have been a number of models put forth to explain the patterns of cognitive impairments associated with OCD. Many explanations of OCD focus on the impairment of appraisal systems and, because appraisal requires the ability to remember and attend to events, the role of memory and attention in generating the impairments associated with OCD.

## **Impairments Associated with the Appraisal of Thoughts and Experiences**

Many individuals have thoughts and experiences that could be classified as intrusive and inappropriate (Coles, Frost, Heimberg, & Rheume, 2003; Rachman, & de Silva, 1978). However, theorists have posited that the *misappraisal* of these thoughts and experiences distinguishes individuals with OCD from normals (Coles et al., 2003; Rachman & De Silva, 1978; Salkovskis, 1985; Salkovskis et al., 2000; Rachman, 2002). For example, most healthy individuals appraise intrusive thoughts as meaningless and inconsequential. In contrast, individuals with OCD appraise these thoughts as dangerous and requiring action.

Researchers have posited several types of misappraisals that explain the kinds of thoughts experienced by individuals with OCD. For example, OC individuals may feel a heightened sense of responsibility for preventing harm, may over-estimate the probability of danger, or may believe that having a thought carries the same moral implication as performing an action [Obsessive Compulsive Cognitions Working Group (OCCWG), 2003, 2005; Rachman, 1993; Salkovskis et al., 2000; Shafran & Rachman, 2004]. Other misappraisals include placing too much importance on control over thoughts, being intolerant of uncertainty, and requiring perfection in actions (OCCWG, 2003, 2005). Interestingly, the tendency to make a specific misappraisal might depend on the type of symptoms expressed. For instance, several theorists have suggested that the misappraisal of inflated responsibility for preventing harm may be most relevant for checkers (Mancini, D'Olimpio, & D'Ercole, 2001; see Rachman, 2002 for a discussion).

Individuals with OCD have been found not only to misappraise thoughts but also to misappraise certain experiences. Specifically, people with OCD have been found to

appraise experiences and situations as being not quite right (Coles et al., 2003; Coles, Heimberg, Frost, & Steketee, 2005; Leckman, Walker, Goodman, Pauls, & Cohen, 1994; Rasmussen & Eisen, 1992). In fact, it is common for all individuals—healthy or otherwise—to have these “not just right experiences” (NJREs; Coles et al., 2003). Moreover, individuals with OCD do not differ from normals on the number and frequency of these NJRE occurrences (Coles et al., 2005). What differentiates individuals with OC symptoms from healthy controls is that OC individuals experience more *distress* in response to NJREs, thus leading theorists again to cite the importance of appraisal in generating OC symptoms (Coles et al., 2005).

Likewise, the appraisal of one’s memory of actions has been suggested to be impaired in OCD (van den Hout & Kindt, 2003a, b). Specifically, individuals with OCD are able to remember their actions as accurately as normals (McNally & Kohlbeck, 1993; Constans, Foa, Franklin, & Mathews, 1995; Hermans, Martens, De Cort, Pieters, & Eelen, 2003). However, OC individuals report lower confidence in these memories than individuals who do not express OC symptoms (Rachman, 2002; Tolin et al., 2001). Doubting their memories leads OC individuals to repeatedly check their actions, which in turn leads to lower confidence ratings of their memory (van den Hout & Kindt 2003b). Interestingly, research has found that memory confidence is affected by one’s sense of responsibility. In OC individuals, as the feeling of responsibility for the consequences of a thought or a behavior increases, the lower they rate their memory confidence (Lopatka & Rachman, 1995; Radomsky, Rachman, & Hammond, 2001).

Impairments to appraisal systems relating to thoughts, experiences, and actions represent one of the leading explanations for the manifestation of OC behavior. Some

experimental research supports a causal link between misappraisals and compulsive behavior (Ladouceur et al., 1995; Lopatka & Rachman, 1995; Shafran, 1997), although, as suggested above, the type of misappraisal may vary by OC subtype. Also, certain misappraisals (low memory confidence, distress from NJREs) have been associated with more severe OCD (Leckman et al., 1995; Nedeljkovic, Moulding, Kyrios, & Doron, 2009) and worse treatment outcomes (Foa, Abramowitz, Franklin, & Kozak, 1999). These findings support the link between appraisal and OC symptoms. However, certain OC behaviors, such as the repetition of actions and the large amount of time spent focused on obsessive stimuli, have prompted researchers to examine other types of cognitive deficits, such as deficits to attention, memory, and inhibition systems.

### **Impairments in Memory, Attention, and Executive Function**

Impairments in cognitive systems supporting memory, attention, and executive functioning have been suggested to play an important role in generating OC symptoms (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Graybiel and Rauch 2000; Mataix-Cols et al., 2003; Omori et al., 2007). With respect to memory, there is evidence that spatial recognition memory and spatial working memory are impaired in individuals with OCD (Barnett et al., 1999; Nielen & Den Boer, 2003; Purcell, Maruff, Kyrios, & Pantelis, 1998; van der Wee et al., 2003). For example, Purcell et al. (1998) compared individuals with OCD to a group matched for age, gender, education, and verbal intelligence on tasks assessing various neuropsychological functions. They found that OCD participants performed poorly when asked to remember the location of boxes on a screen, a spatial recognition memory task. They also found that for individuals with OCD, as task difficulty increased, performance on a spatial working memory task

declined. Purcell et al. (1998) suggested that this decline in performance might not be due to impaired memory per se, but rather to impaired strategy selection mechanisms. If the wrong strategy is selected to complete the working memory task, then this might create an overload on working memory and lead to poor performance (see van der Wee et al., 2003 for a replication). Thus, it is unclear as to whether OC individuals have an impaired memory system or impairments in other functions that lead to downstream memory problems.

The question of whether the impairment is memory or some other function is apparent in other research as well. For instance, Omori et al. (2007) found that OCD was related to the inability to inhibit incorrect responses on tasks such as the Stroop test and the Go-NoGo test. Interestingly, though, these researchers found this relationship only for checkers, not for washers. This suggests that regardless of whether memory (or a related function) is impaired, there are clear differences between the different dimensions of OCD. Research focusing on content specific to OCD dimensions has provided better evidence of actual memory impairments. Tolin, Hamlin, and Foa (2002) examined the effect of content-specificity on memory impairments in OCD and found that individuals with OCD performed worse when directed to forget words that related to their own OCD symptoms versus words that did not. Thus, specific memory impairments might contribute to the incidence of particular symptoms associated with OCD.

In summary, there are mixed findings regarding memory impairments in OCD. Some have found no impairments (e.g., for visual pattern recognition: Nielen & Den Boer, 2003; Purcell et al., 1998; and for actual behaviors: McNally & Kohlbeck, 1993; Constans et al., 1995; Hermans et al., 2003, but see van den Hout & Kindt, 2003a,

2003b). Others have found impairments when content matches the particular OCD dimension experienced (e.g., Tolin et al., 2002). Certainly more research is required to address the question of content specific memory impairments in different OCD dimensions.

With respect to attention, there is some evidence that OC individuals might show signs of impairment (see Chamberlain et al., 2005 for a review). For instance, biases in attention have been found when the stimulus attracting attention is matched to an individual's OC concerns (e.g., Foa & McNally, 1986; Lavy, van Oppen, & van den Hout, 1994; Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996). Tata et al. (1996) found that washers, as compared to those high in trait anxiety, demonstrated vigilance for contamination words but not for other anxiety-related or neutral words. Lavy et al. (1994) used a Stroop paradigm including content specific to washing and checking concerns. They found that washers and checkers evinced greater interference effects than the control group for words that were negatively related to their specific concerns. However, because they used a between group design, it is unclear whether washers would have experienced interference from the checking words and vice versa. Much of the research on attentional processes reveals that impairments, to the that extent they exist, might be limited to the content of OC concerns. For instance, there is no evidence of general attention deficits in OC individuals when using the Stroop color naming paradigm (Martinot et al., 1990; Schmidtke, Schorb, Winkelmann, Hohagen, 1998; for exception see Hartston & Swerdlow, 1999) or the emotional Stroop paradigm (e.g., Moritz et al., 2004). Additionally, OC individuals display normal abilities on tasks that require shifting

attention to changing task goals (Nielen & den Boer, 2003; Purcell et al., 1998; but see Omori et al., 2007). Taken together, evidence suggests that impairments in attentional systems might depend on content.

Researchers have also suggested that deficits in executive functioning may underlie the cognitive impairments observed in OCD (Chamberlain et al., 2005, Hartston & Swerdlow, 1999; Savage et al., 1999; Savage & Rausch, 2000; van der Wee et al., 2003). Executive functions include the set of abilities that help us to plan, make decisions, inhibit responses, and exert flexibility over our behavioral responses. With regards to individuals with OCD, Chamberlain et al. (2005) proposed that “OCD cognitions might be best characterized in terms of failures to inhibit, or shift attention from, these ongoing thoughts or motoric activities towards other more pleasant, or less distressing, cognitions” (p. 412). Similarly, Graybiel and Rauch (2000) proposed that OC symptoms arise from impairment in the ability to exert executive control over mechanisms that are responsible for habit formation. Deficits in regulation of emotions have also been suggested to account for the exaggerated emotional response seen in individuals with OCD (Mataix-Cols et al., 2003). In short, theorists are turning to executive function deficits as explanations for the perseveration and excessive responding seen in OCD.

In summary, past explanations of the pathogenesis of OCD have examined the role of various cognitive systems such as appraisal mechanisms, memory, attention, and executive functions. The research hints that deficits might be particular to each OC dimension and might be content-specific. But, in general, previous research has not approached the factors associated with OCD with the concept of functional specificity. In

contrast, recent theorists taking an evolutionary approach have started to dissect OC symptoms and to look for functional specificity in cognitive mechanisms underlying the different subtypes.

### **An Evolutionary Model of OCD**

Researchers applying evolutionary principles to understanding human cognition have started to apply these same principles to clinical and abnormal psychology. Specifically, the goal is to better understand psychological disorders by determining whether the disorder results from the proper or impaired functioning of evolved psychological adaptations, independent of the positive or negative outcomes generated by the disorder (Wakefield, 1999). With respect to OCD, a number of evolutionary models have been proposed, each positing that the symptoms associated with the various dimensions of OCD are due to impairments in different evolved systems (e.g., Abed and de Pauw, 1998; Boyer & Lienard, 2006; Feygin, Swain, & Leckman, 2006; Szechtman & Woody, 2004). Here we focus on an evolutionary perspective of two pervasive dimensions of OCD, the washing/cleanliness dimension and the checking dimension. An evolutionary approach might also inform the impairments associated with other dimensions of OCD, but here the discussion is limited to these two.

### **Washing Dimension of OCD**

The washing behaviors observed in OCD are proposed to result from the impairment of psychological systems governing disease avoidance (Abed & de Pauw, 1998). Evolutionary considerations suggest that humans should have evolved lines of defense to protect against the harmful effects of disease causing organisms (e.g., short generation microorganisms including bacteria, viruses, and worms; Tooby, 1982). In

addition to a robust immune system that protects against internal pathogens, humans also evolved a suite of abilities enabling the avoidance and elimination of substances that were associated with disease causing organisms throughout human evolutionary history—a behavioral immune system (Schaller & Duncan, 2007). As many have suggested, disgust is the emotion governing many of these abilities (Rozin & Fallon, 1987; Tybur, Lieberman, Griskevicius, 2009). That is, the cognitive processes and behaviors associated with disgust appear to be well tailored to the function of avoiding disease.

The washing behaviors and ruminations over cleanliness associated with the washing dimension of OCD look, at first glance, like a characteristic impairment in the disgust system (Olatunji & McKay, 2007). Indeed, behavioral and neurological studies point to disgust being impaired in individuals expressing these symptoms. For instance, individuals who express contamination concerns consistently evince heightened disgust sensitivity. Disgust sensitivity is frequently measured with the Disgust Scale (DS: Haidt, McCauley, & Rozin, 1994). Although this scale is said to measure multiple domains of disgust – disgust in response to animals, body products, death, envelope violations, food, hygiene, sex, and items that resemble or have touched infectious items – most studies use this scale as a unitary construct and conceptualize disgust as a general adaptation to avoid contact with contaminants (e.g., Olatunji & Armstrong, 2009; see Tolin, Woods, & Abramowitz, 2006 for an exception). Scores on the DS have been most strongly and consistently related to the washing subtype of OCD (e.g., Mancini, Gragnani, & D’Olimpio, 2001; Thorpe, Patel, & Simonds, 2003; & Tolin, Woods, & Abramowitz, 2006). Although associations have been reported for disgust sensitivity and the checking

and ordering subtypes (e.g., Mancini, Gragnani, et al., 2001; Thorpe et al., 2003; Tolin et al., 2006;), upon closer analyses, for example, when controlling for other variables, these associations have been found to markedly diminish (David et al., 2009; Thorpe et al., 2003; Tolin et al., 2006). Some researchers have examined the possibility that different domains of disgust have unique relationships with the contamination subtype. For example, the relationship between disgust sensitivity and washing tendencies has been found to be accounted for specifically by the hygiene domain of the DS (Tolin et al., 2006). Taken together, these findings indicate that individuals who express contamination concerns experience higher levels of disgust related to contamination and disease items than do those with other types of OC concerns or healthy controls.

Along with a heightened general sensitivity to disgust, washers also report experiencing more disgust in response to contact with stimuli that pose a contamination threat than do healthy controls or those with other types of OC concerns (Olatunji, Lohr, Sawchuk, & Tolin, 2007; Power & Dalgleish, 1997). For example, Olatunji et al. (2007) found that those high in contamination concerns experienced more disgust after watching a disgusting clip than those low in these concerns. Importantly, disgust was the only emotion experienced differently between these two groups. Moreover, those high in contamination symptoms exhibited more avoidance of behavioral tasks that required them to engage in disgusting acts (e.g. approaching a pair of stained underwear). This effect was significantly mediated by an individual's disgust sensitivity. Disgust also appears to be a predominant motivator of engaging in compulsions. For instance, when asked about compulsive behavior individuals with washing concerns reported using compulsive behavior to reduce disgust rather than fear, whereas those with other types of

compulsions did not report engaging in compulsions to reduce disgust (Sieg & Scholz, 2001). These findings suggest that an over-activation of disgust in the face of contaminants drives much of the avoidance and compulsive behavior seen in individuals with washing tendencies.

Neurological research confirms the role of disgust in generating the symptoms of the washing dimension of OCD. Much of this research has examined the reaction of individuals with different symptom profiles of OCD to different types of images: images reflecting concerns specific to symptom dimensions and images reflecting more general threat. For example, Phillips et al. (2000) found that images rated as “normally” disgusting (e.g., decaying food, roaches) activated brain regions implicated in disgust perception (e.g., insula) for all OCD individuals and healthy controls. Yet, the same brain regions were activated only for washers when images were less directly related to contamination (e.g., urinals, trash). Importantly, these images were rated as significantly more disgusting by the washing group than the checking or normal groups. Similar research has shown that pictures rated as disgusting activate regions related to disgust perception for individuals with and without washing concerns, but that individuals with washing tendencies display heightened activation of these regions (insula, parahippocampal region, and the inferior frontal gyrus) relative to those without these tendencies (Matiax-Cols et al., 2004; Shapira et al., 2003). Additionally, Shapira et al. (2003) found that washers and controls did not differ in regions of activation to images rated as threatening or neutral. Checking and hoarding images also elicited distinct neural regions, and moreover, the levels of neural activation for these regions were associated with self-reported symptom severity (Matiax-Cols et al., 2004). Taken together, these

findings suggest that (1) washers evince impairments in disgust, but not in general threat activation and (2) distinct neurological substrates exist in response to different types of information.

In summary, the emerging evidence concerning the role of disgust in OCD lends support to the possibility that contamination-based OCD reflects impairments in cognitive mechanisms associated with disease avoidance. Specifically, individuals expressing washing tendencies are more likely than those expressing other OC symptoms to experience disgust in the face of contaminants and consequently to avoid or neutralize this emotion. Neurological evidence supports that disgust is uniquely activated in response to stimuli that overlaps with concerns of the washing dimension and that greater levels of washing symptoms are associated with enhanced activation of these regions.

### **Checking Dimension of OCD**

In contrast to the washing symptoms of OCD, obsessions and compulsions relating to checking do not appear to be related to the avoidance of disease threats. Rather, many checking behaviors (e.g., ensuring appliances are turned off and unplugged; ensuring doors are closed and locked) appear to focus on physical harm and its prevention. From an evolutionary perspective, the identification of physically harmful situations (to oneself or others) would have constituted a separate adaptive problem from avoiding disease, requiring a different specialized suite of systems, for instance ones for identifying possible threats and activating appropriate behavioral sequences to protect against them. In fact, research on inferential abilities in humans supports the existence of specialized systems, in this case, a reasoning system, for successfully taking precautions in the presence of hazards (Cosmides & Tooby, 1997; Fiddick, 2004; Fiddick, Cosmides,

& Tooby, 2000; Fiddick, Spampinato, & Grafman, 2005). Additionally, causing harm to others could have resulted in social exclusion or possible reproductive impairment in kin or offspring (Boyer & Lienard, 2006). The excessive concern over actions seen in checkers is suggestive of impairments to systems that support assessment of responsibility for regulating danger in the environment.

Research provides support for the existence of specialized cognitive mechanisms underlying the checking dimension. For one, a heightened sense of responsibility for actions—a misappraisal that is thought to characterize all types of OCD—has been found to be more prevalent in checkers than in other types of OCD (Mancini, D'Olimpio et al., 2001). Moreover, increasing an individual's sense of responsibility increases checking behavior, and conversely, decreasing responsibility markedly reduces checking behaviors (Lopatka & Rachman, 1995; Shafran, 1997). Checkers also appear to display less confidence for memories specific to their compulsive behaviors than individuals who engage in other types of compulsions (Hermans et al., 2003; Rachman, 2002; Radomsky et al., 2001; Van den Hout and Kindt, 2001a). Specifically, they fear that they have not performed a behavior adequately or safely (Rachman, 2002). Additionally, repeated checking reduces the vividness of memories for checking behaviors (Tolin et al., 2002), which arguably increases the doubt that an action was performed correctly. Importantly, these memory issues are related to feelings of responsibility. For instance, Radomsky et al. (2001) manipulated responsibility appraisals in people expressing checking tendencies. They found that individuals with an induced sense of responsibility for their checking behaviors were less confident but not less accurate in their memories of the checking behavior than individuals with reduced levels of responsibility. Indeed,

Rachman (2002) states that the checking dimension is characterized by indecisiveness and doubt. Additionally, guilt, an emotion associated with committing an offense, has been found to be more associated with the checking dimension than the washing dimension (Emmelkamp & Aardema, 1999). In conclusion, checkers appear to be overwhelmed by the sense that they are responsible for preventing harm and additionally to lose confidence in their ability to produce safety. It seems that psychological mechanisms specialized for preventing physical danger are impaired in checkers such that they are driven to focus—through feelings of responsibility, guilt, and doubt—on this specific adaptive problem.

Behavioral and neurological evidence supports the existence of distinct psychological mechanisms relating to the checking dimension that respond to content specific to checking concerns. For example, Mataix-Cols et al. (2004) found that images containing features characteristic of checking concerns activated brain regions (bilateral globus pallidus/putamen and left thalamus) distinct from regions activated by washing- and hoarding-related images. Moreover, self-reported anxiety in response to the checking images, as well as scores on a measure of checking symptoms, correlated significantly with these brain regions. Similarly, behavioral studies have found attention (Lavy et al., 1994) and memory (Constans et al., 1995; Radomsky et al., 2001) biases for concern-related material in checkers. For example, Radomsky et al (2001) found that checkers remembered material related to their checking behaviors (e.g., having touched a stove) better than non checking-related material that was present at the same time (e.g., the color of the experimenter's pen). Thus, the cognitive mechanisms involved in the expression of checking symptoms appear to be specialized and respond to specific types of content.

In short, the checking dimension appears to be characterized by a suite of cognitive systems tailored to harm prevention. A sense of responsibility for others' well-being is heightened along with doubt in the reliability of the safety measures taken. This inability to ensure safety may produce guilt, which in turn would promote more precautionary behaviors. This system also appears to be fine-tuned to input relevant to physical danger leading to attention and memory biases for checking-related material.

Taken together, findings from these studies suggest that although the different dimensions of OCD might overlap in various ways (i.e., the experience of obsessions, compulsions, and some neurological substrates), there appears to be functional specificity across dimensions. This possibility generates a number of predictions regarding the kinds of impairments that might be associated with different OCD dimensions. For instance, to the extent that different types of OC symptoms reflect impairments or over-expressions of cognitive mechanisms that solve specific adaptive problems, then there might exist different patterns of impairments in abilities (e.g., attention, memory, and reasoning) associated with content that is specific to those adaptive problems.

### **Domain Specific Attention Processes**

Recent research suggests that there exist domain-specific visual attentional processes. Visual attention has been defined as “the set of operations that select some portions of a scene, rather than others, for more extensive processing” (p. 16598; New, Cosmides, & Tooby, 2007). Along with goal-directed attentional processes, humans would have developed biases in attention for features of the world that provided information relative to survival, such as information regarding the intentions of conspecifics (e.g., whether an individual is a mate, foe, or friend) and information

indicating the presence of danger (e.g., whether the danger faced is a predator, pathogen, or dangerous object/action). In fact, research shows that humans preferentially attend to social information such as faces (Mack & Rock, 1998; Ro, Russell, & Lavie, 2001), eye gaze (Friesen & Kingstone, 1998), hand gestures (Langton & Bruce, 2000), and depictions of human figures (Orians & Heerwagen, 1992).

To examine whether evolution has shaped attentional processes to track categories that could have jeopardized one's chances at surviving, New et al. (2007) developed a visual attention task. Specifically, they used a change blindness paradigm, which presents a series of rapidly alternating images: an original scene, followed by a white screen, and then the original scene again with one feature removed. The feature removed can be manipulated to be a person, non-human animal, plant, building, artifact, etc. This design allows examination of which categories of information in the scene, irrespective of goal states, have more influence over attentional systems than others. New et al. (2007) found that subjects were faster at detecting changes to animals than changes to inanimate objects. This led New et al. (2007) to suggest that attentional processes are organized to monitor for ancestrally important categories.

Here I describe a study using a similar method to determine whether those expressing washing and checking symptoms show evidence of heightened attentional awareness of stimuli relating to disease hazards and physical hazards, respectively (see Study 1 below).

### **Domain Specific Memory Systems**

In the same way that different adaptive problems require different attention capabilities, they also might require dedicated memory systems (Klein, Cosmides, Tooby,

& Chance, 2002; Nairne & Panderada, 2008; Sherry & Schacter, 1987; Tooby & Cosmides, 1992). Functionally specific memory systems have been identified in non-human animals. For example there appears to be specific memory systems for information regarding food (Hampton et al., 1995), danger (Mineka & Cook, 1988) and offspring (Beecher, 1990; Kendrick, Levy, & Keverne, 1992). In humans, recent research suggests multiple memory systems exist as well, for instance as shown by stress induced recovery of fears (Jacobs & Nadel, 1985), memory recovery in PTSD (Pittman & Orr, 1995), and sex differences in spatial memory (Silverman & Eals, 1992). Recent research also suggests specialized memory for cheaters. Research on social exchange and cheater detection has shown that individuals have better facial recognition for cheaters (Farrelly & Turnbull, 2008; Mealey, Daood, & Krage, 1996), especially when the recognition occurs in the context where the cheating took place (Buchner, Bell, Mehl, & Musch, 2009). More generally, information relative to survival (both in the form of words and images) is remembered better than other types of information even when the non-survival information is encoded in ways that strengthen memory such as creating mental imagery, deepening the meaning of information, and intentionally learning words for later recall (Nairne, Thompson, & Pandeirada, 2007; Nairne, Pandeirada, & Thompson, 2008; Otgaar, Smeets, & Saskia van Bergen, 2010). This advantage for survival information holds even when other non-survival scenarios are matched for arousal and novelty (Kang, McDermott, & Cohen, 2008).

In short, recent theoretical arguments and empirical data point to the evolution of multiple memory systems, each responsible for organizing information pertinent to a particular adaptive problem (Sherry & Schacter, 1987; Klein et al., 2002). If this is indeed

the case, then it is possible that different memory systems might govern disease avoidance and physical hazards, two adaptive problems that would require specialized sets of information and memory search engines for a successful solution. On these grounds, one of the studies aims to investigate content-specific memory in individuals scoring high on the washing and/or checking dimensions of OCD (see Study 2 below).

### **Domain Specific Reasoning**

Previous research suggests the human mind contains specialized mechanisms—or expert systems—for reasoning about different adaptive domains. For instance, there appears to be distinct systems for reasoning about social agents (Baron-Cohen, 1995, Leslie, 1987), object mechanics (Baillargeon, 1986; Spelke, 1990), biological systems (Keil, 1994), and social interactions such as social exchange (Cosmides, 1985, 1989; Cosmides & Tooby, 1989, 1992).

One of the tools employed to study human reasoning is the Wason Card Selection Task (WCST; Wason, 1968). Specifically, the WCST allows for an analysis of how humans reason about conditional statements. In the WCST subjects are presented with a conditional rule in the form of “If  $P$  then  $Q$ ”, where  $P$  and  $Q$  are propositions, for instance “If one eats sugary foods, then one will get cavities”. Subjects are then presented with four separate cards displaying statements expressing the  $P$ , not- $P$ ,  $Q$ , or not- $Q$  condition. Their task is to select the card(s) they would need to turn over to check whether the conditional statement had been violated. According to the rules of formal logic, potential violations are always represented by the  $P$  and not- $Q$  choices. That is, the rule is violated whenever an instance of  $P$  and not- $Q$  co-occur. Thus the correct answer

choice is to select the P card (to see if an instance of not-Q exists on the reverse) and the not-Q card (to see if an instance of P exists on the reverse)—these are the only two cards that could potentially be instances of a violation.

One of the strengths of the WCST is that it is possible to vary the content of P and Q and observe whether performance changes. Despite the relative simplicity of the task, when subjects are given descriptive rules, for instance “If a card is marked E, then it is also marked 5”, subjects tend to perform poorly, choosing the P and not-Q cards between 5 and 30% of the time (Ermer, Guerin, Cosmides, Tooby, & Miller, 2006; for reviews see Cosmides, 1989 & Evans, Newstead, & Byrne, 1993). However, when one changes the content of the conditional rule to include propositions germane to an ancestrally re-occurring adaptive problem, then performance on the WCST improves markedly. This has been taken as evidence for the existence of specialized reasoning mechanisms that operate on input specific to a particular functional domain (but see Sperber, Cara, & Girotto, 1995). Thus far, research using the WCST points to the existence of specialized mechanisms for reasoning about two separate functional domains: social exchange and hazards, each described next in greater detail.

Humans engage in social exchange for mutual benefit. One of the potential costs associated with trade, however, is the possibility of being cheated. For this reason, researchers have suggested that humans possess specialized reasoning abilities to detect instances of cheating, that is, instances in which someone takes a benefit without paying the associated cost (Cosmides, 1989). Indeed, Cosmides and Tooby have shown that performance on the WCST increases when conditional rules describe a social contract

(e.g., “If you borrow the car, then you must fill it with gas”). In this context, subjects select the P card (“borrowed the car”) and not-Q card (“did not fill with gas”) 65-80% of the time (Cosmides, 1985, 1989; Cosmides & Tooby, 1989, 1992).

Performance on the WCST also suggests there exist specialized mechanisms for reasoning about hazards (Cosmides & Tooby, 1997; Fiddick, 2004; Fiddick et al., 2000; Fiddick et al., 2005). Over human evolutionary history, there would have been many situations that could have caused harm (e.g., building a fire, making stone flints, climbing a tree, and handling a dead carcass). Taking the appropriate precautions to ensure safety would have led to more successful outcomes. Fiddick et al. (2000) define a precaution rule as taking the form “If a valued entity is subjected to a hazard, then taking an appropriate precaution lowers the risk of harm” (p. 17). When presented with precaution rules (e.g., “If you take the cookies from the oven, then you should wear an oven mitt”), subjects perform significantly better than when they are given standard descriptive rules (Ermer et al., 2006; Fiddick, 2004; Fiddick et al., 2000; Fiddick et al., 2005).

Evidence that separate mechanisms for reasoning about social exchange versus precautions exist comes from recent fMRI investigations. For instance, Stone et al., (2002) found that patient R.M., who had bilateral damage to his medial orbitofrontal cortex and anterior temporal cortex, which caused disconnection of both the right and left amygdala, displayed deficits in reasoning about social exchange but not hazards even though the WCST were matched for logical structure and task demands. In another study, Ermer et al., (2006) found that different brain regions were activated when subjects were asked to reason about social exchange versus precautions. Specifically, they found that regions associated with Theory of Mind (e.g., the anterior and posterior temporal cortex)

were activated when individuals reasoned about social exchange rules but not precaution rules. This makes good sense, as intentionality is more important in understanding the (devious) desires of agents than in understanding whether the physical world holds danger. Evidence that reasoning about cheating relies on intentionality comes from studies looking at accidental versus intentional acts of cheating. Performance on social contract rules declines when the rule represents an accidental breach of a social contract rather than an intentional breach. In contrast, performance on rules relating to avoidance of hazards does not depend on whether the rule was violated intentionally or accidentally (Fiddick, 2004).

In sum, different types of adaptive problems activate different inferential capabilities and associated reasoning mechanisms. Furthermore, the WCST appears to be a useful tool in exploring domain specific reasoning abilities. For Study 3, the WCST was used to investigate whether deficits in reasoning about disease, and separately physical hazards, underlies the washing and checking dimensions associated with OCD (see Studies and Predictions).

### **Studies and Predictions**

This dissertation addressed the following questions: To what extent are the proposed cognitive mechanisms underlying the washing and checking dimensions of OCD distinct and specialized? Is each dimension an impairment in a specific psychological adaptation (e.g., one for disease avoidance and one for assessing physical hazards)? If so, can this be evidenced by impairments to specific reasoning mechanisms, category-specific memory systems, and category-specific attentional processes? Three studies were conducted to examine the questions above.

### **Study 1: Obsessive-compulsive symptoms (OCS) and Attention**

Cognitive models of OCD recognize the important role of attention in the processing of information related to obsessions and compulsions (Chamberlain et al., 2005; Salkovskis et al., 2000). Most studies examining attention in OCD have used the dot-probe or Stroop tasks. Both of these tasks present two types of information that compete for attention. The traditional dot-probe task presents a series of trials with two words, and on some of the trials a dot replaces one of the words. Participants are required to indicate which word has been replaced. Faster responding to a specific category of words (e.g. threatening words) is said to indicate attention or vigilance for that category. Studies that use this method find that an attention bias exists for threatening material that relates to an individual's OC concern (Amir, Najmi, & Morrison, 2009; Tata et al., 1996; but see Harkness, Harris, Jones, & Vaccaro, 2009) and that the extent of this bias is associated with levels of symptom expression (Amir et al., 2009).

In the case of the Stroop task, two types of information compete for attention so that interference can attenuate reaction times to the task goal. For example, an emotional word (depression) is presented in yellow, and an individual is asked to name either the color or the word. If individuals take longer naming the color for a word such as depression, then they are displaying biased attention towards emotional stimuli (see MacLeod, 1991 for a review). As with the dot-probe tasks, findings using the Stroop task point to attention biases for concern-related material (Lavy et al., 1994) rather than attention deficits for individuals with OCD (Martinot et al., 1990; Omari et al., 2007; Schmidtke et al., 1998; but see Hartston & Swerdlow, 1999).

Other tasks have been used to assess whether the ability to switch attention from one aspect of a task to another (i.e., set-shifting) is impaired in individuals with OCD. Findings using these tasks (e.g., Wisconsin Card Sorting Task, object alternation test, delayed alternation test) have been mixed (for a review see Chamberlain et al., 2005). Notably, these tasks use information that is irrelevant to OC concerns. Also these studies usually lump individuals with different types of OCD together in their analyses (e.g., Hartston & Swerdlow, 1999). To the extent that the dimensions of washing and checking reflect aberrations in distinct underlying cognitive mechanisms for disease and harm avoidance, respectively, then biases in attention should be content-specific. That is, washers should display attentional capture for disease-related items and thus experience difficulty when shifting attention from these items. Checkers should display attentional capture for physically dangerous items and thus experience difficulty shifting attention away from these items.

### **Predictions for Study 1**

Study 1 examines the possibility that features of the environment relating to pathogen presence and physical safety will preferentially recruit attention in those expressing washing and checking symptoms, respectively.

**Prediction 1a.** High scores on the washing dimension of OCD, but not the checking dimension of OCD, will be associated with faster identification of scene changes that relate to contamination.

**Prediction 1b.** High scores on the checking dimension of OCD, but not the washing dimension of OCD, will be associated with faster identification of scene changes that relate to physical safety concerns.

**Prediction 1c.** High scores on the washing dimension of OCD, but not the checking dimension of OCD, will be associated with slower identification of changes to neutral items within scenes that relate to contamination.

**Prediction 1d.** High scores on the checking dimension of OCD, but not the washing dimension of OCD, will be associated with slower identification of changes to neutral items within scenes that relate to physical safety.

**Prediction 1e.** There should be no relationship between scores on either the washing or checking dimensions and speed of identifying changes within scenes unrelated to disease or physical safety.

## **Study 2: OCS and Memory**

Memory provides organisms with the ability “to adjust their behaviors on the basis of information they acquire” through their life experiences (p. 306; Klein et al., 2002). When faced with an adaptive problem, information is retrieved from memory based on its relevance to the adaptive problem (Klein et al., 2002). To the extent that information regarding disease and physical hazards is called upon and used in response to different eliciting stimuli, different memory systems might underlie these separate functional domains. That is, avoiding pathogens and avoiding harm to others pose two distinct adaptive problems and thus would require encoding, storage, and retrieval of different kinds of information. If individuals with washing and checking OCD are experiencing an over-activation in mechanisms related to adaptive problems of disease avoidance and physical harm avoidance, respectively, then they might display memory biases with regards to information relevant to each adaptive problem.

Although a few studies of memory in OCD individuals have examined the role of content specific stimuli on OC behavior (Hermans et al., 2003; Tata et al., 1996; van den Hout & Kindt 2003 a, b), these studies have mainly focused on memory for compulsive behaviors. However, biases should also be seen with regards to the environmental information that is encoded into memory, with this bias depending on the type of OC concern. To the extent that the behavior of washers is related to the adaptive problem of avoiding contamination, washers should display memory biases with regards to contamination items specifically. Similarly, if the behavior of checkers is related to a specific adaptive problem of avoiding harm to others, then checkers should also display biased encoding, retrieval, and storage of information that reflects physical safety.

### **Predictions for Study 2**

Study 2 explores the possibility that memory biases seen in OC symptoms are category specific and dependent on symptom expression.

**Prediction 2a.** Individuals who score high on the washing dimension of OCD will be more likely to encode and recall information about possible sources of contamination than other types of information.

**Prediction 2b.** Individuals who score high on the washing dimension might also be more likely to falsely remember stimuli relating to contamination.

**Prediction 2c.** Similarly, individuals who score high on the checking dimension of OCD will be more likely to encode and recall stimuli related to physical safety as compared to other types of stimuli.

**Prediction 2d.** Individuals who score high on the checking dimension of OCD might also be more likely to falsely remember stimuli relating to physical hazards/safety.

**Prediction 2e.** There should be no relationship between scores on either the washing or checking dimensions and the ability to remember stimuli unrelated to disease or physical safety.

### **Study 3: OCS and Reasoning**

The distinct adaptive problems associated with the washing and checking dimensions of OCD suggest there exist separate systems for reasoning about disease versus physical harms. That is, there would need to be different mechanisms for identifying instances in which a disease hazard versus a physical hazard could be present. For instance, given someone who did not wash his or her hands after using the bathroom, specialized reasoning mechanisms would be needed to assess the possibility that this behavior could lead to contamination. These reasoning mechanisms would be different from those used to assess whether a steaming iron could be a source of physical harm.

The idea that there might be different reasoning processes for hazards relating to disease and hazards relating to physical harm is novel. Previous theoretical approaches and research have considered “hazards” or “precautions” to be a singular domain (e.g., Boyer & Lienard, 2006; Fiddick et al., 2001). However, different precautions are required for addressing different types of hazards (e.g., those relating to disease versus those relating to the physical world versus those relating to predators).

Study 3 examines whether individual differences in symptom severity for the washing and checking dimensions of OCD are associated with differences in reasoning about disease and physical hazards, respectively. Using the WCST, subjects were presented with rules depicting a disease hazard (e.g., “If you sit on a public toilet seat, then you must use a protective seat cover.”), rules depicting a physical hazard (e.g., “If

you leave the house, then you must lock all the doors.”), and rules depicting social contracts (e.g., “If you park in the parking structure, then you must be an employee.”). Both types of hazard rules are phrased as “If you engage in a hazardous behavior, then you should take the associated precaution to minimize hazard”.

### **Predictions for Study 3b**

**Prediction 3a.** Scores on the washing dimension of OCD will be associated with poorer performance on the disease hazard tasks as compared to physical danger tasks and social contract tasks. This is because scores on the washing dimension will be associated with selecting the incorrect cards representing “did not engage in hazardous behavior (not-P)” and “did take associated precaution (Q)” to double check that no actions leading to contamination were taken along with selecting the correct cards representing “engaged in hazardous behavior (P)” and “did not take associated precaution (not-Q)”. (Performance on the Wason task is scored as correct only if the P and not-Q cards and no other cards are selected).

**Prediction 3b.** Scores on the checking dimension of OCD will be associated with poorer performance for the physical danger hazard tasks as compared to disease tasks and social contract tasks. Specifically, scores on the checking dimension will be associated with selecting the incorrect cards representing “did not engage in hazardous behavior (not-P)” and “did take associated precaution (Q)” to double check that no actions leading to contamination were taken along with selecting the correct cards representing “engaged in hazardous behavior (P)” and “did not take associated precaution (not-Q)”. (Performance on the Wason task is scored as correct only if the P and not-Q cards and no other cards are selected).

**Prediction 3c.** There will be no association with scores on the washing and checking dimensions of OCD and performance the social contract tasks.

## **Chapter 2. General Methods**

Data for the attention, memory, and reasoning studies were collected using the same sample of university undergraduate students. This allowed for the comparison of performance across multiple cognitive tasks. In this chapter, I describe the methods common to all three studies. Chapter 3 will explain the creation of the variables that measure individual differences in washing and checking tendencies. These variables are used in analyses for each study examining how performance on each cognitive task relates to the intensity of washing and checking behaviors. The remaining chapters present the attention (Chapters 4-5), memory (Chapters 6-7), and reasoning (Chapters 8-9) studies. There are two chapters devoted to each study: one that describes the norming of the stimuli created for each study and one that reports on the study-specific methods and results. Chapter 10 provides a General Discussion.

### **Participants**

A total of 167 individuals from undergraduate introductory psychology courses at the University of Miami participated in all studies during the Fall of 2011 and the Spring of 2012. Of the total participants, 167 reported their sex (41.9% men) and 148 reported their age ( $M = 18.97$ ,  $SD = 1.54$ , range = 17 to 31 years).

### **Design**

There were three separate tasks: an attention task, memory task, and reasoning task, followed by a battery of measures. The order of administration of the three tasks was counterbalanced between participants, resulting in a between subject factor for order. There were six possible orders.

## Measures

**Study-specific measures.** Each study had task-specific measures and designs, including stimuli specific to that task. Chapters 5, 7, and 9 describe the task-specific measures for the attention, memory, and reasoning experiment, respectively.

**General measures.** All participants completed the following measures (see Table 1).

***Padua Inventory- Washington State University Revision (PI-WSUR; Burns et al., 1996).*** The PI-WSUR is a 39-item self-report measure which assesses the following domains of Obsessive-Compulsive Disorder (OCD): obsessional thoughts about harm to self or others (OTAHSO), obsessional impulses to harm self or others (OITHSO), contamination obsessions and washing compulsions (COWC), checking compulsions (CHKC), and dressing/grooming compulsions (DRGRC). Raters indicate the degree of disturbance caused by each item on a 5-point scale (1: *not at all disturbed* to 5: *very much disturbed*). This measure has shown good factor structure, good discriminant validity, and adequate test-retest reliability (Meyer, Miller, Metzger, & Borkovec, 1990). Examples of items related to contamination obsessions and washing compulsions include “I feel my hands are dirty when I touch money” and “I avoid using public toilets because I am afraid of disease and contamination.” Items measuring checking compulsions include “I have to do things several times before I think they are properly done” and “I tend to keep on checking things more often than necessary.” Items were averaged separately for each subscale.

***Obsessive Compulsive Inventory Revised (OCI-R; Foa et al., 2002).*** The Obsessive-Compulsive Inventory-Revised is an 18-item self-report measure for assessing

six different symptom dimensions of OCD: Washing, Checking, Ordering, Obsessing, Hoarding, and Neutralizing. Items are rated on a 5-point Likert-scale ranging from 0 (*not at all*) to 4 (*extremely*) for how much each item “distressed” or “bothered” the individual in the past month. This measure has shown sound factor structure, good internal consistency for the full scale as well as the six subscales, and moderate to high test-retest reliability (Foa et al., 2002). Examples of items measuring Washing include, “I find it difficult to touch an object when I know it has been touched by strangers or certain people” and “I sometimes have to wash or clean myself simply because I feel contaminated.” Examples of items measuring Checking include, “I check things more often than necessary” and “I repeatedly check doors, windows, drawers, etc.” Average scores were created for each subscale.

***Three-domain Disgust Scale (TDDS; Tybur, et al., 2009).*** The TDDS is a self-report measure of an individual’s disgust sensitivity in three domains of disgust: pathogen disgust, sexual disgust, and moral disgust. There are seven items for each domain with ratings ranging from 0 (*not disgusting at all*) to 6 (*extremely disgusting*). The measure has shown sound factor structure, good internal reliability, and discriminant and convergent validity for the separate domains (Tyber et al., 2009). Examples of pathogen disgust items include “Seeing a cockroach run across the floor” and “Sitting next to someone who has red sores on their arm.” Items from each subscale were averaged to create a Pathogen Disgust, Sexual Disgust, and Moral Disgust score for each participant.

***Obsessional Beliefs Questionnaire (OBQ-44; OCCWG, 2005).*** The OBQ-44 measures cognitive biases that have been suggested to play an important role in the maintenance and development of OCD (OCCWG, 2003, 2005; Rachman, 2002,

Salkovskis, 1989, Salkovskis et al., 2000). The OBQ consists of three subscales: (1) inflated responsibility for harm (Responsibility/Threat estimation, e.g., “Harmful events will happen unless I am very careful”), (2) perfectionism and intolerance of uncertainty (Perfectionism/Certainty, e.g., “For me, things are not right unless they are perfect”), and (3) importance of thoughts and control over thoughts (Importance/Control of thoughts, e.g., “Having a bad thought is no morally different than doing a bad deed”). The measure assesses level of agreement (from 1: *disagree very much* to 7: *agree very much*) with statements that reflect these different attitudes and beliefs. Individuals received an average score for each subscale. Total scores were created for each subscale as well as the entire measure.

***State-Trait Anxiety Inventory – Trait (STAI-Trait; Spielberger, 1989).*** The STAI-Trait measures an individual’s stable tendency to experience anxiety, evaluate situations as dangerous or threatening, and react to situations with highly anxious reactions (i.e., trait anxiety). Individuals rate 20 items on a 4-point scale (almost never, sometimes, often, and almost always) indicating how they “generally feel” (e.g., “I feel nervous and restless”; “I get in a state of tension or turmoil as I think over my recent concerns and interests”). This measure has shown good reliability and validity (Spielberger, 1989). Items were summed to create a trait anxiety score for each individual.

***Beck Depression Inventory-II (BDI-II, Beck, Steer, & Brown, 1996).*** The BDI-II is a 21-item, self-report measure of the presence and severity of depressive symptoms (scale ranges from 0 to 3; 3 represents the highest level of symptom severity). This

measure has strong psychometric properties such as high internal consistency, high test-retest reliability, and strong convergent and discriminant validity (Beck et al., 1996). A total score was calculated for each participant.

***Letter fluency and category fluency (Baldo & Shimura, 1998).*** This task has been purported to measure the executive function of attention (Omori et al., 2007). Similar tasks have been used to measure the retrieval fluency of verbal information from memory (e.g., Woodcock-Johnson III Tests of Cognitive Abilities, WJC-III: Woodcock, Mather, & McGrew, 2001). This measure includes three letter fluency tasks and three category fluency tasks. The letter fluency tasks require individuals to name as many words as they can, in one minute, that begin with a specific letter (e.g., F, A, S). The category tasks require individuals to generate words belonging to a specific category (e.g., animals, fruits, occupations). The number of words generated for letter fluency and category fluency were tallied and summed to create a total fluency score.

**Procedure.** After signing consent forms, groups of participants, ranging from one to three individuals at a time, were given the tasks and measures. Each group of participants was given the same order of presentation of the tasks. Six orders were created to counterbalance the order of presentation. After the presentation of the tasks, participants were given the tests of fluency followed by the general measures.

## **Results**

Simple correlations were used to examine the association of order of experiment presentation and experimental task results. Effects were considered significant at  $p \leq .05$ . Order of experimental task presentation was not significantly correlated with results of the attention task, memory task, or reasoning task.

**Discussion**

Given that the order of experimental task presentation did not affect results of the experimental tasks, methods and results of each task will be presented as separate studies.

### Chapter 3. Creation and Validation of Study Measures

Measures of contamination and physical harm concerns were created using the PI-WSUR. These measures were created because the original dimensions of the PI-WSUR posed several limitations. Specifically, certain scales contained items that conceptually overlap with other scales. Two items on the checking compulsions subscale (CHCK) contained vague and thus potentially overlapping items. For instance, the item “I have to do things several times before I think they are properly done” could reflect either a washing or checking compulsion. Similarly, the obsessional thoughts about harm to self or others subscale (OTAHSO) contained an item that is appropriate for both contamination and physical harm concerns: “I sometimes worry at length for no reason that I have hurt myself or have some disease”. Additionally, the CHCK subscale contained items not directly related to physical danger: “When I handle money, I count and recount it several times.” Given that the nature of the predictions focused on checking for physical harm, rather than any type of checking, it was important to exclude checking behaviors not obviously related to physical harm.

Items that exclusively reflected concerns for contamination were aggregated to create a Contamination Score. These items included all of the original contamination obsessions and washing compulsions (COWC) items plus one OTAHSO item because this item exclusively related to disease avoidance. Similarly, items reflecting concerns for physical danger were chosen to create a Physical Harm score. The Physical Harm score included items from the Check and OTAHSO scales (See Table 2). The validity of these different subscales was examined against the PI-WSUR, OCIR, TDDS, and OBQ-44.

## Results

Table 3 presents correlations for Contamination Scores, Physical Harm Scores, and the scales of the PI-WSUR, OCIR, TDDS, and OBQ-44. The Contamination Score was highly correlated with the COWC sub-scale ( $r(164) = .996, p < .001$ ). This finding was expected given that all items overlapped for these two scales except one, which also reflected contamination concerns. Likewise, the Physical Harm Scores highly correlated with CHCK ( $r(163) = .83, p < .001$ ) and OTAHSO ( $r(163) = .79, p < .001$ ). Again, these findings were expected due to the high overlap of items between scales.

To demonstrate convergent validity, participants' scores for Contamination and Physical Harm Scores were compared to the Washing and Checking subscales of the OCIR. Contamination Scores were significantly correlated with Washing ( $r(162) = .85, p < .001$ ) and Checking ( $r(163) = .41, p < .001$ ). Notably, the correlation between the Contamination Scores and Washing was significantly greater in magnitude than the correlation between the Contamination Scores and Checking ( $z = 7.33, p < .0001^1$ ). Similarly, Physical Harm Scores were significantly correlated with Washing ( $r(163) = .38, p < .001$ ) and Checking ( $r(164) = .67, p < .001$ ). As expected, Physical Harm Scores were more strongly related with Checking than Washing ( $z = 3.67, p < .001$ ).

Additional tests of convergent and discriminant validity examined the relationships between the Contamination and Physical Harm Scores and pathogen disgust sensitivity from the TDDS (Pathogen). Pathogen disgust was chosen because much of the extant research (e.g., Aylward, Lieberman, Timpano, Cek, & Oum, in prep) has shown that disgust is more strongly related to the washing dimension of OCD than the other OC

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partial eta-squared

dimensions. As seen in Table 3, Contamination Scores were significantly correlated with Pathogen Disgust ( $r(164) = .37, p < .001$ ). Physical Harm Scores were not significantly correlated with Pathogen Disgust ( $r = .04$ ). In contrast, the obsessional thoughts about harm to self or others subscale (OTAHSO) was significantly related to Pathogen Disgust ( $r(164) = .19, p < .01$ ). The significant relationship between OTAHSO and Pathogen Disgust reflects the existence of items within the OTAHSO subscale related to thoughts or worries about diseases, making the OTAHSO a less clean measure of physical harm.

Descriptive statistics for the study measures are presented in Table 4. The possible range of each scale was 0 to 4. Means for the Contamination and Physical Harm variables were both positively skewed. Additionally, the ranges of both variables were limited such that maximum values for both variables ( $\text{Max}_{\text{Contamination}} = 3$ ;  $\text{Max}_{\text{Physical Harm}} = 2.29$ ) did not reach the possible maximum value (i.e.,  $\text{Max} = 4$ ) for the scales. With regards to scale reliability, the Contamination scale demonstrated excellent internal consistency and the Physical Harm scale demonstrated acceptable internal consistency (see Table 4 for values).

## Discussion

Taken together, these findings demonstrate the utility of using the newly created Contamination Scores and Physical Harm Scores. The Contamination and Physical Harm scores differentially predict pathogen disgust sensitivity and, conceptually, contain items relevant to either washing/cleanliness or physical harm. This is in contrast with the various subscales of the PI-WSUR. Given that the hypotheses for each study predict a differentiation between disgust-related and non disgust-related OCD with regards to

performance on attention, memory and reasoning tasks using disgust-related and non disgust-related stimuli, the Contamination and Physical Harm variables appear to be more appropriate for evaluating these hypotheses.

## **Chapter 4.**

### **Study 1: Attention Task, Stimuli Development**

A set of images was created for the attention task following the methods used by New et al. (2007). The set depicted scenes of disease, physical danger, or neutral stimuli (Image Type: Disease, Physical Danger, Neutral). In each Disease image, one contaminated item (e.g., feces) was chosen as the Target Stimulus to be removed in the attention task. Similarly in each Physical Danger image, an object posing a physical threat (e.g., knife) was chosen as the Target Stimulus to be removed in the attention task. Within Neutral scenes, the removed item posed no potential physical or infectious danger (e.g., a banner). Additionally, within the Disease and Physical Danger scenes, neutral items were selected for removal as a control. These were labeled Distractor Stimuli.

Images were rated on distinguishing attributes, such as disgustingness, hazardousness, obviousness, and intensity, by a set of individuals to ensure that the set was valid, as well as to rule out alternative explanations for findings (see Methods section below for a full description).

**Image Design Criteria.** We had multiple criteria for the selection of images. First, disease-related stimuli should be more disgusting than physically dangerous and neutral stimuli. Second, disease-related images/targets and physically dangerous images/targets should be equally hazardous and intense/obvious, yet more hazardous and intense than the Neutral scenes. Last, across scene types, the distractor/neutral stimuli should not significantly differ on attributes because these stimuli were intended to be neutral.

## Methods

**Participants.** During the fall semester of 2012, twenty-six individuals from an undergraduate introductory psychology course from the University of Miami rated the images on various attributes.

**Materials.** Materials consisted of electronic images paired with rating questions.

**Images.** There were 11 images for each Scene Type (Disease, Physical Harm, Neutral), totaling 33 images. Images consisted of colored JPEGs of complex familiar scenes (e.g., kitchen, bathroom, outside view of house). Scenes included a variety of stimuli and situations (e.g., many kitchen items, bathroom items, and a market place with people and goods) and consisted of distance shots such that no one focal item existed. Disease scenes contained one disease cue amongst non-dangerous stimuli (e.g., vomit and people on a subway). Examples of disease items included vomit, feces, a rat, and maggots. Likewise, Physical Danger scenes contained one physical danger cue amongst non-danger cues (e.g., one knife amongst other non-dangerous kitchen items). Examples of physical danger items included a knife, hot burner, scissors, and a manhole. The Distractor Stimuli within the disease and physical danger scenes (i.e., the neutral items) included items such as a small container, a bottle, a pile of clothes, a cup, and a pickle. The location of the Target and Distractor Stimuli varied between images. For the Neutral scenes, examples of items included a cup, bench, and banner. Several of the Neutral images were taken from New and colleagues (2007).

The scenes were approximately 16.7 cm height by 22.2 cm width for landscapes and 18.1 cm width and 27 cm height for portraits. Scenes were viewed from

approximately 50 cm away from the computer screen. See Table 5 for examples of each category.

**Rating Questions.** Participants rated the entire scene (i.e., with nothing removed) and, separately, the Target and Distractor Stimuli within each scene on various attributes. Entire scenes were rated separately for how disgusting, hazardous and intense they appeared (i.e., “How disgusting/hazardous/intense is this scene?”) on a scale from 1 (*not at all disgusting/hazardous/intense*) to 7 (*extremely disgusting/hazardous/intense*). Target and Distractor stimuli were rated for how disgusting, hazardous and obvious they appeared using the same scale. For example, for physically dangerous scene with an open manhole (target stimulus) and a parked car (distractor stimulus), participants were asked: “How disgusting/hazardous/intense is this scene?”, “How hazardous/disgusting/ obvious is the manhole in the street?”, and “How hazardous/disgusting/obvious is the car?” Thus each participant was asked 9 questions about each image.

**Procedure.** Participants signed consent forms and then rated the images on the computer using E-prime, version 2.0. Image presentation and rating questions were randomized.

## Results

Paired sample *t* tests were used to compare the Scene Types, Target Stimuli, and Distractor Stimuli on the different rating questions. Given the large number of *t*-tests, a Bonferonni correction was used to control the experiment-wise error rate ( $p = .05/24 = .002$ ). Results are presented separately for Scene Type, Target Stimuli, and Distractor Stimuli (see Table 6 for Means and Standard Deviations).

**Scene Type.** The three scene types were compared on ratings of disgust, hazard, and intensity. For ratings of disgust, Disease scenes were rated significantly more disgusting than both Physical Danger scenes ( $t(25) = 14.37, p < .001$ ) and Neutral scenes ( $t(25) = 15.78, p < .001$ ). Physical danger scenes were rated significantly more disgusting than Neutral scenes ( $t(25) = 3.90, p = .001$ ). For ratings of hazard, Disease scenes were not rated significantly different from Physical Danger scenes. However, both Disease scenes ( $t(25) = 10.44, p < .001$ ) and Physical danger scenes ( $t(25) = 9.41, p < .001$ ) were rated significantly more hazardous than Neutral scenes. For ratings of intensity, Disease scenes did not significantly differ from Physical danger scenes, whereas Disease scenes were rated significantly more intense than Neutral scenes ( $t(25) = 3.42, p < .002$ ). Physical Danger scenes did not significantly differ from Neutral scenes on ratings of intensity.

**Target Stimuli:** Target Stimuli within the Disease, Physical Danger, and Neutral scenes were compared for ratings of disgust, hazard, and obviousness. For ratings of disgust, disease targets were rated significantly more disgusting than both the physical danger targets ( $t(25) = 15.60, p < .001$ ) and neutral targets ( $t(25) = 22.52, p < .001$ ). Physical Danger targets were not significantly more disgusting than Neutral targets. For ratings of hazard, disease targets were not rated significantly different from physical danger targets. However, both disease targets ( $t(25) = 15.23, p < .001$ ) and physical danger targets ( $t(25) = 16.75, p < .001$ ) were rated significantly more hazardous than neutral targets. For ratings of obviousness, disease targets did not significantly differ on

ratings from physically danger targets. In contrast, disease targets ( $t(25) = 5.40, p < .001$ ) and physical danger targets ( $t(25) = 8.58, p < .001$ ) were rated significantly more obvious than neutral targets.

**Distractor Stimuli.** Distractor stimuli within Disease and Physical Danger scenes were compared for ratings of disgust, hazard, and obviousness. Additionally, given that the Distractor stimuli were intended to be neutral items, the Distractor stimuli were compared to the Target stimuli within Neutral scenes (i.e., neutral stimuli). For ratings of disgust, distractor stimuli within Disease scenes were rated significantly more disgusting than both the Distractor stimuli within Physical Danger scenes ( $t(25) = 3.42, p = .002$ ) and Target stimuli within Neutral scenes ( $t(25) = 4.04, p < .001$ ). For ratings of hazard, there were no significant differences between stimuli. Similarly, for ratings of obviousness, there were no significant differences between stimuli.

## Discussion

The image ratings suggest that our set of images met our criteria for use in the attention task. For one, stimuli and scenes intended to represent sources of disease were rated significantly more disgusting than stimuli and scenes intended to be physically dangerous or neutral. Although physically dangerous targets and scenes were rated slightly more disgusting than neutral targets and scenes, all four means were similarly low (i.e.,  $M_s < 2$ ). Disease-related and physically dangerous stimuli and scenes were rated equally hazardous, and both were rated more hazardous than neutral scenes. Overall, the ratings differentiated disease-related and physically dangerous stimuli from one another as well as both from neutral stimuli.

With regards to how obvious the stimuli appeared within the scenes, disease targets did not differ from physical danger targets. This finding is necessary to rule out obviousness of target as the cause of any significant differences found in the attention task. In contrast, both disease and physical danger targets were rated more obvious than neutral targets. This finding is notable because how obvious a stimulus is within a scene can confound differences found in the attention task. It is possible that disease and physical danger stimuli may be more likely to appear obvious because of their hazardous properties.

Ratings of scene intensity were similar to ratings of obviousness such that Disease and Physical Danger scenes were equally intense, and both were rated as more intense than Neutral scenes. Again, it is possible that scenes containing hazardous stimuli by definition may appear more intense given that a stronger emotional response is evoked in these scenes than in neutral scenes.

Neutral stimuli within the Disease and Physical danger scenes were also rated on the attributes of disgust, hazard, and obvious. The ratings are mostly consistent with predictions. Distractor (neutral) stimuli were rated as equally hazardous and obvious across scenes. Contrary to predictions, neutral stimuli within disease scenes were rated more disgusting than neutral stimuli within physically dangerous or neutral scenes, though the mean was still very low ( $M < 2$ ). This finding may reflect a poor choice of neutral object in one or more of the disease scenes. However, it is possible that the law of contagion (Rozin et al., 1999) could be in effect here. This law reflects the propensity for certain individuals to believe items that come in contact with contaminants become contaminated themselves.

## **Chapter 5.**

### **Study 1: Attention and OCS**

The goal of this study was to examine the effect of different types of hazardous information on attention vigilance and maintenance. Several predictions were made. First, hazardous features of the environment relating to pathogen presence and physical safety should preferentially recruit attention over non-hazardous information. Second, to the extent that separate attention mechanisms exist for disease hazards versus physical safety hazards, then cues signaling the presence of these two types of hazards should elicit unique patterns of biased orienting of attention (i.e., attentional vigilance; Mogg & Bradley, 1998) and/or prolonged attention capture (i.e., maintenance; Weierich, Treat, & Hollingworth, 2008). Third, individuals expressing obsessive-compulsive concerns for contamination threats and/or threat to physical safety should evince concern-related attention biases.

#### **Methods**

**Participants.** Refer to Chapter 2 (page 32) for information regarding the participants. Participants were removed from analyses in a pairwise fashion if they had reaction times less than or equal to 500 ms. This value was chosen because no changes had occurred to the images until after 500 ms, thus, a response below this threshold was meaningless. Additionally, participants were removed in a pairwise fashion if they had missing values on variables of interest (e.g., on measures of disgust).

**Design.** This study was a 2 (Stimulus Condition: Target, Distractor) by 3 (Scene Type: Disease, Physical Danger, Neutral) mixed factorial design with Stimulus Condition as a between subjects factor and Scene Type as the within subjects factor. More

specifically, all participants were shown three different types of scenes, those containing disease-related stimuli, physically dangerous stimuli, and non-dangerous or neutral stimuli. Within the Target Condition, for the Disease and Physical Danger scenes, the stimuli removed were the disease-related and physically dangerous items, respectively. Within the Distractor Condition, the stimuli removed were neutral stimuli within the Disease and Physical Danger scenes. Participants in both the Target and Distractor Conditions detected changes to identical neutral stimuli within the Neutral scenes. The dependent variable was reaction time in milliseconds for detecting the removal of stimuli from the scenes.

### **Materials**

The set of images described in Chapter 4 was used along with the measures described in Chapters 2 and 3. The target and distractor items were removed from the images using Adobe Photoshop CS5 (version 11.0) and the remaining area was replaced with the surrounding background. Two additional neutral images were used as “catch” trials such that no change occurred to these images. The catch trials were intended to ensure that participants were performing the task as directed and to prevent random responding.

### **Procedure**

Participants completed the change blindness task on the computer (procedure similar to New et al., 2007). They were randomly assigned to either the Target or Distractor condition. First, participants read an instruction page explaining that the purpose of the task is to look for a change in the scene and to indicate they have seen this change by pressing the spacebar. Participants were informed that no change occurs on

some of the trials. The presentation order for each image was as follows: (1) a black fixation cross was presented in the middle of the monitor for 500 ms, (2) the unaltered scene, A, was presented for 250 ms, (3) a white “Flicker” screen was shown for 250 ms, (4) the altered scene, A', was presented for 250 ms (or the same scene in the case of the catch trials), and (5) a second white “Flicker” screen was shown for 250 ms (see Figure 1). This sequence was presented until the participant indicated that he or she detected the change or until 30 seconds elapsed (from the time of first presentation of Image A). The participants performed this task for 33 images presented in random order. After they finished the change blindness task, participants completed the questionnaires.

## Results

**The effect of Stimulus Condition and Scene Type on reaction times.** The general linear model (GLM) was used to test the between subject effect of Stimulus Condition (Target, Distractor) and the within subject effect of Scene Type (Disease, Physical Danger, and Neutral) on reaction times (RT, in milliseconds) for detecting changes to the scenes. Results are reported using a Greenhouse-Geisser correction for the within subjects effects because the assumption of sphericity was not met. Estimated marginal means are reported. All follow up comparisons were computed using a Bonferonni correction.

There was a main effect for Stimulus Condition ( $F(1, 161) = 100.25, p < .001$ , partial eta-squared = .38) with individuals responding faster in the Target Condition ( $M = 6003.44, SE = 224.21$ ) versus the Distractor Condition ( $M = 9024.53, SE = 201.93$ ). There was a main effect for Scene Type ( $F(1.96, 308.40) = 21.69, p < .001$ , partial eta-squared = .12). Follow up comparisons indicated that, overall, individuals responded

faster to Physical Danger scenes ( $M = 6737.10$ ,  $SE = 174.76$ ) than to both Disease scenes ( $M = 7639.11$ ,  $SE = 195.83$ ;  $t(308.40) = -4.62$ ,  $p < .001$ ) and Neutral scenes ( $M = 8165.75$ ,  $SE = 218.03$ ;  $t(308.40) = -6.11$ ,  $p < .001$ ). Response times for Disease scenes were not significantly faster than response times for Neutral scenes.

Additionally, the interaction between Stimulus Condition and Scene Type was significant ( $F(1.96, 308.40) = 99.03$ ,  $p < .001$ , partial eta-squared = .38; see Figure 2). Pairwise comparisons revealed that, for those in the Target Condition (i.e., those who detected changes to disease and physical danger stimuli), individuals detected changes to disease stimuli ( $t(308.40) = -10.52$ ,  $p < .001$ ) and physical danger stimuli ( $t(308.40) = -10.01$ ,  $p < .001$ ) significantly faster than changes to stimuli within neutral scenes. Reaction times did not significantly differ between disease stimuli and physical danger stimuli ( $p = 1.00$ ). For those in the Distractor condition, individuals detected changes to neutral stimuli within disease scenes significantly slower than to both neutral stimuli within physical danger scenes ( $t(308.40) = 7.19$ ,  $p < .001$ ) and stimuli within neutral scenes ( $t(308.40) = 8.21$ ,  $p < .001$ ). There was no significant difference in reaction times for detecting changes to neutral stimuli within physical danger scenes versus detecting changes to neutral scenes (Refer to Table 7 for Means and Standard Deviations).

**The effect of Contamination Scores and Physical Harm Scores on reaction times.** The model above was repeated separately for those in the Target and Distractor Conditions while also entering Contamination Scores and Physical Harm Scores as covariates. Follow-up analyses were analyzed with a Bonferroni correction.

**Target Condition.** Because sphericity could not be assumed (Mauchley's  $W(2) = .82$ ,  $p = .001$ ), results are reported using a Greenhouse-Geisser correction. As expected,

there was a main effect for Scene Type ( $F(1.69, 116.74) = 40.80, p < .001$ , partial eta-squared = .37). Comparisons of the means showed the same pattern as above. Individuals responded to Disease scenes ( $M = 4802.55, SE = 199.24$ ) significantly faster than Neutral scenes ( $M = 8320.19, SE = 323.79; t(116.74) = -10.17, p < .001$ ), whereas response time to Disease scenes did not differ from Physical Danger scenes ( $M = 4892.50, SE = 221.05$ ). Additionally, individuals responded to Physical Danger scenes significantly faster than Neutral scenes ( $t(116.74) = -9.80, p < .001$ ). There were no main effects for Contamination Scores or Physical Harm Scores.

Contamination Scores marginally interacted with response times for Scene Types ( $F(1.69, 116.74) = 2.87, p = .07$ , partial eta-squared = .04). Examination of the correlations in Table 7 reveals that, for those subjects in the Target Condition, Contamination Scores were significantly correlated with reaction times for Physical Danger scenes ( $r(72) = .30, p = .009$ ) but not with Disease or Neutral scenes.

Physical Harm concerns did not significantly covary with Scene Type (see Table 7 for correlations).

To test an alternative hypothesis that shared characteristics of OC symptoms are associated with attention biases, a variable was created reflecting the principal component of the shared variance between the Contamination and Physical Harm Scores (OC Overlap). This variable was entered as a covariate into a the three way repeated measures ANOVA examining the effect of Scene Type on reaction times to detecting Target objects. There was no main effect of OC Overlap and this variable did not significantly interact with Scene Type.

**Distractor Condition.** The model was repeated examining the effect of the within subject variable of Scene Type on reaction times for those in the Distractor Condition while entering Contamination Scores and Physical Harm Scores as covariates. Results are reported assuming sphericity. Similar to the results of both models already presented, there was a main effect for Scene Type ( $F(2, 166) = 11.54, p < .001$ , partial eta-squared = .12). Follow up comparisons evinced that reaction times for Disease scenes ( $M = 10526.72, SE = 324.31$ ) were significantly slower than Physical Danger scenes ( $M = 8566.28, SE = 261.60; t(166) = -9.80, p < .001$ ) and Neutral Scenes ( $M = 8014.16, SE = 306.10; t(166) = -9.80, p < .001$ ).

Additionally, there was a main effect for Contamination Scores ( $F(1, 83) = 4.38, p = .04$ , partial eta-squared = .05), indicating a significant negative relationship between overall reaction times and Contamination scores ( $r(88) = -.13, p = ns$ ). There was no main effect for Physical Harm Scores. Neither Contamination nor Physical Harm Scores significantly interacted with Scene Type (see Table 8 for correlations).

An additional model was tested examining the effect of the OC Overlap as a covariate and the repeated measure of Scene Type on reaction times for scene changes to Target objects. Neither the main effect of OC Overlap nor the interaction effect was significant.

**The effect of other traits on reaction times.** The effects of other variables, which may affect attention, such as disgust sensitivity (TDDS pathogen), cognitive biases associated with OCD (OBQ-44), depression (BDI-II), general trait anxiety (STAI-Trait), and executive functioning (Verbal Fluency) were examined. GLM models were tested separately for the Target and Distractor conditions.

**Target condition.** Using a Greenhouse-Geisser correction for the within subject effects (Mauchly's  $W(2) = .82, p = .002$ ), there was a marginal main effect for Scene Type ( $F(1.70, 110.18) = 3.13, p < .06$ , partial eta-squared = .05). Follow up comparisons mirrored the findings above such that individuals reacted faster to Disease scenes ( $t(110.18) = -10.27, p < .001$ ) and Physical Danger scenes ( $t(110.18) = -9.72, p < .001$ ) than Neutral scenes. None of the covariates significantly interacted with Scene Type.

**Distractor condition.** The main effect of Scene Type was not significant. There were main effects for the covariates of BDI-II ( $F(1, 77) = 6.67, p = .01$ , partial eta-squared = .08) and Verbal Fluency ( $F(1, 77) = 6.30, p = .01$ , partial eta-squared = .08). BDI-II scores were positively correlated with overall mean reaction time ( $r(87) = .21, p = .052$ ), whereas Verbal Fluency scores were negatively correlated with overall mean reaction time ( $r(89) = -.24, p = .03$ ).

The interaction between Scene Type and BDI-II scores was significant ( $F(2, 154) = 3.79, p < .025$ , partial eta-squared = .05). BDI-II scores were significantly correlated with reaction times for distractor stimuli within Disease scenes ( $r(88) = .25, p = .02$ ) and Neutral scenes ( $r(89) = .23, p = .03$ ) but not Physical Danger scenes. None of the other covariates significantly interacted with Scene Type.

Given that BDI-II and Verbal Fluency scores affected reaction times in the Distractor condition but not the Target condition, these variables were compared between the two conditions. Independent-samples  $t$  tests revealed that BDI-II scores for those in the Distractor condition ( $M = 9.16, SD = 8.23$ ) did not significantly differ from BDI-II scores for those in Target condition ( $M = 8.28, SD = 7.04$ ). Similarly Verbal Fluency scores did not differ between the two groups ( $M_{\text{Target}} = 93.14, SD_{\text{Target}} = 22.21; M_{\text{Distractor}} =$

99.45,  $SD_{\text{Distractor}} = 20.18$ ). These results suggests that the differential effects of these covariates on reaction times for the two conditions are not a product of the difference in overall group BDI-II and Verbal Fluency Scores.

## **Discussion**

The findings provide some support the existence of specialized attention mechanisms for different types of hazardous information. Specifically, individuals exhibited biased orienting of attention (i.e., vigilance; Mogg & Bradley, 1998) for hazardous cues related to disease and physical danger as compared to non-hazardous cues. Additionally, attention appeared to be captured differently by contamination hazards versus physical danger hazards, such that attention capture was prolonged or maintained for contaminants. Specifically, when a scene contained a contamination hazard, individuals took longer to detect changes to a neutral object within that same scene, suggesting that attention may have been oriented and maintained to another object, presumably the hazardous one given that individuals express biased orienting to hazardous objects. In contrast, when a scene contained a physically dangerous hazard, individuals detected changes to the neutral objects within that scene as fast as they did to neutral objects within scenes that contained no hazardous objects. The effect size of this interaction between scene type and type of object within scene on reaction times was quite large (partial eta squared = .38). These findings may suggest that although attention vigilance is similar for disease hazards and physically dangerous hazards, attention maintenance differs between these two types of hazards. Future research using eye-tracking methods could confirm whether the previous statement is true by examining what objects in a scene are grabbing and holding attention.

Another aim of this study was to examine the existence of concern-related biases in attention for those evincing obsessive-compulsive contamination and physical safety concerns. In short, the findings did not support this prediction. In fact, the positive correlation between contamination concerns and vigilance for physically dangerous hazards was the only significant relationship between OC symptoms and attention. Importantly, the effect size of the interaction between contamination concerns and reaction times for the different types of images was small. This finding, which suggests that those displaying heightened concerns for contamination are slower to detect cues of physical danger, was not predicted and is difficult to explain. In sum, the results did not support the existence of concern-related biases on attention for disease hazards and physically dangerous hazards for those evincing OC contamination and physical harm concerns.

The effects found were mostly maintained despite controlling for other variables that may have an impact on attention for the stimuli chosen, such as depressive symptoms, disgust sensitivity, trait anxiety, executive functioning, and cognitive biases. For those in the Target Condition, the effects remained stable despite the inclusion of potential covariates. In contrast, for the Distractor Condition, including the covariates diminished the differential effects of maintenance found for the different types of hazards. It is possible that because the task was to identify neutral objects rather than hazardous objects, other variables associated with attention, such as depression and executive functioning, became more influential on attention processes. Importantly, the two groups did not differ in depression and executive functioning scores indicating that

the differential effects of these covariates were not a product of group differences in expression of these covariates. More research is needed to better understand the effect of hazards on attention vigilance and maintenance.

## **Chapter 6.**

### **Study 2: Memory Task, Stimuli Development**

Three categories of images, containing a disease, physical danger, or neutral stimulus, were compiled to create a set of 240 images for the memory task. Within each category, images were paired so that there were two (non-identical) images of the same type of stimulus (e.g., two different dirty toilets; see Table 8 for examples). To validate the set, images were rated on attributes such as how disgusting, fear provoking, dangerous, appealing and intense they appear. Then, comparisons of these attributes were made within image pairs and across image categories.

**Image selection criteria.** We aimed to generate image pairs that did not significantly differ on important attributes for each image category. We expected that disease images would elicit higher ratings of disgust than physical danger or neutral images; physical danger images would elicit higher ratings of fear and danger than disease or neutral images; neutral images would elicit higher ratings of appeal than disease or physical danger images; and image categories would not differ on ratings of intensity.

#### **Methods**

**Participants.** Twenty individuals from introductory psychology courses at the University of Miami participated during the fall semester of 2011 for course credit.

**Materials.** Materials consisted of images and rating questions.

**Images.** There were three Image Types: Disease, Physical Danger, and Neutral. Disease images included sources of contamination (e.g., a dirty toilet, used tissues, and cockroaches). Physical Danger images included stimuli that pose threats potential

physical danger (Physical Danger Cues) as well as images depicting consequences of physical danger (Physical Danger Consequences). Examples of Physical Danger Cues included a hot iron, a child touching an outlet, and an unsupervised baby by a pool. Examples of Physical Danger Consequences included a house fire, bloody cut on hand, iron burning clothes. Because disease consequences, such as rash or herpes, also act as cues for potential contamination, the disease images were not separated into cues and consequences. Neutral images contained stimuli directly unrelated to danger or disease (e.g. sunset, mountain scene, and waves). Each Image Type contained 40-paired images (80 images total per category; 240 total images across all categories; see Table 9 for examples).

Photographs were taken directly from the web (searched with Google images) or purchased from iStock.com. Images were edited and standardized with Adobe Photoshop CS5 (version 11.0). All landscape images were resized to a width of 800 pixels (heights ranged from 497 to 781 pixels); all portrait style images were resized to 500 pixels in width (heights ranged from 504 to 788 pixels); square images were resized to 800 by 800 pixels.

**Rating questions.** Individuals rated images on a scale from 1 (*not at all*) to 7 (*extremely*) using the following question, separately, for each attribute: How disgusting/fear provoking/dangerous/intense/appealing is this image?

**Procedure.** Images and rating questions were presented in random order on a computer using Eprime (2.0) such that each participant rated all images for each rating question.

## Results

**Validating image pairs.** Ratings for each attribute (appealing, dangerous, disgusting, fear, and intense) were compared within image pairs. Three Physical Danger image pairs were removed because they significantly differed on ratings of dangerousness. Two Disease image pairs were removed because they significantly differed on disgustingness. One Neutral image pair was removed because it differed on appealingness. A Bonferonni correction was used to control the experimentwise error rate ( $p = .05/600 = .0001$ ). To keep the number of pairs consistent between conditions, thirty-seven pairs for each condition were selected to be the stimuli in the memory study (see Chapter 7).

**Validating categories.** Table 10 gives the means and standard deviations for each attribute within each Image Type. Paired  $t$  tests compared the attributes across Image Type. A Bonferonni correction was implemented to adjust for effects of multiple comparisons ( $p = .05/15 = .003$ ).

With regards to ratings of disgust, Disease images were rated significantly more disgusting than Physical Danger ( $t(19) = 11.65, p < .001$ ) and Neutral images ( $t(19) = 15.79, p < .001$ ). Physical Danger images were rated significantly more disgusting than Neutral images ( $t(19) = 6.96, p < .002$ ).

For ratings of danger and fear, Physical Danger images were significantly more dangerous and fear provoking than both Disease images (danger:  $t(19) = 10.46, p < .001$ ); fear:  $t(19) = 9.49, p < .001$ ) and Neutral images (danger:  $t(19) = 18.58, p < .001$ ;

fear:  $t(19) = 16.03, p < .001$ ). Additionally, Disease images were rated significantly more dangerous and fear provoking than Neutral images (danger:  $t(19) = 4.19, p < .001$ ; fear:  $t(19) = 6.65, p < .001$ ).

Neutral images were significantly more appealing than Disease ( $t(19) = 24.31, p < .001$ ) and Physical Danger images ( $t(19) = 23.27, p < .001$ ). Physical Danger images were not significantly more appealing than Disease images.

Physical Danger images were rated as more intense than both Disease ( $t(19) = 8.62, p < .001$ ) and Neutral images ( $t(19) = 4.03, p = .001$ ). Disease images did not differ in intensity from Neutral images. It is possible that Physical Danger images were rated more intense because a portion of the Physical Danger images were consequences (e.g., house fire) associated with physically dangerous cues or situations (e.g., oven left on). Indeed Physical Danger Consequences ( $M = 5.07, SD = .61$ ) were rated significantly more intense than Physical Danger Cues ( $M = 3.73, SD = .18; t(19) = 10.46, p < .001$ ). Additionally, after removing the Physical Danger Consequence images, the significant differences in intensity between the image types disappeared.

## Discussion

A set of images was created and validated for the memory task. The three types of images were validated on various attributes predicted to be associated with each category. Images with disease content were significantly more disgusting than images with physically dangerous or neutral content. Images with physical danger content were significantly more fear provoking and dangerous than disease-related or neutral images. Additionally, neutral images were more appealing than physically dangerous or disease-related images.

It was originally intended that images would be rated as equally intense, however, physical danger images were significantly more intense than disease and neutral images. As mentioned, physical danger images included images of consequences of physical danger, such as a house on fire. Given that a cue of potential danger does not equal actual danger whereas danger consequences do equate danger, it makes intuitive sense that images of danger consequences were rated as more intense than images of danger cues. In fact, removing the images of danger consequences eliminated the significant difference in intensity between image types.

## **Chapter 7.** **Study 2: Memory and OCS**

The purpose of this experiment was twofold: (1) to examine whether there is a difference in memory sensitivity for threats of disease, physical danger, and non-threatening material and (2) to determine whether expressing OC concerns for contamination and physical harm moderate memory sensitivity for disease and physical danger threats, respectively.

### **Methods**

**Participants.** Refer to chapter 2 (p. 32) for a description of participants.

**Design.** This study employed a four-way repeated measures design examining the effect of different types of images (Image Type: Disease, Physical Danger Cues, Physical Danger Consequences, and Neutral) and Contamination Scores and Physical Harm Scores on memory sensitivity (i.e., d-prime, hit rate, and false alarm rate; see Data Analyses for a description of the dependent variables). The Physical Danger category was divided into Physical Danger Cues and Physical Danger Consequences because these image types significantly differed on ratings of intensity. To the extent that image intensity affects memory, then there should be differences in memory sensitivity for cues versus consequences of physical danger.

**Materials.** Materials consisted of images and measures. The images described in Chapter 6 were used, along with three practice images, which were presented at the start of the recall phase. The practice images consisted of one disease image, one physical danger image, and one neutral image. These images were separate from the image set created and discussed in Chapter 6.

**Procedures.** The memory task was presented to participants on the computer with Eprime (2.0) and consisted of an encoding and recall phase. During the encoding phase, participants viewed the first image from each image pair in random order for 1950 ms. This presentation time was chosen because it exceeds the 400 ms needed to encode an image in memory (Potter, 1976) and was used in a study that presented similar types of images to individuals grouped by OC symptoms (Mataix-Cols et al., 2004). All participants saw the same images in the encoding phase but in different orders of presentation. Between the encoding and recall phase, the three practice images were presented with a question asking the participants to indicate if the image was previously shown. After the practice images, the recall phase began. During the recall phase, all images (i.e., both images from each image pair) were presented in random order. Participants were asked to indicate whether they saw the image during the encoding phase by pressing a key marked ‘Y’ for yes or ‘N’ for no.

#### **Data Analysis.**

**Signal Detection Analysis.** Memory sensitivity (i.e., d-prime) was computed using signal detection analysis. For this study, d-prime represented memory sensitivity for previously seen images amongst new images. A subject’s response fell into one of four categories: (1) a “hit” indicated that a subject categorized a previously seen image as seen (responds “Yes” correctly), (2) a “miss” indicated that a subject categorized a previously seen image as unseen (responds “No” incorrectly), (3) a “false alarm” indicated that a subject classified a previously unseen image as seen (responds “Yes” incorrectly), and (4) a “correct rejection” indicated that a subject classified a previously unseen image as unseen (responds “No” correctly). In brief, the d-prime variable takes

into account the proportion of hits to false alarms (see Macmillan & Creelman, 1991 for full description of computations). The hit rate equals the proportion of YES trials where individuals responded YES. The false alarm rate represents the proportion of NO trials where the individuals responded YES.

## Results

Analyses for d-prime are presented first, followed by analyses for hit rates and false alarm rates. Additionally, d-prime analyses were repeated controlling for other traits that may affect memory sensitivity such as disgust sensitivity, cognitive biases associated with OCD, depression, general trait anxiety, and executive functioning.

**D-prime analyses (i.e., memory sensitivity).** Results are reported with a Greenhouse-Geisser correction because sphericity could not assumed (Mauchly's  $W(5) = .92, p = .02$ ). There was a significant main effect for Image Type ( $F(2.84, 440.22) = 67.49, p < .001$ , partial eta-squared = .30). Follow up comparisons on the estimated marginal means were computed using a Bonferonni correction. Memory sensitivity was significantly greater for Physical Danger Consequences than for both Physical Danger Cues ( $t(440.22) = 3.48, p = .004$ ) and Neutral images ( $t(440.22) = 16.59, p < .001$ ). Memory sensitivity for Physical Danger Cues was significantly greater than Neutral images ( $t(440.22) = 15.00, p < .001$ ). Memory sensitivity for Disease images did not significantly differ from images of Physical Danger Cues or Physical Danger Consequences. However, Disease images produced significantly greater memory sensitivity than Neutral images ( $t(440.22) = 17.96, p < .001$ ).

There were no main effects for Contamination Scores and Physical Harm Scores. Additionally, Contamination Scores did not significantly interact with Image Type. In

contrast, Physical Harm Scores significantly interacted with Image Type ( $F(2.84, 440.22) = 2.96, p = .04$ , partial eta-squared = .02). Examination of the correlations in Table 12 reveals that Physical Harm Scores were significantly negatively associated with d-prime values for Physical Danger Consequences but not with the other Image Type d-primes.

Figure 3 presents the estimated marginal means of d-prime values for each Image Type. Table 11 presents d-prime means, standard deviations, skewness and kurtosis for each Image Type.

An additional model was tested examining the effect of the OC Overlap variable that was created to test the hypothesis that shared characteristics of the washing and checking dimension are related to memory biases rather than content-specific characteristics. This variable was entered as a covariate into the four way repeated measures ANOVA tested above. The interaction between OC Overlap and Image Type was significant ( $F(2.84, 443.29) = 2.94, p = .04$ ); however, the effect size was small (partial eta-squared = .018). Simple correlations revealed that OC Overlap was negatively associated with images of Physical Danger Consequences ( $r(158) = -.20, p = .01$ ). The main effect of OC Overlap was not significant.

**Hit rate and false alarm rate analyses.** Analyses were conducted examining the effect of Image Type (Disease, Physical Danger Cues, Physical Danger Consequences, and Neutral) and OC symptoms (Contamination Scores and Physical Harm Scores) on hit rates and false alarm rates, separately.

**Hit rates.** Because sphericity could not be assumed (Mauchly's  $W(5) = .71, p < .001$ ), results are reported with a Greenhouse-Geisser correction. There was a main effect for Image Type on hit rate ( $F(2.40, 372.64) = 110.18, p < .001$ , partial eta-squared = .42;

see Figure 4). Hit rates for Physical Danger Cues were significantly greater than hit rates for Disease ( $t(372.64) = 3.56, p = .004$ ) and Neutral images ( $t(372.64) = 19.36, p < .004$ ). Hit rates for Disease images were significantly greater than hit rates for Neutral images ( $t(372.64) = 18.38, p < .001$ ). Additionally, hit rates for Physical Danger Consequences were significantly greater than hit rates for Neutral images ( $t(372.64) = 17.79, p < .001$ ). Table 11 presents descriptive statistics for hit rates for each Image Type.

The main effects for the covariates of Contamination Scores and Physical Harm Scores were not significant. The interaction between Physical Harm Scores and Image Type was significant ( $F(2.40, 372.64) = 3.18, p = .03, \text{partial eta-squared} = .02$ ). The correlations in Table 12 revealed that Physical Harm Scores were negatively associated with hit rates for images of Physical Danger Cues and images of Physical Danger Consequences. In contrast the associations between Physical Harm Scores and hit rates for Disease and Neutral images were in the positive direction. Importantly, none of the correlations were significant.

**False alarm rate.** A repeated measures ANOVA examined the effect of Image Type and OC concerns on false alarm rates. Results are reported with a Greenhouse-Geisser correction (Mauchly's  $W(5) = .9, p = .006$ ). There was a main effect for Image Type on false alarm rates ( $F(2.83, 438.38) = 9.17, p < .001, \text{partial eta-squared} = .06$ ; see Figure 5). Follow up tests indicated that false alarm rates for images of Physical Danger Cues were significantly greater than false alarm rates for Disease images ( $t(438.38) = 7.33, p < .001$ ), Physical Danger Consequences ( $t(438.38) = 5.86, p < .001$ ), and Neutral images ( $t(438.38) = 3.86, p < .001$ ). Additionally, the false alarm rates for Neutral images were greater than the false alarm rates for Disease images ( $t(438.38) = 2.83, p = .02$ ).

The main effect of Physical Harm Scores was significant ( $F(1, 155) = 4.09, p = .045$ , partial eta-squared = .03). The correlation indicated that Physical Harm Concerns were significantly positively correlated with false alarm rates across Image Types ( $r(160) = .20, p = .01$ ). In contrast the main effect of Disease Scores was not significant. The interactions between the covariates (Contamination Scores and Physical Harm Scores) and Image Type were not significant. Table 13 presents descriptive statistics for false alarm rates for each Image Type.

**The effect of other variables on memory sensitivity and response bias.** The above d-prime analyses were repeated controlling for disgust sensitivity (TDSS pathogen), cognitive biases associated with OCD (OBQ-44), depression (BDI-II), general trait anxiety (STAI-Trait), and executive functioning (Verbal Fluency). Analyses were repeated separately for memory sensitivity. There was a main effect for Image Type ( $F(3, 444) = 4.26, p = .006$ , partial eta-squared = .03). None of the covariates significantly interacted with Image Type.

## Discussion

The main predictions of this study were partially supported by the results. For one, the data provide support for the existence of memory biases for hazardous information. Individuals demonstrated better memory for previously seen images of disease-related and physically dangerous stimuli than for neutral stimuli. Additionally, the size of this effect was large (partial eta-squared = .30). Memory for hazardous consequences was better than memory for hazardous cues, providing some support that memory mechanisms react in specific ways to differing types of content (i.e., cues versus consequences of physical hazards), even within the same domain (i.e., physical hazards).

Given research on fear conditioning (e.g., LeDoux, 1995; Mineka & Cook, 1993; Pitman & Orr, 1995), indicating the strength of learning that happens when faced with a dangerous consequence, it makes sense that memory would be enhanced for consequences of physical danger given the potential survival impact of these events (Tooby & Cosmides, 2008).

Hit rates and false alarm rates were examined to see if there exists a relationship between types of hazard and the tendency to either forget or falsely remember different hazardous information. Examining the hit and false alarm rates helps illuminate these distinctions because the calculation for  $d'$  creates a ratio of these numbers, masking subtle differences in the processes of accurately categorizing something as seen. Specifically, individuals were best at remembering previously seen images of cues related to physical danger hazards as compared to disease hazards and non-hazardous images. Additionally, the tendency to falsely remember images of physical danger cues was greater than all other categories, including non-hazardous images, which produced the worst memory sensitivity. Additionally disease hazards produced a lower likelihood of false memory than non-dangerous images.

I hypothesized that individuals with washing and checking OC symptoms would show biased memory performance for concern-related material. The data provided partial support for this hypothesis. Specifically, expression of physical harm concerns was significantly related to poorer memory performance for images related to physical danger hazards but not for images related to disease hazards or non-hazards though the size of this effect was small (partial eta squared = .02). However, the shared variance between contamination and physical harm concerns was similarly related to poorer memory

performance for physical danger consequences (again, the effect size was small). Thus, it may be that more general characteristics of OC symptoms – characteristics that cut across the OC dimensions – relate to impairments in memory for this type of content rather than impairments specific to adaptations for physical danger prevention.

The effect of several variables, such as depression, anxiety, disgust, verbal fluency, and cognitive biases, on memory performance for hazardous and non-hazardous images was examined. The data showed that these variables did not interact with memory sensitivity for the different types of images used in the study. Moreover, the main effect remained significant even after controlling for these factors.

In sum, this study may provide evidence for the existence of dedicated memory systems, those that respond to disease related information and those that respond to physically dangerous information. Additionally, there is evidence that expressing OC physical harm concerns, or some common characteristics of physical harm and contamination concerns, produces poorer memory, specifically, for information related to threat of physical harm.

## **Chapter 8.**

### **Study 3: Reasoning Task, Stimuli Development**

A set of Wason Card Selection Tasks (WCST) was created to examine reasoning abilities for taking precautions against disease and physical danger, as well as reasoning abilities for social contracts. In brief, Wason tasks present a conditional rule and examples of individuals' behaviors pertaining to the rule. The task requires that participants use reasoning abilities to ascertain if the presented individuals are potentially violating the rule given their behaviors (see Methods section, p. 32 for a full description of the task).

Each Wason rule was rated for attributes (e.g., disgustingness, dangerousness) to ensure that the content of the rules reflected the domains of interest. Also, rules were rated for how easy they were to understand to ensure that the rules did not differ in clarity or coherence. Ratings of rules were expected to meet the following criteria. I expected that Disease Precautions (DP) rules would be rated as more disgusting than both Physical Danger Precautions (PDP) and Social Contract (SC) rules. PDP rules should be rated more dangerous than both DP and SC rules. Both DP and PDP rules should be rated as having more severe consequences than SC rules but should not differ from one another. Additionally, the rule types should be rated as similarly easy to understand.

#### **Methods**

**Participants.** Twenty-six individuals from University of Miami undergraduate courses in psychology completed the ratings for credit towards course completion.

**Materials.** Fifteen WCSTs were created for each reasoning domain of interest (Rule Type: DP, PDP, SC) for a total of 45 WCSTs. For this norming study, each WCST

consisted of a scenario that ended in logical rule (see Table 14 for examples of Wason task scenarios and rules for each domain). All rules were rated for the following questions on a scale of 1 (*Not at all* [attribute]) to 7 (*Extremely* [attribute]): “If you didn’t follow this rule, how severe would the consequences be?” (consequences); “How disgusting would it be if someone didn’t follow this rule?” (disgusting); and “How dangerous would it be if someone didn’t follow this rule?” (dangerous). An additional question also assessed how easy to understand (understand) each rule was (*Not at all easy to understand to Extremely easy to understand*).

**Procedures.** The 45 WCSTs were presented in random order. Participants rated each Wason rule on the four questions listed above. The order of presentation of rating question remained constant over the experiment and was as follows: consequences, disgusting, dangerous, and understand.

## Results

For each WCST, averages were created for each rating question. Paired *t* tests were conducted comparing attribute ratings for the DP, PDP, and SC rules. Twelve comparisons were conducted in all and thus a corrected Bonferonni *p*-value was used ( $p = .004$ ). See Table 15 for rating question means and standard deviations for each Rule Type.

The consequences of not following the PDP rules were rated as significantly more severe than the consequences of not following both the DP rules ( $t(26) = 5.67, p < .001$ ) and the SC rules ( $t(26) = 11.35, p < .001$ ). Additionally, consequences of DP rules were rated as significantly more severe than consequences of SC rules ( $t(26) = 9.48, p < .001$ ).

Participants perceived not following the DP rules as more disgusting than not following both the PDP ( $t(26) = 7.44, p < .001$ ) and SC rules ( $t(26) = 12.44, p < .001$ ). Additionally, PDP rules were rated as more disgusting than SC rules ( $t(26) = 5.04, p < .001$ ).

Participants perceived not following the PDP rules as more dangerous than not following both DP rules ( $t(26) = 7.3, p < .001$ ) and SC rules ( $t(26) = 16.88, p < .001$ ). Additionally, participants perceived not following the DP rules as more dangerous than not following the SC rules ( $t(26) = 13.97, p < .001$ ).

DP rules did not differ from PDP rules on ratings of rule understandability. SC rules were rated as significantly less easy to understand than both the DP ( $t(26) = -3.77, p = .001$ ) and PDP rules ( $t(26) = -5.04, p < .001$ ). Notably, the means for ease of understanding were high across rule type ( $M_s \geq 5.8$ ).

**Rule removal: 13 tasks in each condition.** Based on the results above, rules were removed from each condition to create a set of stimuli reflecting the criteria mentioned above. For the DP condition, two rules were removed that were rated as the least disgusting because the purpose of the disease precautions was to evoke disgust. These two rules were also rated as the least dangerous and the least easy to understand. For the PDP condition, two rules were removed that were rated as the most disgusting because physical danger precautions were not meant to overlap with disgust. Because the SC rules were rated as the least easy to understand, two social contract Wason tasks with the lowest ratings on this attribute were removed. Consequently, 13 Wason tasks

remained for each category. Table 16 presents the means and standard deviations for rating attributes for the final set of rules. Analyses were repeated to ensure that the rules met the criteria put forth.

After removal of the Wason rules, DP and PDP rules did not differ in ratings of perceived consequences. Ratings of Consequences of both DP ( $t(26) = 9.19, p < .001$ ) and PDP rules remained significantly higher than SC rules ( $t(26) = 9.65, p < .001$ ).

DP rules remained significantly more disgusting than both DPD rules ( $t(26) = 11.63, p < .001$ ) and SC rules ( $t(26) = 14.57, p < .001$ ). However, after rule removal, DPD rules were no longer rated significantly more disgusting than SC rules ( $t(26) = 2.72, p < .01$ ).

PDP rules remained significantly more dangerous than both DP rules ( $t(26) = 4.64, p < .001$ ) and SC rules ( $t(26) = 15.88, p < .001$ ). Similarly, DP rules remained rated as significantly more dangerous than SC rules ( $t(26) = 13.72, p < .001$ ).

After rule removal, SC rules remained rated as significantly less easy to understand than both DP rules ( $t(26) = -4.78, p < .001$ ) and PDP rules ( $t(26) = -3.04, p = .001$ ). Additionally, as was found above, DP and PDP rules did not significantly differ on this attribute. Again, means for this attribute were high across Rule Type ( $M_s \geq 5.98$ ).

## Discussion

Based on the ratings, the initial set of 15 rules for each reasoning domain – precautions against disease, precautions against physical danger, and social contracts – was reduced to 13 Wason tasks for each domain. Disease precautions were rated significantly more disgusting than the other rule types, physical danger precautions were rated as significantly more dangerous than the other rule types, and both precaution rules

(disease and physical danger) were rated as having more severe consequences than social contract rules. Though disease and physical danger precaution rules were easier to understand than social contract rules, social contract rules were still rated as highly understandable. In sum, the final set of Wason tasks met the design criteria put forth for the norming study.

## **Chapter 9.**

### **Study 3: Reasoning and OCS**

This study examined reasoning abilities for different types of precautions – disease precautions and physical danger precautions – as well as reasoning abilities for social contracts. It was predicted that individuals would show content-specific reasoning for disease precautions, physical danger precautions and social contracts. Further, the relationship between reasoning about disease precautions and physical danger precautions and expressing obsessive-compulsive concerns about contamination and physical harm was examined. It was predicated that contamination concerns would moderate performance for disease precautions, and physical harm concerns would moderate performance for physical danger precautions.

#### **Methods**

**Participants.** Refer to chapter two for a description of participants (p.32).

**Design.** A repeated measures three-way ANOVA examined the effect of different types of inference rules (Rule Type: Disease Precautions (DP), Physical Danger Precautions (PDP), and Social Contracts (SC)) on reasoning accuracy with Contamination Scores and Physical Harm Scores entered as covariates. Accurate reasoning included always choosing the P and not-Q cards of the WCST. These cards depicted individuals whose behavior needed to be checked to ensure that the logical rule had not been violated (see Materials for a detailed explanation). Reasoning accuracy was defined as the average proportion that individuals chose only the P and not-Q cards.

Also, the associations between choice of incorrect cards (i.e., not-P and Q) and Contamination Scores and Physical Harm Scores were examined to determine if

individuals expressing OC symptoms made more errors when reasoning about concern-related material. Incorrect choices of not-P and Q cards were quantified by creating an average proportion for the number of times these card types were chosen for each Rule Type.

**Materials: Wason Card Selection Task (WCST).** In general, the WCST presents a conditional rule in the form “If P then Q” (e.g., “If you are walking with a sharp knife, then keep the knife-tip pointed down.”). As part of the task, subjects are presented with four individuals’ actions as they relate to the rule. These actions fall into four categories: (1) individual is doing P (e.g., “Mike walked with a sharp knife”), (2) individual is not doing P (not-P; e.g., “Stephanie did not walk with a sharp knife”), (3) individual did Q (e.g., “Julie kept the knife tip pointed down”), and (4) individual did not do Q (not-Q; e.g., “Larry did not keep the knife-tip pointed down”). The subject’s task, as explained in the instructions for the experiment, is to indicate whether they would need to turn over the card and check the information on the hidden side to see whether the rule has been violated. Visual depictions of cards are presented one at a time to the subject on the computer screen along with the rule. Subjects answer the question, “Could this individual have violated the rule.” The correct cards to turn over for every rule are the P and not-Q cards. Each rule is introduced with a scenario stating reasons why the rule is important. Each rule is followed by the statement, “You are concerned that people may be violating the following rule” (see Figure 6 for an example of a WCST).

Three different types of rules were used in this study – Disease Precautions (DP), Physical Danger Precautions (PDP), and Social Contracts (SC). DP and PDP rules fall under the domain of hazard rules and both take the form, “If you engage in hazardous

activity, then you should take the associated precaution.” SC rules take the form, “If you take the benefit, then you must pay the cost.” All rules fit into the class of deontic rules (should/must statements) with half of the rules for each category using the word “should” and half of them using the word “must” (using various deontic verbs does not affect answers on task; see Fiddick et al., 2005). The reasoning task consists of two practice problems (a descriptive rule and a social contract rule) and 39 testing problems (13 of each: DP, PDP, and SC).

**Procedure.** The reasoning task was presented to participants using E-prime, version 2.0. The first screen welcomed participants to the experiment and explained the directions for the reasoning task. Then participants were given the two practice rules. Participants were given feedback for their answers during the practice sessions. They were told that if they needed additional feedback or an explanation of the task they should notify the researcher. The practice problems consisted of a descriptive rule and an SC rule. The descriptive rule was presented first, followed by the SC rule. For the practice problems, the order of card presentation was the same for each individual. For the descriptive rule the order was as follows: P, not-P, Q, not-Q. The SC practice rule was presented in a different order (not-P, Q, not-Q, P) to familiarize the subject with the shifting order of card presentation that would occur for the remaining tasks.

The general presentation format for every Wason task was as follows (see Figure 7 for visual depiction of the procedure). The first screen presented the introductory scenario followed by the “If P then Q” rule. Subjects were told “You are concerned that people may be violating this rule.” The next screen explained what information is presented on each side of the card. On the third screen a card representing one

individual's action was presented along with a restatement of the rule. Participants answered the following question "Could this individual have violated the rule?" Participants indicated the presence of a potential rule violation by pressing a key marked 'Y' for "yes" and 'N' for "no". They answered this question for four cards (i.e., individual's actions reflecting P, not-P, Q, and not-Q). The 39 WCSTs were presented in random order with the card choices also presented in random order.

## Results

**Reasoning accuracy (choosing the P and not-Q cards only).** A three-way repeated measures ANOVA examined the effect of Rule Type and OC symptoms (Contamination Scores and Physical Harm Scores) on reasoning accuracy, that is, the selection of only the P and not-Q cards. The main effect of Rule Type was significant ( $F(2, 318) = 5.85, p = .003$ , partial eta-squared = .036), indicating a difference in reasoning performance for Disease Precautions (DP), Physical Danger Precautions (PDP), and Social Contracts (SC). Follow up analyses on the main effect were done with pairwise comparisons using a Bonferonni correction. Reasoning accuracy was significantly greater for PDP rules than both DP rules ( $t(318) = 3.56, p = .002$ ) and SC ( $t(318) = 2.4, p = .046$ ) rules (see Figure 8). DP rules did not differ from SC rules for average proportion of choosing only the P and not-Q cards. Table 17 displays the means and standard deviations for reasoning accuracy for each rule type. Notably, accuracy was high across all rule types. These findings are remarkable given the poor performance typically seen for reasoning about descriptive (i.e., non-ancestrally relevant

content). Specifically, for descriptive rules, individuals typically select the P and not-Q cards approximately 5 to 30% of the time (for reviews see Cosmides, 1989 & Evans, Newstead, & Byrne, 1993).

The main effects of the Contamination Scores and Physical Harm scores covariates were not significant. Additionally, neither covariate significantly interacted with Rule Type (see Table 17 for correlations between Contamination Scores, Physical Harm Scores, and d-prime values for each rule type).

The OC Overlap variable was entered as a covariate into the model testing the repeated measure of Rule Type on choice of the P and not-Q cards. Neither the main effect nor the interaction was significant.

#### **Relationship between choosing incorrect cards and OC symptoms.**

Predictions were made that individuals expressing contamination and physical harm concerns would make more errors on reasoning rules related to their concerns. To test these predictions, two separate models were analyzed examining the effect of Rule Type and Contamination Scores and Physical Harm Scores on the average proportion of choosing the incorrect cards of not-P and Q.

***Incorrect choice of not-P card.*** A three-way repeated measures ANOVA examined the effect of Rule Type (DP, PDP, and SC) and OC symptoms (Contamination Scores and Physical Harm Scores) on the average proportion of choosing the not-P card. Neither the main effect of Rule Type nor the interactions between OC symptoms and Rule Type was significant.

***Incorrect choice of Q card.*** The same model was repeated examining the effects of Rule Type and OC symptoms on average proportion of choosing the Q card. With a

Greenhouse-Geisser correction (Mauchly's  $W = .936, p = .006$ ), there was a main effect for Rule Type ( $F(1.88, 291.38) = 15.4, p < .001$ , partial eta-squared = .09) on proportion of choosing the Q card (see Figure 9). Follow up pairwise comparisons, using a Bonferonni correction, indicated that DP rules ( $M = .08$ ) produced significantly more choice of the Q card than both PDP rules ( $M = .04; t(291.38) = 5.43, p < .001$ ) and SC rules ( $M = .05; t(291.38) = 5.17, p < .001$ ). PDP and SC rules did not differ on average proportion of choosing the Q card.

The main effect of the Contamination Scores covariate was significant ( $F(1, 155) = 5.13, p = .025$ , partial eta-squared = .03). Contamination Scores were positively associated with choosing the Q card across rule types ( $r(160) = .18, p = .027$ ). There was no main effect for the Physical Harm Scores covariate. Additionally, neither Contamination Scores nor Physical Harm Scores significantly interacted with Rule Type.

**Effect of other variables on reasoning accuracy (choice of P and not-Q cards only).** The effects of other variables, which may affect reasoning performance, such as disgust sensitivity (TDDS-pathogen), cognitive biases associated with OCD (OBQ-44), depressive symptoms (BDI-II), anxiety symptoms (STAI-trait), and verbal fluency were examined. These variables were entered as covariates into a three-way repeated measures ANOVA examining the effect of Rule Type (DP, PDP, and SC) on reasoning accuracy (i.e., average proportion of P and not-Q card choice).

The main effect of Rule Type was no longer significant after controlling for these variables. Main effects existed for three of the covariates entered: Verbal Fluency ( $F(1, 152) = 5.67, p = .02$ , partial eta-squared = .04), BDI-II ( $F(1, 152) = 5.10, p = .03$ , partial eta-squared = .03), and OBQ-44 ( $F(1, 152) = 4.26, p = .04$ , partial eta-squared = .03).

Verbal Fluency was positively correlated with reasoning accuracy across rules ( $r(166) = .21, p = .008$ ). Neither BDI-II nor OBQ-44 significantly correlated with total reasoning accuracy.

Of the covariates entered, only verbal fluency significantly interacted with Rule Type ( $F(2, 304) = 3.28, p < .04$ , partial eta-squared = .02). This interaction can be explained by examination of the simple correlations between verbal fluency scores and reasoning accuracy for each rule type (see Table 18). These correlations evinced that verbal fluency was significantly positively associated with reasoning accuracy for both DP rules ( $r(166) = .23, p = .002$ ) and SC rules ( $r(166) = .22, p = .004$ ) but not for PDP rules.

## Discussion

The results of this study provide initial support for the existence of dedicated reasoning abilities for different types of hazards. Research to date suggests that reasoning abilities are specifically tailored to solve different adaptive problems such as social exchange (Cosmides, 1985, 1989) and avoiding hazards (Fiddick, 2004; Fiddick et al., 2000; Fiddick et al., 2005). The results of the present study, provide some support for a further specialization for reasoning about different types of hazards, specifically, hazards related to disease avoidance and hazards related to physical danger avoidance. Of note this effect was small (partial eta-squared = .04). Specifically, in this study, individuals were more accurate in their reasoning about hazards related to physical danger avoidance, partly because when reasoning about disease avoidance, individuals unnecessarily checked to see if an individual had come into contact with a contaminant. The difference in the likelihood of making this type of error for the different rule types produced a

medium effect size (partial eta-squared = .09). This type of error for disease hazards makes sense given that one can “catch” a disease from coming into contact with a contaminated individual, whereas one cannot necessarily “catch” physical danger from coming into contact with someone who has faced physical danger.

One of the main purposes of the study was to examine whether individuals evincing OC contamination and physical harm concerns also evince biased reasoning for hazards related to disease and hazards related to physical danger, respectively. There was no support for this hypothesis. It is possible that using a non-clinical sample limited the power of this study to detect the predicted effects.

An individual’s verbal fluency abilities, expression of depressive symptoms, and tendency to exhibit thoughts associated with OCD, all significantly impacted reasoning performance. Of these variables, verbal fluency was most strongly associated with reasoning performance such that stronger verbal fluency ability was associated with more accurate reasoning about disease-related hazards and social contracts. In other words, the ability to quickly recall words or objects associated with a category was related to better categorization of individuals’ behavior as potentially violating rules about disease and social contracts.

In sum, there is initial support for the existence of specialized reasoning mechanisms for different types of hazards. Reasoning about disease appears to produce more errors such that individuals may take fewer risks when engaging with someone who has possibly faced a contaminant.

## **Chapter 10. General Discussion**

The collection of studies presented in this dissertation tested two main hypotheses. The first hypothesis was that specialized mental functions, such as attention, reasoning, and memory, exist to perform the function of disease avoidance and physical danger avoidance. That is, disease avoidance adaptations should activate attention, memory, and reasoning systems differently than physical danger adaptations (e.g., directing attention toward cues of contamination versus cues of physical harm unrelated to disease). The second main hypothesis was that individuals evincing impairments in systems relating to disease and physical danger avoidance – such as those individuals expressing obsessive-compulsive washing and checking symptoms, respectively – should show biases in the attention, memory, and reasoning mechanisms dedicated to the particular function impaired.

### **Dedicated mental mechanisms for disease avoidance and safety management**

In brief, theoretical and empirical advancements point to the existence of adaptations specifically tailored for disease avoidance (Schaller & Duncan, 2007; Tooby, 1982). Importantly, avoiding physical danger hazards appears, at first glance, to require a different set of adaptive responses than avoiding contamination. This response specialization for different types of adaptive problems is consistent with an evolutionary approach to human cognition, which suggests functional specificity in cognitive mechanisms (Tooby & Cosmides, 2008). Support for this approach comes from research on attention (e.g., New et al., 2007), memory (e.g., Sherry & Schacter, 1987; Klein et al.,

2002), and reasoning (e.g., Cosmides, 1985, 1989). If dedicated attention, memory, and reasoning systems exist for the distinct adaptations of disease avoidance and physical harm avoidance, then performance on experimental tasks that measure these functions should differ in those individuals with biases or impairments to adaptations that relate to disease or physical harm avoidance. Furthermore, different patterns of attention, memory and reasoning abilities for disease versus physical danger stimuli provide additional evidence that there might indeed exist separate systems for each functional domain. The results of the three studies presented herein provide some initial support for the existence of specialized attention, memory, and reasoning mechanisms for disease avoidance and physical harm avoidance.

The results of the attention study provided initial evidence that attention maintenance processes – those that hold attention on an object – differ in response to cues for disease versus physical danger. Specifically, individuals appeared more likely to hold attention on disease-related stimuli as compared to both physically dangerous and non-dangerous stimuli. That is, individuals took longer to detect changes to neutral stimuli within scenes that also contained disease-related stimuli. In contrast, physically dangerous stimuli were not more likely to hold attention than non-dangerous stimuli. With regards to attention orienting processes, the findings showed that individuals were equally fast at detecting changes to disease-related (feces, vomit, roach) and physical danger stimuli (knife, manhole, iron), as compared to non-hazardous stimuli (banner, bench). In brief, these findings provide initial support that cues activating psychological programs governing disease avoidance may produce a different suite of attention responses than cues activating programs governing physical danger avoidance. This

specificity in attention response provides some evidence for specialized attention systems for these adaptive problems. These data contribute to the growing literature on the domain specificity of attention processes. For example, New et al. (2007) found evidence that attention processes are organized to monitor for ancestrally important categories such as animate objects. That is, attention is more quickly oriented to animate objects as compared to inanimate objects even when individuals have learned that the inanimate object is potentially dangerous when in motion (e.g., vehicles). The set of current studies showed that ancestrally important hazards, such as disease and physical danger, preferentially recruit attention processes over non-hazardous information. Moreover, disease hazards recruit attention processes differently than physical danger hazards.

Similarly, results of the memory study provided some evidence that memory systems respond in distinct ways to cues of disease versus cues of physical danger. Individuals more accurately remembered stimuli relating to physical danger than stimuli relating to disease. Interestingly, stimuli relating to physical danger produced the most false alarms as compared to both disease-related and neutral stimuli. This pattern suggests that when psychological adaptations for physical danger avoidance are activated, memory programs may be more likely to label stimuli as previously encountered, whether they actually were or not. By contrast, stimuli relating to disease produced the least false alarms, suggesting that when memory programs are called upon to recall sources of disease, individuals may be more likely to remember if they have not seen a certain contaminant. It is unclear why it would be more adaptive to falsely recall physical danger and not contaminants. Future research should replicate these findings.

The memory study provides further support for specialized memory processes for *cues* versus *consequences* of physical danger. Specifically, memory sensitivity for consequences of physical danger (e.g., house fire, bloody cut) was greater than for cues of physical danger (e.g., a lit cigarette next to the bed, a butcher's knife). These results may point to adaptive specialization within the physical danger hazard domain. This specialization makes sense given that cues of hazards indicate a potential future threat, whereas consequences of hazards indicate the current occurrence of a hazard, two classes of events that would have been adaptive to keep straight (e.g., LeDoux, 1995; Mineka & Cook, 1993; Pitman & Orr, 1995; Tooby & Cosmides, 2008). Memory systems might be preferentially recruited by stimuli depicting physically dangerous consequences over stimuli depicting physically dangerous cues because consequences hold information regarding the magnitude of actual danger, whereas for cues, there is greater ambiguity over how much physical danger an event might cause.

Building on research that suggests the existence of specialized reasoning abilities for hazards (Cosmides & Tooby, 1997; Fiddick, 2004; Fiddick et al., 2000; Fiddick et al., 2005), the results of the reasoning study provide additional support for further specialization of reasoning abilities for different types of hazards. Specifically, reasoning performance differed for inferences about possible contamination and inferences about possible physical harm. Individuals were more accurate when reasoning about taking precautions against physical danger than when reasoning about taking precautions against contamination. Examination of the types of reasoning errors indicated that individuals made more errors when reasoning about possible contamination. This error occurred because individuals were checking to see if another individual had contact with a

contaminant, despite this action being a logical error and unnecessary given the logical rule. This type of error was more likely for inferences about disease than inferences about physical danger and social contracts. This error makes sense because disease often spreads through contact with individuals who have been exposed to a contaminant, whereas physical harm does not spread often through contact with individuals who have been exposed to a physical danger.

### **Are OC washing and checking symptoms related to impairments in these mechanisms?**

There is theoretical and empirical evidence that the washing dimension of OCD is related to impairments in psychological mechanisms associated with disease avoidance (Abed & de Pauw, 1998), such as disgust (Olatunji & McKay, 2007, Tybur et al., 2009). Additionally, the checking dimension of OCD appears to be related to a different set of psychological mechanisms, for example, the emotion of guilt (Emmelkamp & Aardema, 1999). If the OC dimensions of washing and checking reflect impairments in the adaptations of disease avoidance and physical danger avoidance systems, respectively, and the impairments lie in attention, memory, and reasoning abilities, then expressing contamination and physical harm concerns should moderate performance on tasks that measure these functions.

In general, no support was found for this hypothesis. Results of the memory study indicated that individuals expressing concerns for preventing physical harm had poorer memory, in terms of fewer hits and more false alarms, for physically dangerous information but not for disease-related or neutral information. However, the shared characteristics of the contamination and physical harm OC scores were also related to poorer memory performance for images of physically dangerous consequences. Thus, it

is unclear whether the relationship between OC symptoms and memory biases for physical danger information is related to impairments in adaptations general to physical danger and contamination OC concerns or rather if the impairment is related specifically to adaptations for physical danger prevention.

Additionally, expressing OC physical harm concerns did not impact attention and reasoning about physically dangerous information. Similarly, expressing OC washing symptoms did not affect performance as predicted for attention, memory, or reasoning when faced with disease-related information. Thus, the data presented herein provide no support that individuals expressing contamination and physical harm concerns have concern-related attention, memory, and reasoning biases. These results are contrary to previous research findings that individuals expressing OC symptoms show concern-related attention (e.g., Foa & McNally, 1986; Lavy, van Oppen, & van den Hout, 1994; Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996) and memory biases (Tolin, Hamlin, & Foa, 2002).

### **Limitations and future directions**

One limitations of the studies presented herein was the use of an undergraduate, non-clinical, sample. The use of such a sample limited the ability of the studies to fully examine the relationship between OCD and performance on tests of the aforementioned psychological abilities. Though research examining the cognitive correlates of OCD has used non-clinical samples and successfully found effects (e.g., Olatunji & Armstrong, 2009; Olatunji et al., 2007), the range of expressed symptoms in the current studies was somewhat restricted. It may be that individuals diagnosed with OCD would exhibit impairments in performance on these cognitive tasks in distinct ways than individuals

expressing some symptoms of OCD. Future research should replicate these studies with a sample of individuals diagnosed with OCD.

It is also possible that the psychological mechanisms chosen (attention, memory, and reasoning) were not specific enough. Given that specific types of attention (i.e., vigilance, maintenance) and memory (hits, false alarms) differed depending on adaptive problem (disease avoidance, physical harm avoidance), it is possible that more fine-grained or specialized psychological mechanisms need to be defined and examined in future studies. Researchers examining these processes should be aware of the various and specific ways that general psychological processes, such as attention, memory, and reasoning, can function.

Last, some of the experimental tasks used (i.e., the change blindness attention task, the Wason card selection task) were novel methods with regards to examining the cognitive impairments associated with OCD. These tasks were chosen because of their utility in demonstrating content-specific attention and reasoning mechanisms for evolutionarily relevant information. Future research should continue to examine the utility of these tasks for examining the cognitive impairments associated with OCD.

### **Clinical Implications**

The results of the memory study were clinically relevant in that they indicated excessive fear of physical harm to self or others is related to poorer memory for information regarding physical danger cues and consequences. It is possible that the poorer memory performance found in this study by those expressing checking-types of symptoms is also related to poorer confidence in memory for stimuli related to potential physical harm. This explanation would be consistent with research that memory

confidence is impaired in those exhibiting checking symptoms (e.g., Radomsky et al., 2001).

Another clinically meaningful finding of the memory study was that the poorer memory in those exhibiting checking symptoms occurred largely for information about physically dangerous consequences rather than physically dangerous cues. This finding suggests that cognitive interventions may be more effective when targeting consequences associated with physical danger rather than cues.

Additionally, the data from these studies suggest that the stimuli and methods used in these studies are valid ways to assess attention, memory, and reasoning for disease and physical danger hazards. These stimuli and methods are somewhat novel to research on OCD and may be useful in future studies examining the association of these cognitive processes for the washing and checking dimensions of OCD.

### **Conclusion**

In conclusion, the studies presented in this dissertation aimed to show that the washing and checking dimensions of OCD reflect impairments in psychological adaptations for disease avoidance and physical danger avoidance, respectively. This hypothesis was only partially confirmed. On the one hand, the current studies pointed to the existence of specialized attention, memory, and reasoning responses depending on whether psychological programs governing disease avoidance or physical danger avoidance are activated. On the other hand, overall, the findings did not support the hypothesis that individuals expressing OC concerns exhibit impairments in these adaptations. However, the use of a non-clinical sample may not generalize to OCD populations. Thus it is unclear whether or not individuals diagnosed with OCD would

demonstrate impairments in attention, memory, and reasoning as hypothesized by this dissertation. Future research is needed to fully answer this question.

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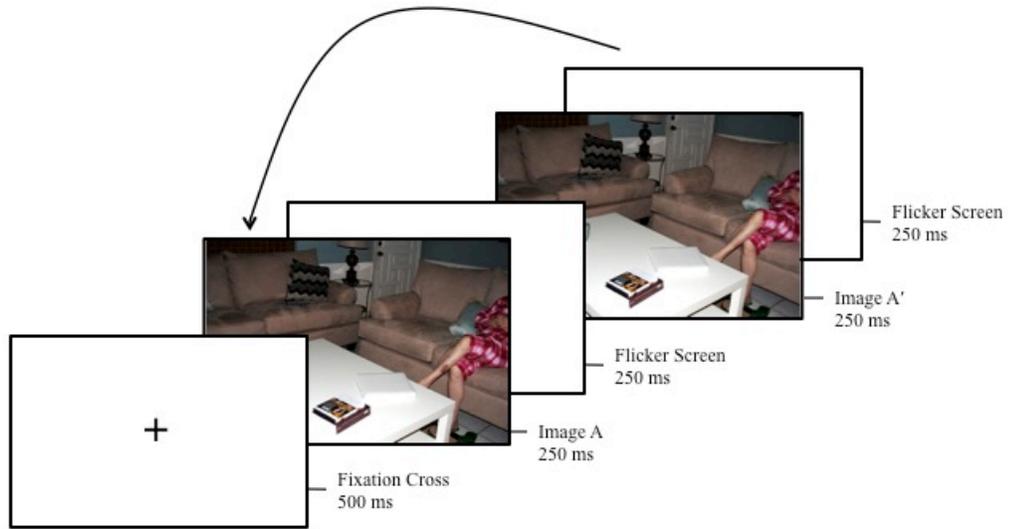
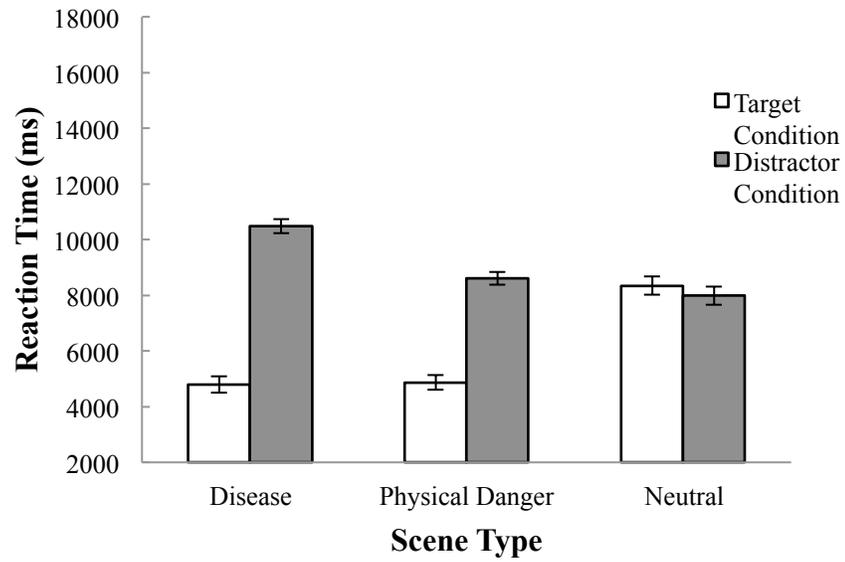
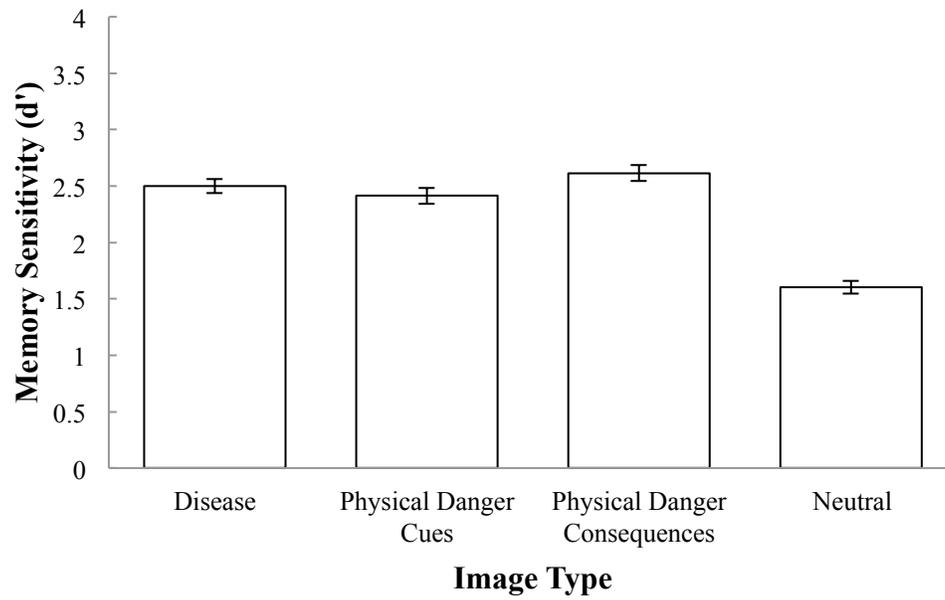


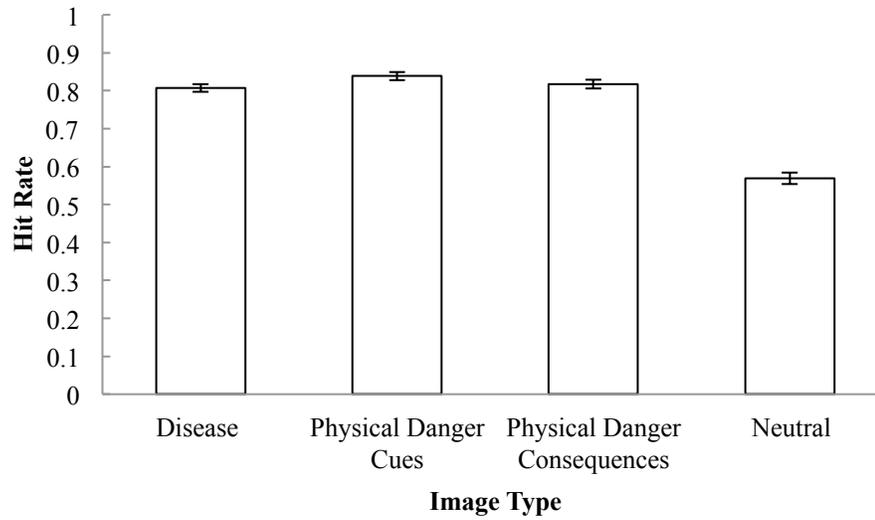
Figure 1. Sequence of image presentation for change blindness procedure.



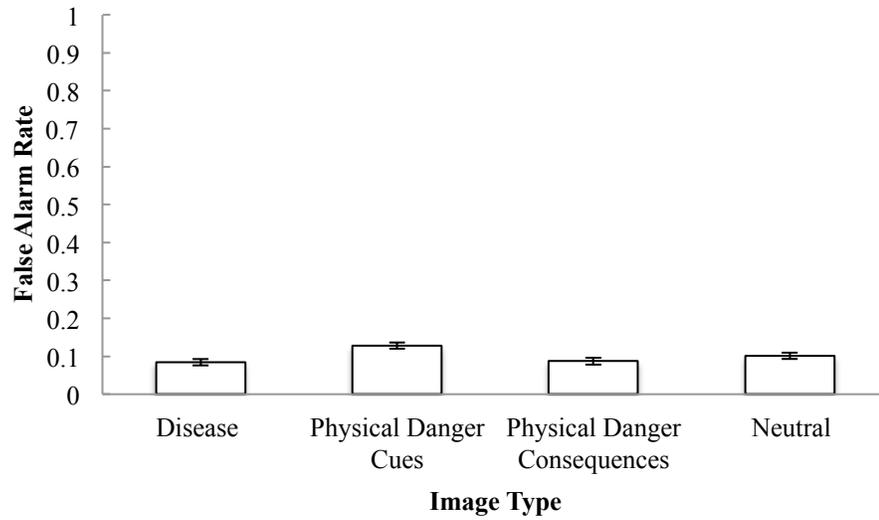
*Figure 2.* The effect of Stimulus Condition and Scene Type on reaction times to detecting object removal within scenes.



*Figure 3.* D-prime variables for Disease, Physical Danger Cues, Physical Danger Consequences, and Neutral images.



*Figure 4.* Hit rates for Disease, Physical Danger Cues, Physical Danger Consequences, and Neutral images.



*Figure 5.* False alarm rates for Disease, Physical Danger Cues, Physical Danger Consequences, and Neutral images.

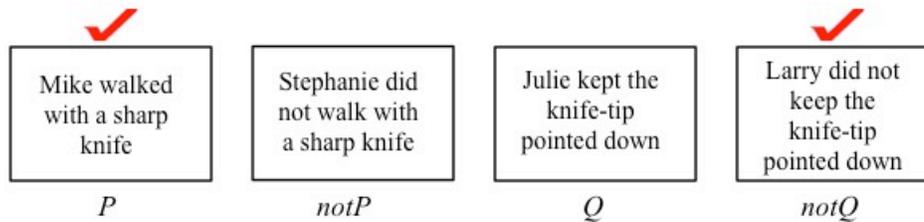
### Physical Danger Precaution Example

*Scenario:*

Accidents involving knives are common. They can lead to injuries on the fingers, upper arm and torso. For this reason, the following rule is very important:

*Rule:*

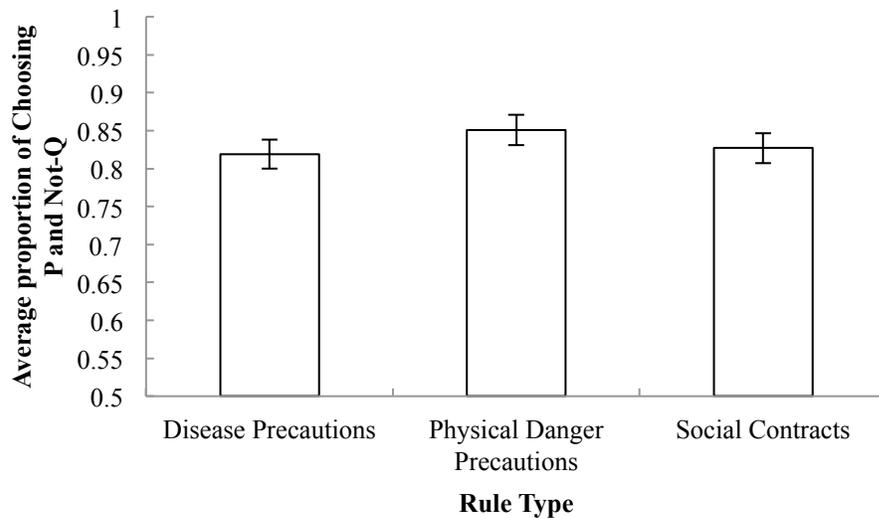
“If you are walking with a sharp knife, then keep the knife-tip pointed down.”



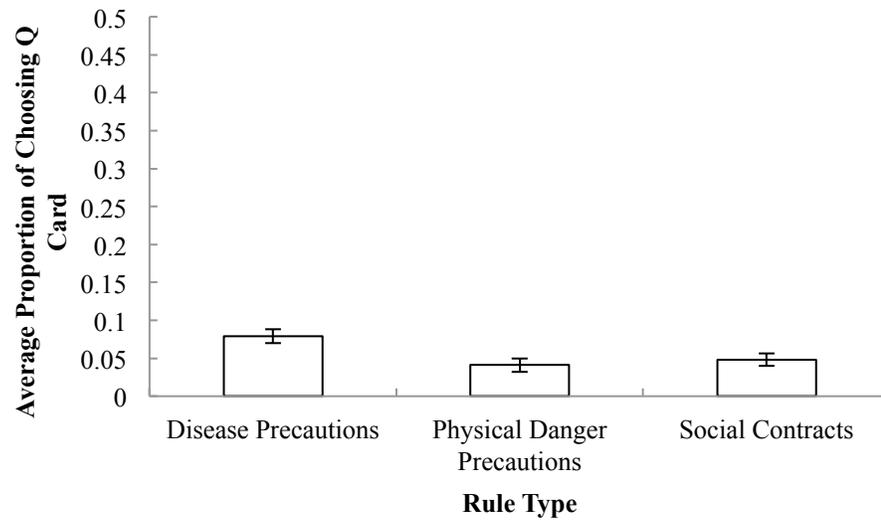
*Figure 6.* An example of a Wason card selection task using a Physical Danger Precaution rule. Each rule is presented with a scenario explaining the importance of the rule. All rules take the form, “If P then Q.” The red checkmarks represent correct card choices for every task. Participants will see all four card choices, presented one at a time in random order.



Figure 7. Depiction of sequence of screen presentation for a Disease Precaution.



*Figure 8.* Reasoning accuracy for inferences about Disease Precautions, Physical Danger Precautions, and Social Contracts.



*Figure 9.* Proportion of incorrect card choice (Q card) for Disease Precautions, Physical Danger Precautions, and Social Contracts.

Table 1  
*Measures and subscales of measures employed in experiment*

<b>Measure</b>	<b>Subscales</b>
Padua Inventory- Washington State University Revision (PI-WSUR)	Obsessional thoughts about harm to self or others (OTAHSO) Obsessional impulses to harm self or others (OITHSO) Contamination obsessions and washing compulsions (COWC) Checking compulsions (CHKC) Dressing/grooming compulsions (DRGRC)
Obsessive Compulsive Inventory Revised (OCI-R)	Washing Checking Ordering Obsessing Hoarding Neutralizing
Three Domain Disgust Scale (TDDS)	Pathogen Disgust Sexual Disgust Moral Disgust
Obsessional Beliefs Questionnaire (OBQ- 44)	Responsibility/Threat Perfectionism/Certainty Importance/Control
State-Trait Anxiety Inventory-Trait (STAI-Trait)	STAI-Trait total
Beck Depression Inventory-II (BDI-II)	BDI-II total
Verbal Fluency	Letter Fluency total Category Fluency total

Table 2  
*Items from PI-WSUR used for the study measures*

Study Measures	PI-WSUR	PI-WSUR Items
Contamination	COWC	<p>I feel my hands are dirty when I touch money.</p> <p>I think even slight contact with bodily secretions (perspiration, saliva, urine, etc.) may contaminate my clothes or somehow harm me.</p> <p>I find it difficult to touch an object when I know it has been touched by strangers or by certain people.</p> <p>I find it difficult to touch garbage or dirty things.</p> <p>I avoid using public toilets because I am afraid of disease and contamination</p> <p>I avoid using public telephones because I am afraid of contagion and disease.</p> <p>I wash my hands more often and longer than necessary.</p> <p>I sometimes have to wash or clean myself simply because I think I may be dirty or 'contaminated'.</p> <p>If I touch something I think is 'contaminated', I immediately have to wash or clean myself.</p> <p>If an animal touches me, I feel dirty and immediately have to wash myself or change my clothing.</p>
		<p>I invent useless worries about germs and disease</p>
Physical Harm	OTAHSO	<p>I think or worry at length about having hurt someone without knowing it.</p> <p>When I hear about a disaster, I think it is somehow my fault.</p> <p>I get upset and worried at the sight of knives, daggers, and other pointed objects.</p>
	CHCK	<p>I tend to keep checking things more often than necessary.</p> <p>I check and recheck gas and water taps and light switches after turning them off.</p> <p>I return home to check doors, windows, drawers, etc., to make sure they are properly shut.</p> <p>I keep going back to see that matches, cigarettes, etc., are properly extinguished.</p>

Table 3  
Correlations between Contamination Scores and Physical Harm Scores and other measures.

Measures	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
<b>New Scales</b>																		
1. Cont	.38**	1.0**	.47**	.53**	.17*	.43**	.85**	.41**	.47**	.22**	.44**	.30**	.37**	.29**	.14	.45**	.40**	.38**
2. PH		.36**	.83**	.79**	.33**	.43**	.38**	.67**	.45**	.33**	.47**	.48**	.04	.19*	.19*	.48**	.44**	.40**
<b>PI-WSUR</b>																		
3. COWC			.45**	.48**	.15	.43**	.84**	.41**	.47**	.22**	.44**	.29**	.37**	.28**	.13	.42**	.37**	.36**
4. CHKC				.61**	.22**	.44**	.41**	.65**	.52**	.27**	.43**	.37**	.01	.22**	.15	.52**	.49**	.39**
5. OTHSO					.40**	.35**	.47**	.51**	.33**	.36**	.44**	.55**	.19*	.28**	.25**	.56**	.50**	.42**
6. OITHSO						.25**	.17*	.17*	.13	.16*	.18*	.44**	-.03	-.01	.00	.24**	.20**	.21**
7. DRGRC							.36**	.29**	.47**	.12	.50**	.26**	.12	.17*	.13	.26**	.19**	.23**
<b>OCIR</b>																		
8. Wash								.41**	.45**	.24**	.42**	.35**	.26**	.16*	.02	.35**	.32**	.32**
9. Check									.56**	.42**	.59**	.42**	.15	.20*	.13	.36**	.38**	.25**
10. Order										.19*	.53**	.36**	.18*	.20**	.16*	.40**	.40**	.35**
11. Hoard											.32**	.40**	.18*	.21**	-.02	.23**	.21**	.15
12. Neut												.41**	.01	.11	.15	.31**	.26**	.23**
13. Obsess													.13	.09	.07	.40**	.40**	.39**
<b>TDDS</b>																		
14. Path														.31**	.11	.12	.10	.07
15. Sex															.24**	.24**	.28**	.31**
16. Moral																.17*	.16*	.16*
<b>OBQ-44</b>																		
17. RT																	.72**	.66**
18. Perfe																		.56**
19. Control																		

Note. Cont = Contamination Scores, PH = Physical Harm Scores, COWC = Contamination obsessions and washing compulsions, CHCK = Checking compulsions, OTHSO = Obsessional thoughts about harm to self or others, OITHSO = Obsessional impulses to harm self or others, DRGRC = Dressing/grooming compulsions; Path = Pathogen Disgust, Sex = Sexual Disgust, Moral = Moral Disgust; RT = Responsibility/Threat, Perfe = Perfectionism/Certainty, Control = Importance/Control

\*  $p \leq .05$

\*\*  $p \leq .01$

Table 4.  
*Descriptive statistics for study measures.*

	M	SD	Range	Cronbach's Alpha
Contamination	.6596	.623	3	.91
Physical Harm	.3589	.440	2.29	.73

n = 164

Table 5  
*Examples of disease, physical danger, and neutral images with target (red) and distractor (blue) stimuli circled*

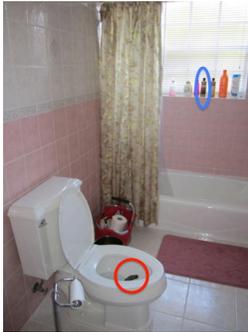
Disease			
Physical Danger			
Neutral			

Table 6  
*Means (and standard deviations) of rating attributes for Target, Distractor Condition and Scene Type*

Scene Type	Rating Questions			
	Disgusting	Hazardous	Intense	Obvious
Disease	4.53 (1.06)	3.55 (1.04)	3.14 (1.00)	
Physical Danger	1.88 (.94)	4.2 (1.41)	3.13 (1.21)	
Neutral	1.44 (.72)	1.98 (.91)	2.47 (.98)	
<b>Target Stimuli</b>				
Disease	5.67 (.88)	4.55 (.96)		5.41 (1.09)
Physical Danger	1.83 (1.00)	5.23 (1.14)		5.63 (1.02)
Neutral	1.39 (.61)	1.90 (.70)		4.31 (1.12)
<b>Distractor Stimuli</b>				
Disease	1.92 (.94)	1.99 (.90)		4.13 (1.11)
Physical Danger	1.40 (.63)	1.95 (.88)		3.78 (1.27)

Table 7  
*Descriptive statistics for Scene Type by Stimulus Condition reaction times*

	<i>M (ms)</i>	<i>SD (ms)</i>	<i>Skewness</i>	<i>Kurtosis</i>
<b>Target Condition</b>				
Disease Scene	4794.35	1682.50	.45	-.39
Physical Danger Scene	4869.57	1943.86	1.09	1.52
Neutral Scene	8346.41	2710.63	.19	-.34
<b>Distractor Condition</b>				
Disease Scene	10477.36	2411.88	.82	1.40
Physical Danger Scene	8586.11	2411.88	.80	.50
Neutral Scene	7973.03	2821.55	2.42	13.92

*Note.* Target condition:  $n = 73$  for all Scene Types; Distractor condition:  $n = 91$  for Disease Scenes and Physical Danger scenes;  $n = 92$  for Neutral Scenes.

Table 8  
*Correlations between traits and reaction times for Scene Type by Stimulus Condition*

	Target Condition			Distractor Condition		
	Disease	Physical Danger	Neutral	Disease	Physical Danger	Neutral
Contamination Score	.16	.30***	-.04	-.04	-.15	-.13
Physical Harm Score	.09	-.02	.06	.16	.01	.04
TDDS pathogen	.10	.05	-.05	-.01	-.12	-.04
OBQ-44	.08	-.03	-.16	.16	.06	.01
BDI-II	.00	.01	-.28*	.25*	-.01	.23*
STAI-Trait	.12	.24*	-.03	.12	-.10	-.09
Verbal Fluency	.03	-.05	-.04	-.21*	-.27*	-.08

\*  $p \leq .05$

\*\*  $p \leq .01$

\*\*\*  $p \leq .001$

Table 9  
*Example of image pairs for memory experiment*

Disease	Physical Danger	Neutral
		
		

Table 10  
*Comparison of image types on various attributes.*

	Disgusting	Fear provoking	Dangerous	Intense	Appealing
Disease	4.39 (.97)	3.15 (1.01)	2.93 (1.09)	3.52 (1.03)	1.95 (.50)
Phys. Dang	2.59 (.96)	4.48 (.76)	4.90 (.60)	4.39 (.67)	2.21 (.57)
Neutral	1.45 (.47)	1.92 (.80)	2.10 (.80)	3.38 (1.00)	5.42 (.62)

Table 11  
*Descriptive statistics for Image Types d-primes*

<b>Image Type</b>	<b><i>M</i></b>	<b><i>SD</i></b>	<b><i>Skewness</i></b>	<b><i>Kurtosis</i></b>
Disease	2.49	.78	-.68	2.75
Physical Danger Cues	2.39	.88	-.18	.94
Physical Danger Consequences	2.60	.91	-.83	2.78
Neutral	1.59	.71	.07	-.14

*Note.* ns = 163 for means and standard deviations.

Table 12

*Correlations between traits and memory for disease, physical danger, and neutral images*

	<b>D-prime</b>	<b>Disease</b>	<b>PD Cues</b>	<b>PD Consequences</b>	<b>Neutral</b>
Contamination Scores		-.03	.01	-.13	-.11
Physical Harm Scores		-.06	-.12	-.21 <sup>***</sup>	-.04
TDDS-pathogen		-.03	-.05	-.06	-.12
OBQ-44		.00	.00	-.12	-.05
BDI-II		.08	.07	.06	.13
STAI-Trait		.04	-.08	-.11	.00
Verbal Fluency		.17 <sup>t</sup>	.15	.12	.13
<b>Hit Rates</b>					
Contamination Scores		-.06	.11	-.06	-.03
Physical Harm Scores		.01	-.02	-.11	.08
<b>False Alarm Rates</b>					
Contamination Scores		.10	.16 <sup>*</sup>	.20 <sup>*</sup>	.18 <sup>*</sup>
Physical Harm Scores		.15	.22 <sup>**</sup>	.20 <sup>*</sup>	.16 <sup>**</sup>

Note. Correlations: Ns range from 158-162

PD = Physical Danger

<sup>\*</sup>  $p \leq .05$ <sup>\*\*</sup>  $p \leq .01$ <sup>\*\*\*</sup>  $p \leq .001$

Table 13  
*Descriptive statistics for Image Type hit rates and false alarm rates (proportions)*

		<b>Statistics</b>			
<b>Image Type</b>		<i>M</i>	<i>SD</i>	<i>skewness</i>	<i>kurtosis</i>
<b>Hit Rates</b>	Disease	.8068	.1261	-1.12	1.47
	Physical Danger Cues	.8382	.1393	-1.3	2.36
	Physical Danger Consequences	.8173	.1527	-1.22	1.66
	Neutral	.5643	.1925	-.72	.03
<b>False Alarm Rates</b>	Disease	.0846	.1025	3.76	19.23
	Physical Danger Cues	.1292	.1041	2.78	13.21
	Physical Danger Consequences	.0869	.1164	3.55	17.18
	Neutral	.1018	.1073	2.71	10.19

*Note.* N =163.

Table 14  
*Examples of scenarios and rules*

<b>Rule Type</b>		
Disease Precautions	Physical Danger Precautions	Social Contracts
<b>Scenarios</b>		
Bacteria that cause some serious illnesses spread easily when an infected person touches surfaces that other people touch.	It's dangerous to ride a bike at night because drivers have trouble seeing you. It is safer if you have a light on your bike.	Imagine you are a bouncer at a bar. You need to make sure that the people who are drinking alcohol are at least 21 years old.
<b>Rules</b>		
If you care for someone who is sick, then use anti-bacterial soap.	If you ride a bike at night, then use a light.	If you are drinking alcohol, then you must be at least 21 years old.
<b>Scenarios</b>		
Bed bugs are small insects that feed on human blood. Bed bugs are very difficult to get rid of because they are hard to find and kill. The best way to eliminate bed bugs is targeted pesticide use by a pest management professional.	The National Candle Association says there are some 18,000 candle-caused fires annually in the United States, and experts blame carelessness on the part of candle users.	A bad credit score can prevent you from getting important future loans. Also, making payments on time will help get you lower rates on mortgages, loans and sometimes even auto insurance.
<b>Rules</b>		
If you have bed bugs, then you must call an exterminator.	If you light a candle, then remove nearby flammable items.	If you borrow money, then you must make your payments on time.

Table 15

*Rating questions means and (standard deviations) for each rule type.*

	Consequences	Disgusting	Dangerous	Understand
DP	5.58 (.64)	5.11 (.73)	5.39 (.69)	6.21 (.62)
PDP	6.16 (.67)	3.28 (1.52)	6.27 (.47)	6.43 (.60)
SC	4.1 (.95)	2.57 (1.18)	3.1 (1.04)	5.8 (.91)

*Note.* DP = Disease Precautions; PDP = Physical Danger Precautions; SC = Social Contracts

Table 16

*Rating questions means and (standard deviations) for each rule type.*

	Consequences	Disgusting	Dangerous	Understand
DP	5.86 (.62)	5.9 (.76)	5.65 (.68)	6.45 (.52)
PDP	6.12 (.67)	3.04 (1.51)	6.23 (.52)	6.44 (.61)
SC	4.32 (1.02)	2.63 (1.28)	3.25 (1.07)	5.98 (.84)

*Note.* DP = Disease Precautions; PDP = Physical Danger Precautions; SC = Social Contracts

Table 17

*Descriptive statistics for proportion of choosing only P and not-Q for each Rule Type*

<b>Rule Type</b>	<b><i>M (%)</i></b>	<b><i>SD (%)</i></b>	<b><i>Skewness</i></b>	<b><i>Kurtosis</i></b>
Disease Precautions	.819	.247	-2.31	4.41
Physical Danger Precautions	.851	.260	-2.26	4.19
Social Contracts	.827	.259	-2.08	3.55

*Note.* n = 167

Table 18

*Correlations between various traits and reasoning accuracy for each rule type*

P, not-Q	Disease Precautions	Physical Danger Precautions	Social Contracts
Contamination Scores	-.14	-.17*	-.14
Physical Harm Scores	.01	-.02	-.04
TDDS pathogen	-.10	-.12	-.10
OBQ-44	-.07	-.12	-.08
BDI-II	.11	.08	.12
STAI-Trait	.04	.05	.01
Verbal Fluency	.23***	.14	.22***

\*  $p \leq .05$ \*\*  $p \leq .01$ \*\*\*  $p \leq .001$