AN EXAMINATION OF THE STRUCTURE AND COMMON CORRELATES OF THREE DOMAINS OF CONTAMINATED MINDWARE IN ADOLESCENCE AND YOUNG ADULTHOOD

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Abstract

Limited research has examined individual differences in the accumulation of misinformation and unwarranted beliefs, known as contaminated mindware. The three unwarranted beliefs examined in this dissertation are paranormal, conspiracy, and anti-science beliefs. These beliefs remain prevalent in the public despite their epistemically suspect or unsubstantiated nature. This dissertation focused on the psychometric properties of items measuring individual differences in unwarranted beliefs to address three research objectives: (1) examine the underlying dimensional structure of unwarranted belief items in adolescents and young adults, (2) examine individual differences predicting susceptibility to these beliefs, and (3) examine differences between adolescents and young adults with respect to these beliefs. Study One examined the underlying structure of individual differences in unwarranted belief scores and its correlates in a sample of young-adults. Study Two confirmed that the same structure and correlates are found in adolescents. Both studies demonstrate the multidimensional nature of unwarranted beliefs that form domains of contaminated mindware. Specifically, the optimal factor model among adolescents and young adults was a hierarchical factor model with three correlated general factors (paranormal, conspiracy, and anti-science beliefs) and four specific paranormal factors (i.e., psi, superstition, spiritualism, and precognition). Further, we observed unique effects of individual differences in thinking and reasoning on individual differences in unwarranted beliefs. In Study Three, we assessed the measurement invariance of these scales across the two developmental groups, to allow for cross-sectional comparisons and age associations. The paranormal and conspiracy scales were characterized by strict invariance and the anti-science scale was characterized by strong invariance. With respect to developmental comparisons, endorsement of the unwarranted beliefs did not differ across development, except for a small

difference in paranormal belief. Further, the unwarranted beliefs total scores were not associated with age. We discuss the novelty of the results within the belief literature on contaminated mindware and focus on the utility of this scale for future research.

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Chapter 1: General Introduction

There has never been a time in history when we have been bombarded with more information, especially information that may be unsubstantiated. These unsubstantiated or unwarranted beliefs can be harmful for individuals and society, and accumulating these beliefs results in the problem of *contaminated mindware* (Stanovich, 2009; Stanovich, Toplak, & West, 2008; Stanovich, West, & Toplak, 2016). Mindware refers to one's accumulated and stored knowledge, beliefs, strategies, and rules that are relied upon for making decisions (Perkins, 1995). Contaminated mindware specifically refers to the accumulation of misinformation and unwarranted beliefs, some of which may stop individuals from engaging in reflection and considering alternatives (Stanovich, 2009). Irrespective of how intelligent we may be as a society, individuals continue to believe in pseudoscience, such as paranormal, conspiracy, and anti-science beliefs (Lobato, Mendoza, Sims, & Chin, 2014; Pennycook, Fugelsang, & Koehler, 2015b). Although these unwarranted beliefs are prevalent (Angus Reid Poll, 2015; 2016; Gallup & Newport, 1990), research examining the associations among these three domains of contaminated mindware remains scarce. Even less work has been done on contaminated mindware in adolescence as most measurement tools have been developed for adult samples, raising the question of whether current measures are appropriate for adolescents. Here we examined the underlying dimensional structure of unwarranted belief items in two periods of development: adolescence and young adulthood. In doing so, we estimated the relations among three unwarranted beliefs which help to constitute contaminated mindware. Our research also examined likely predictors of unwarranted beliefs, including cognitive ability, academic achievement, actively open-minded thinking, cognitive reflection, and ontological confusions. Adolescents and young adults heavily rely on media outlets and the Internet (Pew Research

Center, 2010; 2015). This information technology makes the widespread dissemination of unwarranted beliefs easier than ever before (Eve & Dunn, 1990), making it increasingly important to study such beliefs.

Contaminated mindware can impact thinking and reasoning when trying to make a rational decision. Similarly, the ability to think rationally can also impact the amount of contaminated mindware accumulated. This research may inform educational curricula, helping adolescents and young adults recognize beliefs that may be harmful or unhelpful. We begin with a review of the literature on rational thinking and contaminated mindware generally, then describe our studies in detail.

Rational thinking and belief acquisition

Rational thinking is a broad and multifaceted construct that encompasses multiple aspects of thinking (Stanovich & West, 2000), including holding relevant goals and beliefs in mind and acting on them (Stanovich et al., 2008). Work on rational thinking has often been informed by research on how this thinking can be undermined, through heuristics and biases in judgment and decision-making (Evans, 2008; Kahneman, 2003; 2011; Tversky & Kahneman, 1986). Heuristics are a set of mental shortcuts that are characterized by intuition and speed. Although they can be adaptive in familiar settings, they can lead to errors in judgment in novel situations (Kahneman, 2011; Tversky & Kahneman, 1974). People also tend to make systematic judgemental errors, referred to as biases (Stanovich, 2018; Stanovich et al., 2016). Rational thinking is typically indexed using tasks that measure such heuristics and biases (West, Toplak, & Stanovich 2008). These types of thinking can also be conceptualized within the framework of dual-process models of information processing (Stanovich et al., 2016).

Dual-process models generally consist of two types of processes that function at different levels of speed, intuition, awareness, and deliberation. Different authors attribute different names to the two separate modes of processing (see Evans 2008; Stanovich, 2011, for a discussion of the different versions). In line with Evans (2008), we use the terms *System 1* and *System 2* in this dissertation (Kahneman, 2011; Stanovich, 1999). System 1 processes are intuitive, implicit, and autonomous processes, whereas System 2 processes are deliberative, reflective, and analytical (Stanovich, 1999). More specifically, System 1 encompasses several types of processing that share an automaticity feature but can have distinct etiologies, including innate procedures, overlearned associations, and emotion regulation processes (Stanovich et al., 2016). System 1 processes are typically the default processes employed when one is reasoning or making daily decisions, unless System 2 processes are deliberately employed. System 2 processes are complex, multi-level, and serial in nature (Kahneman, 2011), and System 2 is important for overriding incorrect responses generated by System 1 (Kahneman, 2003; Frederick, 2005). For System 2 to succeed, it needs to identify and inhibit intuitive responses and generate potential alternatives (Stanovich et al., 2016). To generate these alternatives via mental simulations, System 2 must be able to separate these alternatives from reality, known as cognitive decoupling (Stanovich, 2009; 2011). In addition, Stanovich (2009; 2012) divides System 2 processes into algorithmic and reflective processes. Algorithmic-level processes include one's cognitive abilities. These processes reflect one's potential and intellectual resources, but are not always relied on when making daily decisions. Reflective processes, the aspect of System 2, are dispositions that represent one's values, beliefs, and attitudes about how these values and beliefs are formed and revised (Stanovich et al., 2016). One of these reflective dispositions is known as Actively Open-minded Thinking (AOT), the tendency to actively seek and consider several

possible conclusions even if they contradict or challenge one's initial or preferred conclusion and beliefs (Baron, Gürçay, & Metz, 2016; Sá, West, & Stanovich, 1999). Higher AOT invites deliberation and reflection when making decisions and reviewing evidence in both adults (e.g., Baron, Scott, Fincher, & Metz, 2015; Heijltjes, van Gog, Leppink, & Paas, 2015; Stanovich et al., 2016) and children (e.g., Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Toplak, West, & Stanovich, 2014a).

A person typically relies on System 1 when making daily decisions in familiar, well-acquainted, and learnt situations, without the need to make modifications using System 2 (Kahneman, 2011). In other words, people can comfortably rely on their initial impressions when acting on their desires in most routine and mundane situations. However, System 1 might be insufficient when making a decision regarding a novel problem or goal and might need to resort to one's stored mindware before making a decision. System 2 processing relies on one's mindware to successfully override System 1 processing. System 2 processes are also vital for updating and revising one's mindware.

We need to ensure that our decisions and actions are based on what we know to be true of the world and on beliefs that are accurate, known as epistemic rationality (Stanovich, 2016; Stanovich et al., 2016). Epistemic rationality and goal pursuit work in tandem (Kelly, 2003). People improve their epistemic position whenever they pursue a specific goal, solve a problem, or address a question, in turn acquiring knowledge or belief that more accurately reflects what is true of the world. Accumulated beliefs are generally stable and persistent, and reflect "enduring, unquestioned ontological representations of the world and comprise primary convictions about events, causes, agency, and objects that subjects use and accept as veridical" (Connors & Halligan, 2015). Simply put, a person believes in something when they regard it as true, without

needing to actively reflect on that belief (Schwitzgebel, 2015). Individuals make meaning of life and process new information and situations through their beliefs (Halligan, 2007). They also base their behaviour and actions on these beliefs (Tullett, Prentice, Teper, Nash, Inzlicht, & Mcgregor, 2013). Nonetheless, beliefs should be challenged and revised as new information is presented, and System 2 plays an integral role in updating and revising one's mindware and epistemic position.

It is expected that most people desire to hold beliefs that are true (Foley, 1987). People are also expected to continuously update their epistemic positions (Kelly 2003). However, humans are susceptible to holding some form of epistemically-suspect and unwarranted beliefs in their mindware due to their limited cognitive system (Foley,1992). Our information processing system is inherently disposed to reasoning errors and biases that lead to the accumulation of unwarranted beliefs (Gilovich, 1991; Nisbett & Ross, 1980). For example, people's misunderstanding of randomness results in superstitious beliefs and behaviour (Vyse, 1997). An over-reliance on pattern recognition and causal inference can also contribute to the acquisition of unwarranted beliefs (Foster & Kokko, 2009). Despite the shortcomings of our cognitive system, our cognitive system generally works well and is not so harmful that we abandon it (Foley, 1992). Nonetheless, the accumulation of unwarranted beliefs becomes concerning when it contributes to a problematic and self-sustaining worldview (Swami et al., 2011; Wood et al., 2012). The problem of accumulating misinformation and unwarranted beliefs, resulting in contaminated mindware, is particularly relevant in the current age of information virality (Gleick, 2012).

Contaminated mindware

There are many categories of contaminated mindware, but the focus here is on three related domains of unwarranted beliefs: paranormal, conspiracy, and anti-science beliefs. These beliefs have been well-documented in adults, but to a lesser extent within adolescents.

Paranormal beliefs. Paranormal phenomena generally violate the principles of science or current scientific understanding (Broad, 1953; Tobacyk & Milford, 1983). Paranormal phenomena are further distinguished as beliefs that are incompatible with core knowledge about mental phenomena, material objects, and living and animate organisms (Lindeman, 2018; Lindeman & Svedholm, 2012). Humans universally possess, learn, and rely on several systems of core knowledge about the world that do not necessitate explicit education (Spelke, 2004; Spelke & Kinzler, 2007). Systems of knowledge represent central aspects of physical, biological, and mental ontologies, as well as knowledge about inanimate objects and agents with goal-directed behaviour. Paranormal phenomena seem to confuse or blur the distinctions among core knowledge systems (Lindeman, 2018). For example, these confusions can often be categorized into one of the following categories: (1) biological and physical phenomena interpreted as possessing psychological properties, such as beliefs, desires, and intentionality; (2) mental and physical phenomena seen as possessing the properties of biological beings, such as living and healing; and (3) mental phenomena viewed as possessing the properties of physical phenomena, such as force, energy, independent existence, and an ability to influence or touch objects (Lindeman & Aarino, 2006). For example, the erroneous belief that a flightless bird (e.g., an ostrich) can fly is not paranormal, but the belief that horoscopes can predict the future or determine one's personality is, because it includes a category confusion or ontological mistake (Risen, 2016). This paranormal belief assumes that a symbol (i.e., horoscope) or a mental property exists independently and has the ability to influence external events.

Paranormal beliefs include a belief in Psi (e.g., psychokinesis), witchcraft (e.g., spells and black magic), superstition (e.g., lucky numbers), spiritualism (e.g., communication with the deceased), precognition (e.g., astrology predicting the future), extraordinary life forms (e.g., The abominable snowman of Tibet), and supernatural phenomena (Lindeman & Aarino, 2007; Lindeman & Svedholm, 2012). The New Age movement in the 1970s and 1980s helped to propagate paranormal beliefs in contemporary society, rejecting Western science and technology and reintroducing superstition (Vyse, 1997). Conspiracy theories also helped to cultivate paranormal beliefs, such as the belief in extraterrestrials and unidentified flying objects (UFOs) (Vyse, 1997). We conceptualize these multifarious and distinct beliefs within a broader paranormal belief domain (Lindeman & Svedholm, 2012). Such a conceptualization has also been adopted and empirically supported by two popular measures of paranormal beliefs in young adulthood and adulthood: The Australian Sheep-Goat Scale and the Revised Paranormal Belief Scale (Drinkwater, Denovan, Dagnall, & Parker, 2017;2018; Thalbourne & Delin, 1993; Tobacyk, 2004). The measures in the child and adolescent research remain relatively separate in their measurement of these sub-domains of belief (e.g., Bolton, Dearsley, Madronal-Luque, & Baron-Cohen, 2002; Preece & Bexter, 2000; Kokis et al., 2002).

Conspiracy Beliefs. Conspiracy theories attribute the cause of an event to secret plots by powerful groups or forces (Douglas & Sutton, 2008; Goertzel, 1994; McCauley & Jacques, 1979). These theories are resistant to falsification and lack evidence of their validity (Sutton & Douglas, 2014), despite sometimes being true. A general conspiracist belief reflects “the unnecessary assumption of conspiracy when other explanations are more probable” (Aaronovitch, 2009, p. 5). Conspiracist belief rejects and deflects criticism, labeling any criticism as part of the conspiracy, further confirming the conspiracist belief system (Bourdy &

Braeckman, 2012). Part of what makes conspiracist beliefs so robust is that they support all kinds of other similar beliefs, including contradictory conspiracy theories (Wood, Douglas, & Sutton, 2012) and fictitious conspiracies concocted by researchers (Swami et al., 2011). Examples of generic conspiracist belief include "the government routinely hides information in order to deceive the public," and "the government secretly perpetrates terrorist activities on their own citizens". These generic conspiracy beliefs appear to precede one's tendency to endorse more specific event-based conspiracies (Brotherton, French, & Pickering, 2013; Wood et al., 2012).

Individual differences in holding conspiracy beliefs have been conceptualized as a unidimensional construct, such that a general conspiracy factor or construct underlies one's endorsement of separate conspiracy beliefs (Dagnall, Drinkwater, Parker, Denovan, & Parton, 2015). In the young-adult and adult literature, two prominent generic conspiracy belief questionnaires exist: The Conspiracy Mentality Questionnaire and the Generic Conspiracist Beliefs scale (e.g., Brotherton et al., 2013; Bruder, Haffke, Neave, Nouriparah, & Imhoff, 2013). Generic conspiracy belief measures remain largely underdeveloped within research on children and adolescents.

Anti-science beliefs and attitudes. Anti-science beliefs refer to the rejection of and opposition to the scientific method (Holton 1992;1993). General anti-science attitudes and beliefs include seeing science as possessing low credibility (Hartman, Dieckmann, Sprenger, Stastny, & DeMarree, 2017), with a preference for intuition and instinct instead (Stanovich et al., 2016). Examples include denying climate change, being skeptical of the effectiveness of vaccinations, questioning the validity of evolution (Hmielowski, Feldman, Myers, Leiserwoitz & Maibach, 2014; Lewandowsky et al., 2013; Lewandowsky, Oberaur, & Gignac, 2013; Lobato et al., 2014), and endorsing alternative medicine (e.g., van den Bulck & Custers, 2009). The

American public remains divided on many of these scientific issues (Pew Research center, 2015). Much of the past research with young-adult and adult samples has studied individuals' trust in science using psychometrically underdeveloped or unsupported items, such as single questions (e.g., Malka, Krosnick, & Langer, 2009). Only recently has the 6-item Credibility of Science Scale been developed for use with young-adults and adults (Hartman et al., 2017). Unfortunately, we could not identify any work on anti-science beliefs and attitudes using child and adolescent samples, although some studies have assessed attitudes towards science as a subject of study in grade school (e.g., Francis & Greer, 1999; 2001; Kind, Jones, & Barmby, 2007). In line with the Credibility of Science Scale, we focused on generic anti-science beliefs and attitudes that are context independent and represent rejection of using scientific findings to adjudicate knowledge. We expect that a general anti-science belief and attitude factor precedes and explains one's inclination towards a range of scientific issues and outcomes, such as climate change and vaccination.

Shared characteristics among unwarranted beliefs

Paranormal, conspiracy, and anti-science beliefs often present themselves as science, but are in fact an imitation that offers inaccurate information (Boudry, Blancke, & Pigliucci, 2015). Further, these beliefs rely upon a "nonscientific evidentiary process" (Losh, Tavani, Njoroge, Wilke, & Mcauley, 2003) and some fail empirical tests, or cannot be empirically tested (Peerce and Baxter, 2000). The self-validating nature of these beliefs increases their appeal and prevalence in the public (Boudry & Braeckman, 2012). Stanovich (2004) discusses unwarranted beliefs within the framework of memetic theory, in which a *meme* is a cultural unit analogous to a gene (Dawkins,1976). A meme is a selfish replicator that exists for its own propagation across culture, regardless of its validity and in the absence of benefit to the person that holds it

(Stanovich, 2004). The persistence of these beliefs is partly a function of their structure, which enables various "epistemic defense mechanisms" (Boudry & Braeckman, 2011; 2012). Because these beliefs support multiple interpretations, they are difficult to contradict. For example, horoscopes make multiple predictions (Gilovich, 1991), including broad ones that allow anyone to find inevitable matches with real events. These beliefs also often retreat to a weaker version of an original hypothesis in the face of a failed prediction, known as "deflationary revision." Some beliefs also permit retrospective interpretation of phenomena and are therefore inherently resistant to falsification (Boudry & Braeckman, 2011). For example, alternative medicine and spiritual healing attribute any failure to one of three causes: (1) inappropriate administration of the intervention, (2) a specific type of intervention being unsuitable, or (3) interference of invisible factors or spirits. A fundamental defense mechanism of conspiracy belief is the tendency to deflect any troubling counterevidence or criticism. Believers of conspiracy theories "turn the evidence on its head," claiming that any contradiction is precisely what would have been predicted by their theory (Boudry & Braeckman, 2011; 2012).

These three domains of contaminated mindware have been primarily studied either singularly or in pairs, but they are all positively associated (e.g. Browne, Thomson, Rockloff, & Pennycook, 2015; Bruder et al., 2013; Darwin, Neave, & Holmes, 2011; Drinkwater, Dagnall, & Parker, 2012; Lewandowsky et al., 2013; van den Bulck & Custers, 2010), supporting the comorbid nature of unwarranted beliefs. It also supports the idea that when a person endorses some unwarranted beliefs, they are likely to endorse similar beliefs using prior beliefs as evidence, contributing to a self-sustaining worldview, known as a monological belief system (Lobato et al., 2014; Swami et al., 2011; Wood et al., 2012).

Although they may seem harmless, the comorbid nature of unwarranted beliefs can have negative effects on rational thinking (Stanovich, 2009; Evans & Stanovich, 2013), by discouraging critical thinking and reflection (Boudry, Blancke, & Pigliucci, 2015). This lack of thoughtful consideration and resistance to scientific advancements is concerning to society (Mackintosh, Lovas, & Schopper, 1999), with endorsement of unwarranted beliefs associated with increased rejection of science, reduced civic engagement, and reduced prosocial behaviour (Lewandowsky et al., 2013; Jolley & Douglas, 2014; van den Bulck & Custers, 2010; van der Linden, 2015). Economically, these effects translate into billions of dollars spent on untested and unsubstantiated treatments (Nahin, Barnes, Stussman, & Bloom, 2009) and a decline in concern regarding climate change (Brulle, Carmichael, & Jenkins, 2012; Scruggs & Benegal, 2012). Considering the negative consequences of these beliefs, it is important to understand the predictors of contaminated mindware.

Factors that contribute to contaminated mindware

Based on the literature reviewed, we have identified some important correlates of these three unwarranted beliefs, including cognitive ability, cognitive reflection, and AOT (e.g., Hartman et al., 2017; Pennycook, Gheyne, Barr, Koehler, & Fugelsang, 2015a). These three aspects of System 2 processes are expected to be negatively associated with unwarranted beliefs. Although people become more sophisticated with age (Seplke & Kinzler, 2007), adults continue to show systematic biases in core knowledge (Lindeman 2018). Even young adults and adults blur the distinctions among the physical, mental, and biological worlds (Lindeman, 2011; Lindeman & Svedholm, 2012; Svedholm, Lindeman & Lipsanen, 2010). Ontological confusions are expected to be positively associated with unwarranted beliefs. The associations between these factors and unwarranted beliefs will be discussed in detail in the chapters to follow.

Understanding the role of these relevant factors in accumulating contaminated mindware across development will help us identify aspects of thinking and reasoning that can be developed and improved to protect against unwarranted beliefs. Measuring individual differences in unwarranted beliefs and identifying likely predictors among adolescents and young adults advances the study of these important unwarranted beliefs and sheds light on possible protective factors.

Development and the study of contaminated mindware

With development, individuals acquire information, beliefs, attitudes, and knowledge that vary in their level of substantiation to form one's mindware. The study of contaminated mindware across development remains scarce compared to other aspects of cognition, although it has received a recent surge of attention for young adults and adults (e.g., Hartman et al., 2017; Jolley & Douglas, 2013; Lobato et al., 2014). However, very little has been done to study contaminated mindware or measure it in childhood and adolescence, leaving the current measurement tools underdeveloped for those developmental periods. Nonetheless, work has been conducted to understand beliefs about human knowledge and biases relevant to unwarranted beliefs as early as childhood.

Past research has utilized self-report measures to examine how beliefs about what is true of the world and the nature of knowledge, known as epistemic beliefs, develop as we age (e.g., Boys & Chandler, 1992; Muis, Bendixen, & Haerle, 2006; Hallett, Chandler, & Krettenauer, 2002; Schommer, 1990; 1993; Smith, Mcalin, Houghton, & Hennessey, 2000; Ricco, Pierce, & Medimilla, 2010). Adolescents and middle-school students recognize that scientific knowledge emerges from experimentation and investigation and is subject to revision based on new evidence (Conley et al., 2004; Hallet et al., 2002; Smith et al., 2000). These studies find

individual differences in the content of beliefs and knowledge acquisition and show that those aspects are measurable entities in adolescence. Further, although developmental scientists initially thought that ontological confusions to be a characteristic of childhood thinking, specifically, we now know that adolescents and adults also demonstrate similar confusions and biases (Bolton, Dearsley, Madronal-Luque, & Baron-Cohen, 2002; Lindeman, 2011; Lindeman & Svedholm, 201; Werner, 1948). As discussed previously, these confusions are important characteristics of paranormal beliefs and have been associated with other unwarranted beliefs. The prominence of these confusions beyond childhood and across development provides further support for the study of contaminated mindware in adolescence.

To study individual differences in contaminated mindware in adolescence and adulthood, we assume the following: (1) individuals are exposed to information relevant to these unwarranted beliefs, and (2) there exist individual differences in these unwarranted beliefs. With respect to the former, adolescents are exposed to unwarranted beliefs from teachers (Eve & Dunn, 1990), through friends, family, and television programs (Preece & Baxter, 2000), and through the media and internet (Gleick, 2012). Thorburn and Bogart (2005) also discuss the role of sociocultural and historical factors in creating a distrust in the government and medical institutions, which precedes and reinforces conspiracy beliefs as early as adolescence. With respect to the latter, there is evidence that contaminated mindware happens as early as childhood and adolescence, warranting its study in those periods of development. For example, some research has assessed individual differences in paranormal beliefs in child and adolescent samples (e.g., Preece & Bexter, 2000; Kokis et al., 2002) and individual differences in specific conspiracies in adolescence (e.g., Bogart & Thorburn, 2006; Thorburn & Bogart, 2005). Taken together, there is evidence that adolescents are exposed to and, to varying extents, have

accumulated some unwarranted beliefs. In this dissertation we build on existing work to develop the necessary measurement tools needed to study unwarranted beliefs in adolescence and young adulthood.

Why study unwarranted beliefs as early as adolescence?

Unwarranted beliefs should be studied at early developmental stages because these beliefs are acquired domains and exposure increases with age (Stanovich, 2009). However, there is not much research with adolescents and this is especially concerning because the use of the Internet and social media has increased over the last decade (Anderson, Steen, & Stavropoulos, 2016; Gottfried & Shearer, 2016), and are platforms for spreading misinformation and unwarranted beliefs (Evans, 1996; Gleick, 2012; Sparks & Pellechia, 1997). The digital revolution has changed the way adolescents learn and communicate in the past 15 years, at rates that surpass any changes that have taken place in the preceding hundreds of years (Giedd, 2012). There is a growing need to process abundant information automatically and intuitively, increasing the likelihood of accumulating unwarranted beliefs. Further, with increased automaticity and intuition, one tends to rely more heavily on prior beliefs and knowledge, including contaminated mindware, rather than inviting deliberation and reflection. Therefore, it is important to help young people better evaluate and filter information in the media (Giedd, 2012; Potter, 2004). For example, increased exposure to television content on science fiction, astrology, fortune-telling, and alternative therapy is associated with increased beliefs in those domains (Tseng, Tsai, Hsieh, Hung, & Huang, 2014). Exposure to fake news headlines also increases beliefs in such news, particularly when relying on System 1 processes (Pennycook, Cannon, & Rand, 2017).

No research has yet examined all three domains of contaminated mindware in adolescence. There is even less work on the suitability of the measurement tools used to assess individual differences in unwarranted beliefs in adolescence, or whether such tools would be appropriate for cross-sectional or longitudinal analysis. Therefore, we furthered the study of contaminated mindware by using the same set of items to measure these beliefs in both adolescence and young adulthood.

A summary of the current project

The accumulation of contaminated mindware is a function of both the structure of these beliefs and the person that holds them (Boudry & Braeckman, 2012). Therefore, it is important to empirically investigate the underlying structure of unwarranted beliefs, as well as the likely predictors of these beliefs in young-adult and adolescent samples. The current project had three overarching objectives: (1) examine the underlying dimensional structure of contaminated mindware among young adults and adolescents; (2) examine the effect of individual differences in cognitive ability, cognitive reflection, AOT, and ontological confusions on contaminated mindware among young adults and adolescents; and (3) assess developmental differences in unwarranted beliefs. We conducted three studies using two samples to address these objectives.

In Study One, we compiled and adapted items from the literature assessing individual differences in unwarranted beliefs (i.e., paranormal, conspiracy, and anti-science). We sampled items from several scales used in the literature and adapted them for reading ease and appropriateness for both adolescent and young-adult samples. This endeavor was important because the measurement tools in the literature have mostly been developed for use with adult samples, limiting the research that can be done with adolescents. To examine how well the items measure the constructs of interest, we examined the dimensional structure underlying the

associations among these items using a young-adult sample. We also examined the reliability of the observed scale scores implied by the model that presented with optimal fit to ensure that those scores represent reliable variance in unwarranted beliefs. Based on theory, we tested three competing confirmatory factor analysis (CFA) models to determine which provides the best representation of the dimensional structure of the proposed items. We then expanded the CFA model of optimal fit into a structural regression model to examine how strongly individual difference variables (i.e., cognitive ability, cognitive reflection, AOT, and ontological confusions) were associated with the factors underlying individual differences in unwarranted beliefs.

Study Two replicated the Study One analyses but instead used an adolescent sample. Specifically, we estimated the three CFA models tested in Study One in order to assess whether the same model presented with optimal fit in both a young-adult and adolescent sample. In addition, we examined the reliability of the observed scale scores implied by the model that presented with optimal fit. We then expanded the CFA model to a structural regression model to examine the associations between individual difference variables (i.e., cognitive ability, cognitive reflection, AOT, and ontological confusions) and the factors underlying unwarranted beliefs using an adolescent sample.

In Study Three, we merged the samples from the first two studies to assess measurement invariance of the items as a function of developmental period (adolescence vs. young adulthood). Measurement invariance assesses whether the scale indexes the construct of interest equivalently across sub-populations (Reise, Widaman, & Pugh, 1993). This investigation removes ambiguity about whether differences between adolescent and young adults can be attributed to true

developmental differences or are merely measurement differences. We then examined cross-sectional and developmental differences for the three domains of unwarranted beliefs.

Chapter 2: An examination of the underlying structure and common correlates of three domains of contaminated mindware in a sample of young adults

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Research examining concurrent associations among the three domains of contaminated mindware remains scarce, despite the prevalence of these beliefs. Examining these associations is important for our understanding of the structure of individual differences in unwarranted beliefs and, more importantly, for how to best measure it. The current research focused on paranormal, conspiracy, and anti-science beliefs. In this study, we examined the underlying dimensional structure of these three categories of contaminated mindware in a sample of young-adults. This examination furthers our understanding of the co-occurring nature of those beliefs. We also assessed individual differences that may make some people more susceptible to endorsing these beliefs than others, namely cognitive ability, AOT, cognitive reflection, and ontological confusions.

Associations among the three unwarranted beliefs in young-adults and adults

As noted earlier, research has mainly focused on examining the domains of contaminated mindware separately or in pairs, with a focus on bivariate associations rather than the underlying factor structure. Specifically, positive associations have been observed among paranormal beliefs and belief in alternative medicine (van den Bulck & Custers, 2010), and conspiracy beliefs and rejection of scientific claims (Lewandowsky et al., 2013a; 2013b). Further, belief in paranormal phenomena is associated with belief in specific conspiracy theories (Darwin et al., 2011; Drinkwater et al., 2012) and generic conspiracist ideation or mentality (Bruder et al., 2013; Drinkwater et al., 2012). Two studies examined all three domains, using young-adult and adult samples, and both only examined bivariate associations. In one study, anti-science attitudes, as

measured by individuals' perception of the credibility of science, were positively associated with paranormal and conspiracy beliefs (Hartman et al., 2017). In another, positive associations were observed among paranormal, conspiracy, and specific pseudoscientific beliefs (Lobato et al., 2014).

Overall, the concurrence among these different domains of contaminated mindware has been supported. However, the underlying structure of contaminated mindware items remains unexplored. We examined the underlying dimensional structure of these belief items to determine whether a unidimensional or multidimensional factor structure better represents the associations among these domains of unwarranted beliefs. Further, we examined possible predictors of these unwarranted beliefs to help validate the dimensional structure and assess the role of individual difference variables.

Correlates and predictors of unwarranted beliefs in young-adults and adults

Intelligent people accumulate contaminated mindware (Stanovich, 2009) and so deficits in knowledge or cognitive ability cannot fully explain the endorsement of unwarranted beliefs (Lewandowsky et al., 2013; Browne et al., 2015). Despite the accepted notion that even intelligent people believe in the unbelievable, research has yet to examine the unique effects of cognitive ability alongside other aspects of reasoning which may explain variation in the endorsement of unwarranted beliefs. Unwarranted beliefs are associated with performance on rational thinking tasks and measures of AOT. Specifically, AOT is negatively associated with specific unwarranted beliefs, including anti-science beliefs and attitudes, conspiracy beliefs, and paranormal beliefs (Stanovich et al., 2016; Svedholm & Lindeman, 2013a; Swami, Voracek, Stieger, Tran, & Furnham, 2014). Further, cognitive biases captured by ontological confusions or mistakes are associated with greater endorsement of paranormal and conspiracy beliefs, and

belief in alternative and complementary medicine (Lindeman & Aarnio, 2007; Lobato et al., 2014). Belief in alternative medicine and the paranormal are also negatively correlated with aspects of rational thinking, as measured by a set of tasks that measure heuristics and biases (Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2015a). Cognitive reflection is also associated with perceiving science as credible (Hartman et al., 2017). Taken together, these findings support the negative association between unwarranted beliefs and System 2 processes and dispositions. On the other hand, System 1 processes are associated with the accumulation of unwarranted beliefs. However, the unique effects of these multiple predictors has yet to be assessed concurrently in a multivariate model, controlling for indices of cognitive ability.

Study One

Not until recently has research attempted a concurrent examination of the three domains of unwarranted beliefs (see Hartman et al., 2017; Lobato et al., 2014). Lobato and colleagues (2014) examined bivariate associations among the three domains and suggested that those beliefs may have a unitary underlying structure. Stanovich and colleagues (2016) examined the factor structure of the Comprehensive Assessment of Rational Thinking (CART), a prototype measure of rational thinking subtests that includes superstitious thinking, generic anti-science attitudes, and specific conspiracy beliefs. Those three subtests of the CART were influenced by a single latent factor. To build on this research, we examined the dimensional structure of the three unwarranted belief domains of contaminated mindware by modeling the associations among those beliefs.

We first compiled items measuring unwarranted beliefs from the literature. In order to confirm that these items were representative of the content domain (Cizek, 2012), colleagues in

developmental psychology evaluated their representativeness. They also provided feedback on whether the items were suitable for use with adolescents.

Three separate CFA models were estimated to test competing hypotheses regarding the latent structure of these three domains of unwarranted beliefs. CFA models are measurement models that represent the associations between observed variables and a smaller number of latent variables or factors (Flora, 2017). In our case, the patterns of associations are among sets of items purported to measure three unwarranted beliefs and their respective latent variable. The regression coefficients in a CFA model (i.e., factor loadings) represent the strength of the causal relation between the factor and its respective items. The general matrix form of the CFA models is $Y = \Lambda\eta + \varepsilon$, where:

Y is a vector of the *J* observed variables,

Λ is a $J \times M$ matrix of factor loadings,

η is a vector of *M* common factors,

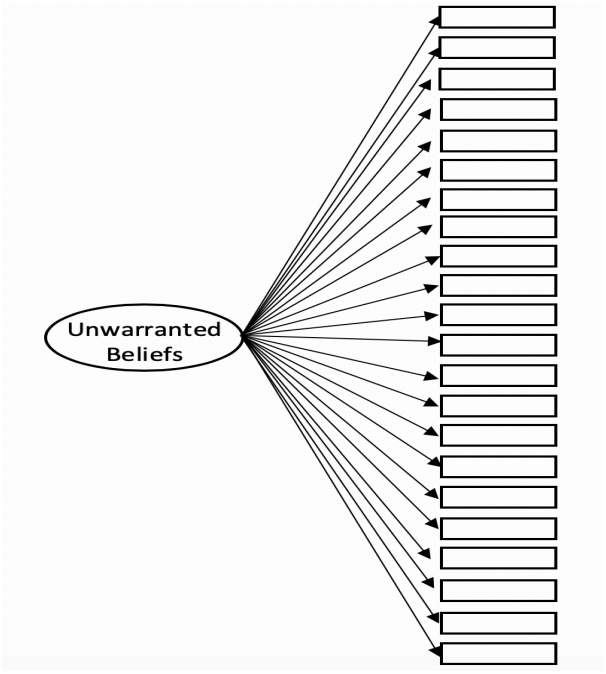
ε is a vector of *J* unique factors

First, we tested a one-factor model of unwarranted beliefs to examine whether the associations among unwarranted belief items might be explained by a single underlying variable. Second, to examine the multidimensional nature of unwarranted belief items, we estimated a model with three correlated factors, one for each domain. Most research reviewed conceptualizes each of the separate domains of contaminated mindware as unidimensional in nature, with correlations among these unidimensional domains (e.g., Bruder et al., 2013; Hartman et al., 2017). Unidimensional means that the associations among the items in a measure are a result of one underlying factor representing the respective belief being studied. Third, because the paranormal items are multifaceted and sample multiple aspects of the broader paranormal beliefs

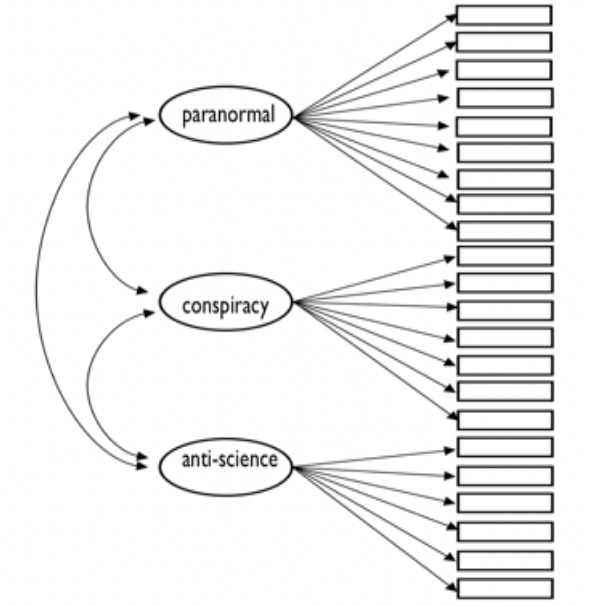
domain (Lindeman and Svedholm, 2012), we tested a hierarchical model. The hierarchical model consisted of three general factors for paranormal, conspiracy, and anti-science beliefs, along with five specific factors representing different sub-domains of paranormal beliefs, namely spiritualism, superstition, witchcraft, psi, and precognition. The paranormal domain tested in the latter model is similar to the structure of the Australian Sheep-Goat Scale and the Revised Paranormal Belief Scale (see Drinkwater, Denovan, Dagnall, & Parker, 2017;2018). Figure 1 shows generic forms of the three CFA models estimated.

We expanded the CFA model that obtained the best fit into a structural regression model to examine the unique effects of cognitive ability, cognitive reflection, AOT, and ontological confusions on the latent variables of contaminated mindware. This examination helps uncover how aspects of thinking and reasoning uniquely contribute to the accumulation of contaminated mindware.

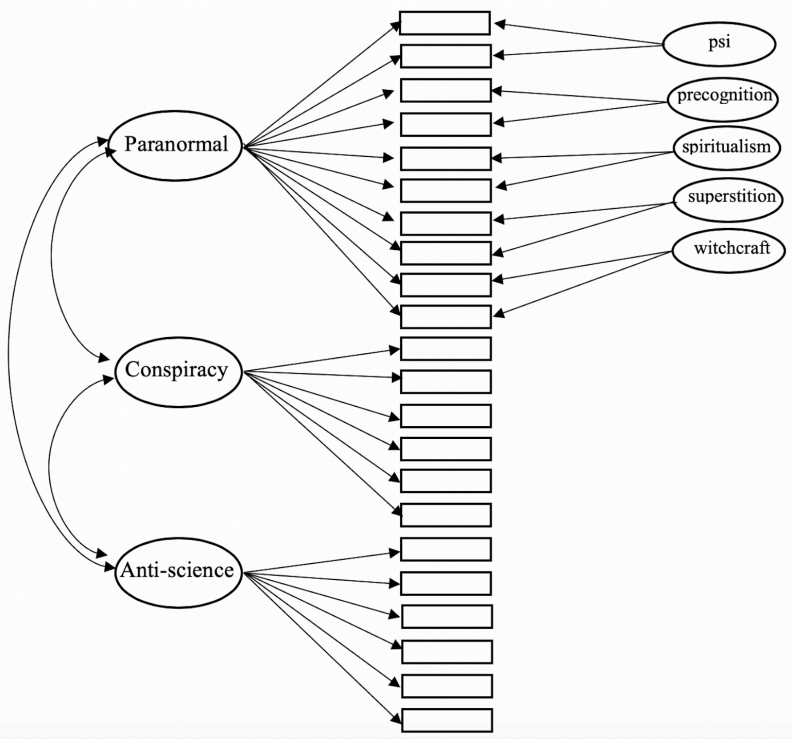
Figure 1. Generic CFA models tested



1a. Unidimensional model



1b. Three-factor model



1c. Hierarchical model

Method

Participants

Data were taken from 321 participants recruited through an undergraduate student research portal and participants received course credit for their participation. There were 58 males and 263 females and their age ranged between 18 and 30 years (M = 19.36, SD = 2.09). Of the total sample, 29.9% identified as South Asian, 25.5% as White/Caucasian, 8.7% as Black or African American, 7.8% as Arab or Middle Eastern, 6.9% as East Asian, 6.5% as South East Asian, 1.9% as Hispanic or Latino, 0.6% as Central Asian, 12.1% as other, and 0.6% chose not to disclose their ethnic identity. The majority of participants identified as Christian (40.2%), 18.7% as Muslim, 10.3% as Hindu, 6.2% as Agnostic, 2.5% Buddhist, 1.2% as Jewish, and 16.5% with a different religion, whereas 4.4% chose not to disclose.

Three hundred and fifty-nine participants were recruited originally. Data from 31 participants were discarded because of random responding, identified using the five-item Conscientious Responders Scale (CRS; Marjanovic, Struthers, Cribbie, & Greenglass, 2014). These attention check items were mixed in with the unwarranted beliefs items and instructed participants to respond with a specific option (e.g., response option 3); they were scored as either correct or incorrect. In the original CRS paper a 7-item scale was used and the cutoff for random responding was a score lower than 3. Because we used a 6-point likert scale, a cutoff score of 4 was used, such that participants who scored lower than 4 were considered random responders and their data was excluded. Of the remaining 327 participants, 6 participants were older than 30 and their data were excluded from further analyses because of this study's focus on young adults. Analyses were only conducted on the final sample of 321 participants.

Measures

For all rating-scale measures (i.e., paranormal beliefs, generic conspiracy, anti-science beliefs and attitudes, and AOT scales), participants rated how much they agree with statements on a six-point Likert-type scale (1 = *strongly disagree,* 2 = *moderately disagree,* 3 = *disagree,* 4 = *agree,* 5 = *moderately agree,* 6 = *strongly agree*).

Contaminated mindware. The full list of paranormal, conspiracy, and anti-science items is in Appendix A, including the breakdown of the paranormal items by sub-domain.

Paranormal beliefs. Paranormal beliefs were measured using 35 items, which were adapted from several extant scales measuring paranormal belief in adults (Epstein & Meier, 1989; Lobato et al., 2014; Tobacyk, 2004), children, and adolescents (Bolton, Dearsley, Madronal-Luque, & Baron-Cohen, 2002; Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Preece & Bester, 2000). Of the 35 items, four represented belief in Psi (e.g., psychokinesis), four

represented belief in witchcraft (e.g., spells and black magic), eight represented superstition (e.g., lucky numbers), eight represented spiritualism (e.g. communication with the deceased), and five items represented precognition (e.g., astrology's ability to predict the future). One item represented extraterrestrial activity and five items were generated based on belief in characters from modern fiction that represent extraordinary life forms, some of which possess supernatural powers (e.g., Hobbits really exist). These life forms were considered more timely than other folklore figures such as Bigfoot or the Loch Ness monster. The number of items per sub-domain were determined by availability of content in the extant scales examined. Participants were instructed to rate how much they agree with each statement. Higher scores indicate greater endorsements of paranormal belief.

Generic conspiracy beliefs. Conspiracy beliefs were measured using items adapted from the generic conspiracy belief scale (Brotherton et al., 2013). Twelve items were used which asked about the occurrence and normalcy of conspiracies in the real world without providing context or cues to any specific historical events (e.g., "The government is secretly involved in the murder of innocent citizens and a small secret group of people control world events"). Higher scores indicate greater endorsements of conspiracy belief.

Generic anti-science beliefs and attitudes. Items assessing anti-science beliefs and attitudes were adapted from Stanovich et al. (2016). Ten items were included asking about one's beliefs and attitudes towards science and preference for intuition (e.g., "I tend to rely on my gut feeling even when it contradicts a scientific finding" and "Evidence from science is usually biased or wrong"). Higher scores indicate greater endorsement of anti-science beliefs and attitudes.

Actively open-minded thinking. The 30-item Actively Open-Minded Thinking scale was used to measure AOT (Stanovich et al., 2016). The scale measures participants' disposition to take evidence into account even when it contradicts one's preferred conclusion or belief (e.g., "Changing your mind is a sign of weakness" (reverse scored) and "People should always consider evidence that goes against their beliefs"). The one factor underlying the positive associations among AOT items had an omega of .80[1].

Cognitive reflection. The expanded seven-item version of the Cognitive Reflection Test (CRT; originally from Frederick, 2005; Toplak, West, & Stanovich, 2014) was used. These problems elicit an intuitive incorrect response that participants need to override to obtain the correct answer. Each item was scored as correct (1) or incorrect (0), with a possible total score of 7. Higher scores are indicative of better performance. The one factor underlying performance on all seven problems of the CRT had an omega of .79.

Ontological confusion. The 30-item Ontological Confusions scale was used to measure ontological confusion (Lindeman & Aranio, 2007; Lindeman et al., 2011; Svedholm & Lindeman, 2013). The items on the scale assesses six content domains of ontological confusions, each with five confusion statements. The six domains are: Natural, lifeless objects are living; Force is living and animate; Lifeless objects are animate; Living inanimate entities (e.g., plants) are animate; Artificial objects are animate; And mental states are material objects. Example items include "stars live in the sky" which is from the domain of natural, lifeless objects are living and "earth wants water" from the domain of lifeless objects are animate. Participants were

[1] Coefficient alpha assumes "essential tau equivalence," implying equal factor loadings across items. Therefore, reliability was estimated using McDonald's (1999) coefficient omega for all of the total scores used in this research project. Confirmatory factor analysis was used to estimate one-factor models for all scales in order to obtain reliability estimates for the total scores used in the study. The one-factor model fit the data well for all the measures, except in the case of the AOT scale. A hierarchical AOT model was also tested but the fit of the model remained poor. Therefore, the reliability of the total AOT score should be interpreted cautiously as poor model fit might inflate omega values.

asked whether the statements are *literally true* or *not literally true.* Before asking participants to rate the literal truth of the statements, they were provided with an example to explain the difference in meaning between literally true and metaphorically or not literally true: "Do you think the following statements can be literally true, the way a sentence such as 'Wayne Gretzky was a hockey player' is true? Or are they true only in a metaphorical sense, like the expression 'Friends are the salt of life?" (Pennycook et al., 2015a). Answers were coded as either 1 (correct) or 0 (incorrect) and a higher total score was indicative of better performance and less ontological confusion (Omega for an ontological confusions factor was .93). There were also eight filler statements (four metaphors and four literal statements) which were not included in the ontological confusion score.

Verbal and nonverbal reasoning. Verbal reasoning was assessed using the checklist-with-foils format. The test included 40 words and 20 pronounceable nonwords, taken largely from Zimmerman et al. (1977). The words and nonwords were intermixed through alphabetization. Participants were told that some of the letter strings were actual words and that others were not, and that their task was to put a check mark next to those that they knew to be words. The total score was obtained by subtracting the number of foils checked (i.e., nonwords) from the sum of correctly identified words. This measure has been shown to be a reliable and valid way of assessing individual differences in vocabulary knowledge (R. C. Anderson & Freebody, 1983; Cooksey & Freebody, 1987; Zimmerman, Broder, Shaughnessy, & Underwood, 1977). The omega for the factor explaining positive associations among the identified words in the correct item pool was .92. The omega for the factor representing the associations among incorrectly identified words (i.e., foils or nonwords) among the pool of nonwords was .80.

To assess non-verbal reasoning, the 18-item short form of Raven's Advanced Progressive Matrices (APM) was used. Participants were presented with an abstract visual design that had a portion missing. The participants' task was to choose the missing portion from eight alternatives. Support for the use of this short form has been established by multiple studies (Arthur & Day, 1994; Chiesi, Ciancaleoni, Galli, Morsanyi & Primi, 2012). Each item was scored as correct (1) or incorrect (0), with a maximum possible total score of 18 (omega for the one-factor nonverbal reasoning was .67).

The raw scores on these two subtests were converted into z-scores and summed to create a composite measure of cognitive ability for use in the analyses. A higher score indicates greater cognitive ability.

Procedure

Participants completed the study online using Qualtrics software (Qualtrics, Provo, UT). Upon consent, participants were presented with a battery of questionnaires and tests in the following order: CRT, a block of paranormal items and AOT items intermixed and presented in a randomized order, Raven's APM, a block of conspiracy items in a randomized order, OCS, a block of anti-science items presented in a randomized order, demographic questionnaire, and the Vocabulary Checklist. We chose this order to switch between performance-based and rating measures whenever possible, to keep the participants engaged. The attention check items were intermixed within blocks with the unwarranted beliefs items.

Data Analysis

First, we calculated item-level descriptive statistics to assess the most and least prevalent contaminated mindware beliefs in the sample. We retained only those items that elicit variability in responses (more than 10% endorsement of either agree or disagree dimensions) in the

subsequent factor analyses. To address the first goal, CFA was used to model the dimensional structure of individual differences in unwarranted belief items. We then removed items with smaller factor loading estimates to create scales more succinctly representative of contaminated mindware. Then we calculated correlations among these unwarranted belief scales and other individual-difference variables. Finally, we extended the CFA model to a structural equation model (SEM) to measure the unique effects of each of the other individual-difference variables on the general factors of contaminated mindware estimated in the CFA model.

All models were estimated using R software with the lavaan package (version 0.5-17; Rosseel, 2012). Maximum likelihood estimation was used with robust standard errors and fit statistics to adjust for multivariate non-normality (Yuan & Bentler, 2000). Model fit was evaluated using the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), the comparative-fit index (CFI), and the Tucker-Lewis index (TLI). Hu and Bentler (1999) recommend values lower than .08 for the SRMR and .06 for the RMSEA and a value close to .95 or above for CFI and TLI to indicate acceptable model fit. Less rigorous guidelines have been proposed by others, in which values of .90 or greater for CFI and TLI are acceptable (Kline, 2011), along with values smaller than .08 for the RMSEA (MacCallum, Browne, & Sugawara, 1996).

Results

CFA Models of the Structure of Contaminated Mindware Items

Before running the CFA models, the frequency of the individual contaminated mindware items were examined. Items that were endorsed by less than 10% of the sample for either the agree or disagree dimensions were removed. This resulted in 4 of the paranormal and 2 of the anti-science items being removed (i.e., “bad things happen when you step on a crack on the

pavement", "zombies can really be found in graveyards after midnight", "werewolves are real living people during the daytime", "mermaids really live in the ocean near the South Pacific", "scientific understanding gets better over the years", "science is based on measuring observable events in the world and this has led to important knowledge").

The hierarchical model described earlier, with three general factors of paranormal, conspiracy, and anti-science beliefs and five specific factors (i.e., psi, spiritualism, precognition, witchcraft, and superstition) fit the data (CFI = .85, TLI = .84, RMSEA = .06, SRMR = .07) better than the three-factor model (CFI = .80, TLI = .79, RMSEA = .07, SRMR = .07) and one-factor model (CFI = .60, TLI = .58, RMSEA = .09, SRMR = .10)[2]. Based on these results, we reduced the number of items to improve model fit of the hierarchical model: for the revised model, we retained items with completely standardized factor loadings of .60 or higher on their respective general factor.

Revised Hierarchical model of contaminated mindware items

The revised model was specified for 20 paranormal items, eight conspiracy items, and five anti-science items. This hierarchical model with three general factors and four specific factors (i.e., psi, precognition, spiritualism, and superstition) fit the data well (CFI = .91, TLI = .90, RMSEA = .06, SRMR = .06). In the revised model, among the paranormal items only one witchcraft item was retained and two conspiracy items were allowed to covary because of a strong residual correlation (r = .34) ("The government hides information and facts to trick the public" and "The government blames other people to hide its criminal activity"*)*. Table 1

[2] The same three models were also estimated using the full item list. Results were similar: The hierarchical model fit the data (CFI = .83, TLI = .82, RMSEA = .06, SRMR = .08) better than the three-factor model (CFI = .76, TLI = .75, RMSEA = .07, SRMR = .08) and one-factor model (CFI = .60, TLI = .57, RMSEA = .09, SRMR = .10).

presents the completely standardized general factor loadings and the proportion of item-level variance explained by the revised model.

The three contaminated mindware factors were positively correlated with each other: The paranormal general factor was moderately correlated with the anti-science (r = .43) and conspiracy factors (r = .34), ps <.001, and the anti-science and conspiracy factors were also moderately correlated (r = .38, p <.001). Further, the total score reliabilities of the three general factors were good. The general paranormal factor has an omega of .93 and the conspiracy and anti-science factors have omegas of .89 and .79 respectively, indicating that the three general factors represent reliable variance in their respective items (for further discussion on the interpretation of statistical indices in bifactor models, see Rodrigues, Reise, & Haviland, 2016).

Table 1. General factor standardized factor loadings and proportion of variance explained in the revised hierarchical model

General Factor Item	**Standardized factor loadings**	**Proportion of variance explained**
Paranormal		
Some people can lift objects using the power from their minds	.69	.63
A person's thoughts can influence the movement of a physical object	.60	.61
Witches really exist and practice their magical powers in certain parts of the world	.60	.36
If you break a mirror, you will have bad luck	.73	.57
Some numbers are unlucky	.65	.75
Your mind or soul can leave your body and travel (astral projection)	.65	.95
During altered states, such as sleep or trances, the spirit can leave the body	.61	.51
It is possible to communicate with the dead	.61	.38
Astrology is a way to accurately predict the future	.78	.62
Horoscopes accurately predict the future	.76	.57
Some psychics can accurately predict the future	.77	.62
Some people have an unexplained ability to predict the future	.74	.87
You can prevent something bad from happening by *just* touching wood	.62	.48

Certain objects, such as rabbit's feet and four-leafed clovers, are known to bring good luck	.68	.48
Astrology is a valid explanation for the behaviors and personality of people	.76	.58
Dead people can communicate with living people through séances or Ouija boards	.70	.49
Some numbers and dates are more lucky or unlucky than others	.68	.70
Certain types of crystals have special powers	.70	.50
Hobbits really exist	.60	.36
Some people have a "sixth sense" that allows them to accurately predict the future	.71	.58
Conspiracy		
The government is secretly involved in the murder of innocent citizens	.71	.50
The spread of certain diseases is secretly caused by certain organizations	.79	.62
The government hides information and facts to trick the public	.62	.38
A secret organization is responsible for making all major world decisions, such as going to war	.78	.61
The government blames other people to hide its criminal activity	.62	.39
A small secret group of people control world events	.73	.53
The government routinely tries new drugs on people without them knowing	.81	.65
Scientists routinely hide important information from the public to protect their jobs	.60	.37
Anti-science		
I tend to rely on my gut feeling even when it contradicts a scientific finding	.61	.37
Evidence from science is usually biased or wrong	.70	.49
Because scientists disagree with each other, this shows that science is about the personal opinions of scientists more than actual evidence	.67	.45
Your gut feeling is better than relying on science in making decisions	.63	.40
I don't rely on findings from science because scientific facts can be used to prove anything	.69	.48

Note. $N = 321$.

Revised hierarchical model with a general unwarranted beliefs factor. In order to further explore the dimensional nature of these unwarranted beliefs and directly assess the

reliability of a unitary general factor, we examined a general unwarranted beliefs factor. Specifically, we estimated a hierarchical model with a general unwarranted beliefs factor along with the three specific factors for paranormal, conspiracy, and anti-science beliefs, accounting for residual correlations in the three specific domains (in addition to specific factors for psi, precognition, spiritualism, and superstition). The model fit the data well (CFI = .94, TLI = .93, RMSEA = .05, SRMR = .05). The three factors of paranormal, conspiracy, and anti-science beliefs and attitudes had omegas of .06, .76, and .62 and the unwarranted beliefs general factor had an omega of .81. Notably, the general factor's high omega is mainly due to the paranormal items having high standardized general factor loadings (ranging from .58 to .75) in contrast to the conspiracy and anti-science items having lower standardized general factor loadings (ranging from .12 to .42), meaning that the general unwarranted beliefs factor is actually a paranormal factor (for a discussion on anomalous results in bifactor models, see Eid, Geiser, Koch, & Heene, 2017). Therefore, the model without the general unwarranted beliefs factor is preferred, because its factor structure is a better representation of reliable variance in the items.

Total Scale Score Descriptive Statistics

Descriptive statistics are in Table 2 for all total scale scores, including the unwarranted beliefs scales based on the factors of the revised CFA model with three correlated general factors. All variables were approximately normally distributed with values of skewness and kurtosis near zero.

Table 2. Descriptive statistics of total scale scores

Variable	Mean	SD	Observed range	Skewness	Kurtosis
Predicted correlates					
Ravens	5.79	3.42	0, 15	0.51	-0.46
Vocabulary Checklist	18.37	7.45	-2, 40	0.67	0.60
Cognitive ability composite	0.00	1.57	-3.51, 4.64	0.30	-0.29

CRT	2.25	2.09	0, 7	0.86	-0.38
AOT	120.51	13.14	90, 156	0.58	-0.26
OCS	17.68	7.63	0, 30	-0.25	-0.63
Contaminated mindware					
Paranormal	51.79	19.08	20, 119	-0.02	-0.77
Conspiracy	27.26	8.04	8, 48	0.03	0.13
Anti-science	14.77	3.90	5, 30	-0.33	0.23

Note. CRT = Cognitive Reflection Test*; AOT* = Actively Open-Minded Thinking*; OCS* = Ontological Confusions Scale.

Bivariate Correlations

Correlations among scale scores are presented in Table 3. As expected, cognitive ability, CRT, AOT, and OCS were all positively correlated, with correlations ranging from .22 to .37, all *p*s < .05. Further, cognitive ability, CRT, AOT, and OCS were all negatively associated with the unwarranted beliefs, with correlations between -.14 and -.56, all *p*s < .05. Finally, as hypothesized, the paranormal beliefs, conspiracy beliefs, and anti-science beliefs and attitudes scores were all positively associated (*r*s from .30 to .39).

Table 3. Correlations among all variables and their respective 95% confidence intervals

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Cognitive ability	1						
2. CRT	.30 (.20, .40)	1					
3. AOT[3]	.34 (.24, .43)	.22 (.12, .32)	1				
4. OCS	.31 (.21, .41)	.28 (.18, .38)	.37 (.27, .46)	1			
5. Paranormal	-.14 (-.24, -.03)	-.22 (-.32, -.11)	-.44 (-.53, -.35)	-.32 (-.42, -.22)	1		
6. Conspiracy	-.15 (-.26, -.04)	-.18 (-.28, -.07)	-.20 (-.30, -.09)	-.22 (-.33, -.12)	.32 (.22, .41)	1	
7. Anti-science	-.23 (-.33, -.12)	-.19 (-.29, -.08)	-.56 (-.63, -.48)	-.33 (-.43, -.23)	.39 (.29, .48)	.30 (.20, .40)	1

[3] We also calculated correlations using a revised 23-item AOT scale which excludes the belief items from the original scale (see Stanovich and Toplak, 2019), which yielded similar results. Specifically, the revised 23-item AOT scale was positively associated with cognitive ability ($r = .31$, $p < .05$), CRT ($r = .20$, $p < .05$), and OCS ($r = .34$, $p < .05$), and negatively correlated with beliefs in the paranormal ($r = -.41$, $p < .05$) and conspiracy ($r = -.19$, $p < .05$) and anti-science attitudes ($r = -.54$, $p < .05$).

Note. All correlations are significant $p < .05$. *CRT* Cognitive Reflection Test*; AOT* Actively Open-Minded Thinking*; OCS* Ontological Confusions Scale.

Structural Equation Model Results

The structural equation model shown in Figure 2 had acceptable fit to the data (CFI = .91, TLI = .90, RMSEA = .05, SRMR = .06). The set of individual-difference variables (cognitive ability, CRT, AOT[4], and OCS) explained 24.8% of the variance in the paranormal beliefs latent variable, 9.5% for conspiracy beliefs, and 41.3% for anti-science beliefs and attitudes. AOT and OCS were statistically significant unique predictors of the paranormal beliefs latent variable, $p < .001$ and $p = .003$, respectively. AOT and OCS also predicted the anti-science attitudes latent variable, $p < .001$ and $p = .012$, respectively. Only OCS was a unique predictor of the conspiracy beliefs latent variable, $p = .004$. Cognitive ability and cognitive reflection did not predict any of the three unwarranted beliefs. Table 4 presents the unstandardized path coefficients and their respective 95% confidence intervals. Comparing standardized path coefficient estimates (see Figure 2), AOT was the strongest predictor of both paranormal beliefs and anti-science beliefs and attitudes, such that higher AOT scores predicted higher disagreement with those beliefs. Greater ontological confusions predicted more endorsement for all three unwarranted beliefs.

Table 4. SEM unstandardized path coefficients and 95% confidence interval

Outcome Variable	Predictor Variable	Unstandardized Path Coefficient	95% Confidence Interval
Paranormal			
	Cognitive ability	0.06	-0.02, 0.14
	CRT	-0.06	-.12, 0.00
	AOT	-0.03	-0.05, -0.02
	OCS	-0.03	-0.05, -0.01
Conspiracy			
	Cognitive ability	-0.03	-0.11, 0.05
	CRT	-0.05	-0.10, 0.01

[4] The structural equation model was also estimated using the 23-item AOT scale, excluding the 7 belief identification items (see Stanovich and Toplak, 2019 for further discussion of the issue), and had adequate fit to the data (CFI = .91, TLI = .90, RMSEA = .05, SRMR = .06). The 23-item AOT significantly predicted paranormal beliefs ($B^* = -.35$, $p < .001$), anti-science attitudes ($B^* = -0.53$, $p < .001$), and conspiracy beliefs ($B^* = -0.13$, $p < .05$).

	AOT	-0.01	-0.01, 0.00
	OCS	-0.02	-0.04, -0.01
Anti-Science			
	Cognitive ability	-0.01	-0.12, 0.09
	CRT	-0.02	-0.09, 0.05
	AOT	-0.06	-0.07, -0.04
	OCS	-0.03	-0.05, -0.01

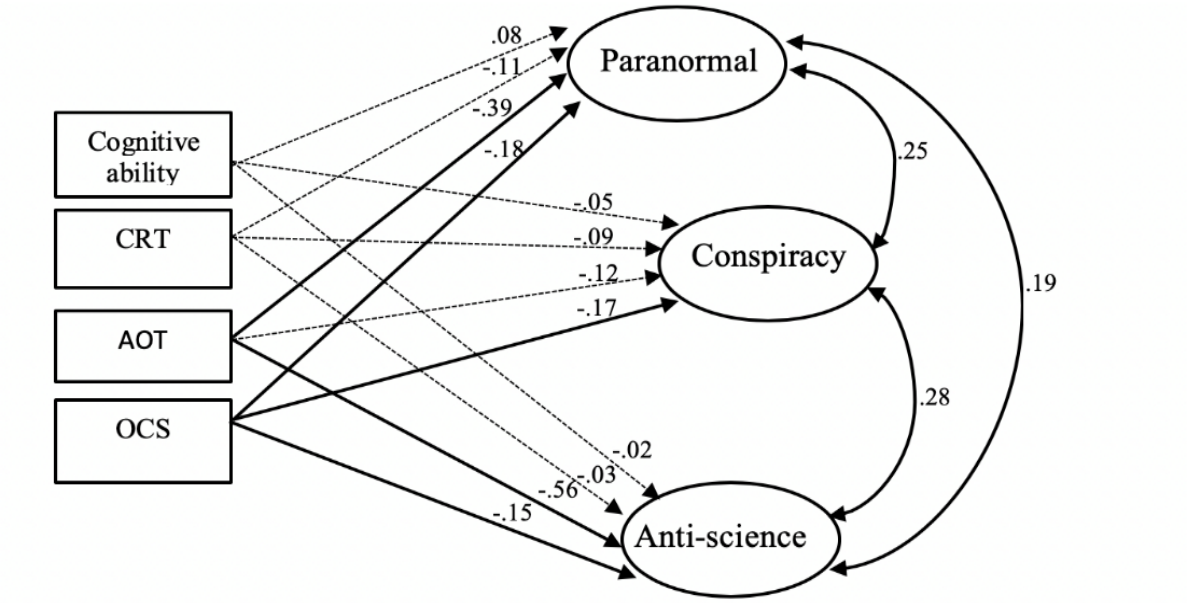


Figure 2. SEM testing the unique effect of individual difference variables on contaminated mindware. Dashed lines indicate non-significant standardized regression coefficients ($p < .05$). Double headed arrows show the correlation among the remaining variance in the three aspects of contaminated mindware. Ovals are latent variables and rectangles are observed variables. The figure omits the observed item-level indicators of the contaminated mindware latent variables, to reduce clutter.

Discussion

In the current study, we examined the dimensional structure of individual differences in three unwarranted beliefs (i.e., paranormal, conspiracy, and anti-science). We also examined the unique effects of cognitive ability, CRT, AOT, and OCS on these domains in a young-adult sample. This study advances research on positive associations among unwarranted beliefs (Lobato et al., 2014), by examining the underlying variables causing these positive associations among observable belief measures. The hierarchical model with three correlated general factors

for each unwarranted belief, along with specific factors for 4 aspects of paranormal beliefs, had the best fit. Further, these unwarranted beliefs were uniquely associated with aspects of cognition other than ability, including cognitive biases (i.e., ontological confusions) and thinking dispositions (i.e., AOT).

Based on the results from the two hierarchical models with and without a general unwarranted beliefs factor, the current findings support the multidimensional structure of the three contaminated mindware domains as measured by our items. The multidimensional structure constitutes three correlated general factors of paranormal, conspiracy, and anti-science beliefs, with four specific factors accounting for excess covariation among items representing specific aspects of paranormal belief. Results from a hierarchical model with a general unwarranted beliefs factor did not support a unitary construct of unwarranted beliefs, with the general factor loadings indicating that it is essentially a paranormal belief factor. Our results address Lobato and colleagues' (2014) question of whether those three domains of belief have a unified underlying structure despite their superficial differences. Specifically, our CFA results suggest that those beliefs items do not represent a unidimensional latent factor and, instead, the underlying structure of those items consists of correlated, yet separate, factors based on the three domains (i.e., paranormal, conspiracy, and anti-science). The implication is that differences among those beliefs are the result of their distinct underlying dimensions, whose intercorrelations partially explain the commonalities among those unwarranted beliefs, such as their self-validating nature and ease of propagation. However, based on the results, equating those beliefs is misleading and can lead to suboptimal measurement of the constructs of interest. Therefore, researchers should sample items across all three domains if they are interested in measuring the three domains examined here.

In terms of common correlates, higher cognitive ability and better performance on the CRT were weakly associated with lower endorsement of the three domains of contaminated mindware, with correlations ranging between -.14 and -.23 and between -.18 and -.22, respectively. Also as expected, higher AOT and lower ontological confusions were associated with lower endorsement of the three domains of contaminated mindware, with correlations ranging between -.20 and -.56 and between -.23 and - .34, respectively. Based on the structural model, neither cognitive ability nor performance on the CRT uniquely predicted the unwarranted beliefs scales over and above AOT and ontological confusions. These results provide evidence that ability and capacity are not the determinants of unwarranted beliefs, when entered alongside AOT and OCS scales, consistent with suggestions posed in previous research (e.g., Browne et al. 2015; Lewandowsky et al., 2013). More importantly, the results support the notion that even intelligent people believe in the unbelievable (Stanovich, 2009; Stanovich et al., 2016).

On the other hand, AOT and ontological confusions or biases were unique predictors of unwarranted beliefs scales in the structural model. Specifically, higher AOT scores predicted lower endorsement of paranormal and anti-science beliefs, whereas higher ontological confusions predicted greater endorsement of all three unwarranted beliefs. These results replicate and extend previous research (e.g., Lindeman, Svedholm-Häkkinen, & Lipsanen, 2015; Lobato et al., 2014; Pennycook et al., 2015a; Stanovich et al., 2016; Swami et al, 2014).

Summary of findings in Study One

In Study One we found support for the utility of questionnaire items reflecting three domains of unwarranted beliefs in a young-adult sample. We also demonstrated that individual differences in ontological confusions and actively open-minded thinking are uniquely associated with endorsement of unwarranted beliefs in young adults, independent of cognitive ability and

reflection. In Study Two we extend this examination to a sample of adolescents using the same questionnaire items.

Chapter 3: Confirming the structure and common correlates of three domains of contaminated mindware in a sample of adolescents

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The study of rational thinking and decision-making has made recent progress with developmental samples (e.g., Cimpian & Steinberg, 2014; Chiesi, Primi, & Morsanyi, 2011; Levin, Bossard, Gaeth, & Yan, 2014; Toplak et al., 2014a). However, very little has been done to understand individual differences in unwarranted beliefs as well as the likely predictors of those beliefs among adolescents. Thus, the implications of accumulating contaminated mindware remain uninvestigated for adolescents. This scarcity is concerning because mindware is acquired across development and contaminated mindware, in particular, is propagated through widespread unwarranted beliefs and misinformation in the media and the Internet (Kata, 2010; Lewandowsky et al., 2015; Wood & Douglas, 2015).

Research to date is partly limited by less availability of measurement tools appropriate for developmental samples, particularly tools that would allow for direct comparisons across developmental periods. Therefore, in Study One we validated the structure of a set of developmentally appropriate items measuring individual differences in unwarranted beliefs using a young-adult sample. In Study Two, we tested the validity of the underlying structure of these items using a sample of adolescents and confirmed the reliability of its scores. In addition, we also examined correlates and predictors of the unwarranted beliefs factors to further validate the dimensional structure using a sample of adolescents. This investigation uncovered the unique effects of cognitive ability, cognitive reflection, AOT, and ontological confusions on the unwarranted beliefs factors.

Measuring Unwarranted Beliefs in Adolescence

Unwarranted beliefs have been examined to a lesser extent with children and adolescents compared with the literature on young adults and adults. This lack of research is surprising considering the strong evidence of comorbidity for these belief domains in young adults and adults (e.g., Bruder et al., 2013; Hartman et al., 2017; Lobato et al., 2014). Further, the tools for measuring individual differences in unwarranted beliefs among children and adolescents are also limited. Several scales have been used to measure aspects of paranormal beliefs in children and adolescents, including the Exeter Superstitious Questionnaire (Preece & Bexter, 2000), Magical Thinking Questionnaire (Bolton et al., 2002), Revised Paranormal Belief Scale (Tobacyck, 1998), Thinking Dispositions Questionnaire (Kokis et al., 2002), Constructive Thinking Inventory (Ammerman, Lynch, Donovan, Martin, & Maisto, 2001; Urben, Suter, Piber, Straccia, & Stephan, 2014), and the Gambling Beliefs Scale (Ricijas, Dodig, Huic & Kranzelic, 2011). These questionnaires either assess one aspect of the paranormal (e.g., only superstitious belief) or have not been properly validated for adolescent populations. Studies that have examined paranormal beliefs in children and adolescents have done so to the exclusion of other unwarranted beliefs, such as conspiracy and anti-science beliefs and attitudes.

Very few studies have examined conspiracy beliefs among adolescents. Three studies have focused on assessing specific conspiracy theories, including conspiracies about birth control (Bogart & Thorburn 2006; Thorburn & Bogart, 2005) and specific nationalities (Grzesiak-Feldman & Irzycka, 2009). One prominent measure, the conspiracy mentality questionnaire (Imhoff & Bruder, 2014), was developed and validated using young-adult and adult samples, but has been employed with participants ranging in age from 14 to 80 years old. This questionnaire's psychometric properties have not been assessed with adolescents.

Research examining anti-science attitudes and beliefs in adolescence is also scarce. There is relatively more work in the field of education on secondary-school students' attitudes toward science, participation in science, and appreciation of practical work in science (e.g., Francis & Greer, 1999; 2001; Kind, Jones, & Barmby, 2007). Although these attitudes can be related to general anti-science beliefs and attitudes, the measures used mainly focus on capturing students' fondness and affective inclination towards engaging in science. These measures are not suitable for comparison with other developmental periods (e.g., young adulthood) when individuals are not engaged in similar types of schooling. Further, these measures do not fully reflect the construct of interest in this study. Generic anti-science beliefs are captured by one's perceptions of the credibility of the scientific enterprise generally (e.g., Hartman et al., 2017) and one's preference for intuition and instinct over the scientific method (Stanovich et al., 2016).

Taken together, the measurement tools in the adolescent literature are not well-developed to capture individual differences in the three unwarranted beliefs of interest. Therefore, using the scale from Study One, we first tested the underlying dimensional structure of individual differences in unwarranted beliefs using an adolescent sample. Validating this structure of unwarranted beliefs and their respective scores in adolescence allows examination of their concurrence and their associations with individual-difference predictors.

Correlates and Predictors of Unwarranted Beliefs in Adolescents

Regarding child and adolescent populations, a few empirical studies report a negative association between rational thinking and superstitious beliefs. Specifically, in a sample of children in Grades 5, 6, and 8, superstitious thinking was negatively correlated with performance on a deductive reasoning task, a cognitive ability index, and an AOT scale (Kokis et al., 2002). In a sample of children in Grades 2 through 9, superstitious thinking was negatively associated

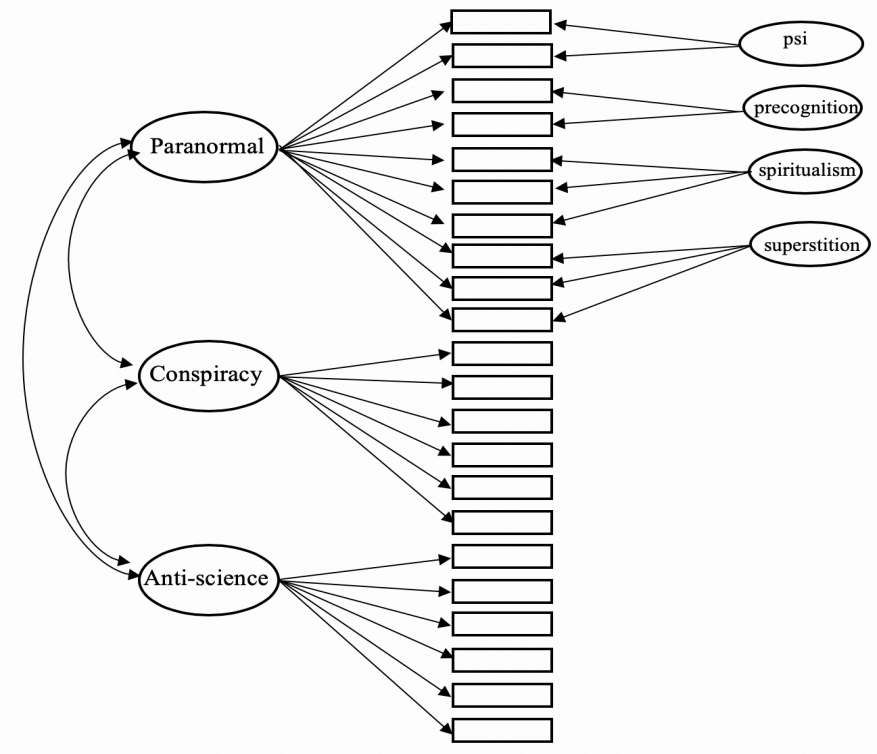
with cognitive ability, higher-order cognitive processes, AOT, and rational thinking measures (Toplak et al., 2014). Further, in a sample of adolescents in Grades 8 through 12, superstitious beliefs correlated positively with an intuitive style of thinking and negatively with a rational style of thinking (Marks, Hine, Blore, & Phillips, 2007). These associations are consistent with those reported in the literature on adults. Yet, the associations between rational thinking and other unwarranted beliefs, including conspiracy and anti-science beliefs, remain unexamined in the adolescent population.

With the saturation and mass dissemination of information in media outlets and the Internet, there has been an associated decline in the quality of information (Poulet, 2011). Examining individual differences associated with susceptibility to accumulating unwarranted beliefs in adolescence will help us to identify potential domains for intervention at early periods of development.

Study Two

We presented the unwarranted belief scale to a sample of high school students to confirm the accessibility and appropriateness of the content. In addition, we assessed the reading level of the items. Upon confirming accessibility, appropriateness, and reading level of the unwarranted belief scale, the three models tested in Study One were also tested in Study Two to confirm the latent structure of individual differences in paranormal, conspiracy, and anti-science beliefs. The models were fitted to the final list of items obtained in Study One, which included 20 paranormal items, eight conspiracy items, and five anti-science items. As shown in Figure 3, the hierarchical model in Study Two has three general factors of paranormal, conspiracy, and anti-science beliefs and four specific paranormal factors (i.e., psi, precognition, spiritualism, and superstition).

Figure 3. Generic hierarchical model of unwarranted beliefs tested in the adolescent sample



As in Study One, we expanded the optimally fitting confirmatory factor analysis (CFA) model into a structural regression model to examine the unique effects of cognitive ability, cognitive reflection, AOT, and ontological confusions on the latent variables of unwarranted beliefs. This examination helps uncover the extent to which the same aspects of thinking and reasoning that contribute to the accumulation of contaminated mindware in young adults also play a role in adolescence.

Method

Participants

Data were taken from 324 participants, residents of North America, who were recruited through Qualtrics Panels service (Qualtrics, Provo, UT) and received monetary compensation for their participation. There were 115 males and 209 females (64.5% female) with ages ranging between 12 and 19 years (M = 15.93, SD = 1.25). Eighty-five (26.2%) participants were in Grade

9, 75 (23.1%) were in Grade 10, 84 (25.9%) in Grade 11, and 80 (24.7%) were in Grade 12. Participants predominantly identified as being white/Caucasian (69.1%), followed by Black or African-American (13.3%), Hispanic and/or Latino (8%), Asian (3.1%), Indigenous (0.9%), Arab (0.3%) or other (5.2%). In terms of religious affiliation, 69.1% of the participants identified as Christian, 6.5% as Agnostic, 1.5% as Muslim, 0.9% as Jewish, 0.6% as Buddhist, and 21.0% as other. Most participants (90.7%) reported that their mother finished high school and 84.3% reported that their father finished high school. Further, 45.4% reported that their mother finished college (i.e., an undergraduate degree) and 37.7% reported that their father finished college.

Three hundred sixty-eight participants were recruited originally. Data from 44 participants were discarded because they reported ages outside of the 12- to 19-year range. Data were not analyzed prior to removing those participants.

Measures

For all items in all measures, participants rated how much they agree with statements using a six-point Likert-type scale (1 = *strongly disagree,* 2 = *moderately disagree,* 3 = *disagree,* 4 = *agree,* 5 = *moderately agree,* 6 = *strongly agree*).

Contaminated mindware. In order to assess the readability of adapted items and ensure their suitability for adolescents, we used the online Coh-Metrix Text Easability Assessor. The readability of the statements was assessed at a Flesch-Kincaid Grade Level of 6.9 and items had a score of 63.8 for reading ease (Flesch, 1948; 1951). Further, the Gunning Fog index was 8.8, indicating that the items are fairly easy to read. Together, these scores indicate that the readability of the adapted items is suitable for a high-school sample. Further, no issues regarding the accessibility of the content were identified in a pilot sample of high school students.

Paranormal beliefs. Paranormal beliefs were measured using the 20 items from the revised model in Study One. Of the 20 items, one represented belief in witchcraft ("Witches really exist and practice their magical powers in certain parts of the world"), two represented belief in Psi (e.g., psychokinesis), five represented superstition (e.g., "some numbers are unlucky"), six represented spiritualism (e.g. "it is possible to communicate with the dead"), and five items represented precognition (e.g., "astrology is a way to accurately predict the future"). One item was based on modern fictional characters (e.g., "Hobbits really exist"). Participants were instructed to rate how much they agree with each statement. Higher scores indicate greater endorsements of paranormal belief.

Generic conspiracy beliefs. Conspiracy beliefs were measured using the eight items from the revised model in Study One, which were adapted from the generic conspiracy belief scale (Brotherton et al., 2013). See Study One for a more detailed description of the individual items. Higher scores indicate greater endorsement of conspiracy beliefs.

Generic anti-science beliefs and attitudes. Items assessing anti-science beliefs and attitudes were adapted from Stanovich et al. (2016). Five items from the final revised model in Study One were included in this study (See Study One for a more detailed description of the individual items). Higher scores indicate greater endorsement of anti-science beliefs and attitudes.

Actively open-minded thinking. The 12-item Actively Open-Minded Thinking scale (Stanovich et al., 2016) was used to assess adolescents' tendency to consider different conclusions, even those that contradict their preferred conclusions and prior beliefs. Participants can have a total possible score of 72 with higher scores indicating greater AOT (omega[5] = .72).

[5] Confirmatory factor analysis was used to estimate one-factor models for all scales in order to obtain reliability estimates for the total scores used in the study. The one-factor model fit the data well for all measures except the

Cognitive reflection. The expanded 11-item version of the Cognitive Reflection Test (CRT; Frederick, 2005) adapted for adolescents (Toplak, West, & Stanovich, 2014b; Toplak et al., 2016) was used to measure cognitive reflection. The items assess participants' ability to reflect rather than rely on their intuition. The items are designed to elicit an intuitive incorrect response that participants need to override to obtain the correct answer. Each item was scored as correct (1) or incorrect (0), with a possible total score of 11. Higher scores are indicative of better performance. The reliability of the CRT factor was strong, omega = .90.

Ontological confusion. The Ontological Confusions Scale (OCS; Lindeman & Aranio, 2007; Lindeman et al., 2011; Svedholm & Lindeman, 2013) described in Study One was used. The OCS has been used with samples across a wide range of ages, including adolescents (e.g., Napola, 2015; Lindeman, 2011; Svedholm et al., 2010; Lindeman et al., 2015). We used 29 of the 30 items in this study because one item (*force aims to influence)* was confusing for adolescents during piloting. Answers were coded as either 1 (correct) or 0 (incorrect) with a possible total score of 29. Higher scores indicate better performance (i.e., lower ontological confusions). There were also four filler statements (two metaphors and two literal statements) that were not used to compute the ontological confusion score. Reliability of a total ontological confusions score based on the 29 items used in Study Two was strong (omega = .92), and comparable to the estimate presented in Study One (.93).

Cognitive Ability. The International Cognitive Ability Resource five-item version (ICAR-5) was used to assess cognitive ability (Kirkegaard & Bjerrekaer, 2016). The ICAR-5 is a short version of the 16-item ICAR (Condon & Revelle, 2014). We used the ICAR-5 because of time constraints and to eliminate fatigue effects and inattention. The ICAR-5 is particularly

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AOT scale. A hierarchical AOT model was also tested but its fit remained poor. Therefore, the reliability of the total AOT score should be interpreted cautiously as poor model fit might inflate omega estimates.

difficult for younger students (6th and 7th grades; Kirkegaard & Bjerrekaer, 2016). Although our sample constituted participants in grades 9 through 12, our results show the presence of a floor effect in that a large portion of the sample scored near zero. The reliability of the ICAR-5 for measuring a cognitive ability factor in our sample was not strong, omega = .52.

Academic achievement. Participants reported their overall average (out of 100) in four academic domains, including Science, Math, English, and Social Studies and History. An average of these reports was taken as a composite measure of overall academic achievement. Self-reported grade point average scores are often used in research with adolescents (e.g., Fröjd, et al., 2008; Quiroga, Janosz, & Bisset, 2013). The reliability of the overall academic composite was strong, with omega = 0.90.

Procedure

Participants completed the study online using Qualtrics. We contacted registered parents in Qualtrics Panels service who have children within the specified age group and who have indicated interest in participating in research studies. Parents and youth were presented with separate consent forms. Upon parent and youth consent, participants were presented with the following screening questions “Are you in high school (i.e., grades 9 through 12)” and “Is English your first language?” Only participants who indicated that they were in grades 9 through 12 were allowed to continue. If a participant noted that English was not their first language, they were allowed to continue the study only if they indicated that they have been schooled in English for at least eight years.

Following the consent forms and screening questions, participants were presented with a battery of questionnaires and tests in the following order: reflection and intuition questions (CRT), a block of paranormal items and AOT items presented in a randomized order, the ICAR-

5, a block of anti-science items in a randomized order, the OCS, a block of conspiracy items in a randomized order, and a demographic questionnaire. The five-item Conscientious Responders Scale (CRS; Marjanovic et al., 2014) was intermixed within the unwarranted beliefs items. The CRS items instructed participants exactly how to respond and were scored as either correct or incorrect. Participants with CRS total scores below 4 out of 5 were deemed random responders and their data were not recorded for this study.

Data Analysis

To address the first goal, CFA was used to test the dimensional structure of individual differences in the unwarranted belief domains. Then correlations and SEM were used to assess associations among the unwarranted beliefs scores and other individual-difference variables.

All models were estimated using R software with the lavaan package (version 0.5-17; Rosseel, 2012). Maximum likelihood estimation was used with robust standard errors and fit statistics (Yuan & Bentler, 2000) to adjust for multivariate non-normality. Model fit was evaluated using the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), the comparative-fit index (CFI), and the Tucker-Lewis index (TLI). The same standards for model fit evaluation used in Study One were used in this study.

Results

CFA Models of the Structure of Three Domains of Contaminated Mindware

The final hierarchical model discussed earlier, with three general factors (i.e., paranormal, conspiracy, and anti-science) and four specific paranormal factors (i.e., psi, precognition, spiritualism, and superstition), fit the data well (CFI = .93, TLI = .93, RMSEA = .05, SRMR = .05). The hierarchical model fit the data better than a one-factor model (CFI = .70, TLI = .68, RMSEA = .11, SRMR = .10) and a three-factor model (CFI = .88, TLI = .87, RMSEA

= .07, SRMR = .06). Table 5 presents the completely standardized general factor loadings and the proportion of item-level variance explained by the hierarchical model. The paranormal general factor was moderately correlated with the anti-science (r = .54) and conspiracy factors (r = .58), and the anti-science and conspiracy factors were also moderately correlated (r = .52). Further, the total score reliabilities based on the three general factors were good. Paranormal total score had an omega of .93 and the conspiracy and anti-science scores had omegas of .89 and .81, respectively. The omega scores indicate that the observed total scores based on each general factor represent reliable variance (Rodrigues, et al., 2016).

Table 5. General factor standardized factor loadings and proportion of variance explained in the revised hierarchical model in the adolescent sample

General Factor Item	**Standardized factor loadings**	**Proportion of variance explained**
Paranormal		
Some people can lift objects using the power from their minds	.71	.72
A person's thoughts can influence the movement of a physical object	.70	.72
Witches really exist and practice their magical powers in certain parts of the world	.68	.46
If you break a mirror, you will have bad luck	.61	.51
Some numbers are unlucky	.68	.72
Your mind or soul can leave your body and travel (astral projection	.76	.99
During altered states, such as sleep or trances, the spirit can leave the body	.74	.59
It is possible to communicate with the dead	.69	.48
Astrology is a way to accurately predict the future	.74	.56
Horoscopes accurately predict the future	.72	.52
Some psychics can accurately predict the future	.67	.52
Some people have an unexplained ability to predict the future	.71	.69
You can prevent something bad from happening by *just* touching wood	.58	.37
Certain objects, such as rabbit's feet and four-leafed clovers, are known to bring good luck	.53	.34
Astrology is a valid explanation for the behaviors and personality of people	.72	.52

Dead people can communicate with living people through séances or Ouija boards	.75	.57
Some numbers and dates are more lucky or unlucky than others	.69	.70
Certain types of crystals have special powers	.75	.56
Hobbits really exist	.50	.25
Some people have a "sixth sense" that allows them to accurately predict the future	.67	.63
Conspiracy		
The government is secretly involved in the murder of innocent citizens	.73	.53
The spread of certain diseases is secretly caused by certain organizations	.79	.63
The government hides information and facts to trick the public	.60	.36
A secret organization is responsible for making all major world decisions, such as going to war	.78	.61
The government blames other people to hide its criminal activity	.64	.41
A small secret group of people control world events	.77	.59
The government routinely tries new drugs on people without them knowing	.78	.60
Scientists routinely hide important information from the public to protect their jobs	.70	.49
Anti-science		
I tend to rely on my gut feeling even when it contradicts a scientific finding	.70	.50
Evidence from science is usually biased or wrong	.69	.47
Because scientists disagree with each other, this shows that science is about the personal opinions of scientists more than actual evidence	.68	.46
Your gut feeling is better than relying on science in making decisions	.70	.49
I don't rely on findings from science because scientific facts can be used to prove anything	.65	.43

Note. $N = 324$.

Hierarchical model with a general unwarranted beliefs factor. We also estimated a hierarchical model with a general unwarranted beliefs factor and three specific factors of paranormal, conspiracy, and anti-science beliefs accounting for residual correlations in the three specific domains (in addition to specific factors for psi, precognition, spiritualism, and

superstition). This investigation further explores the dimensional nature of individual differences in responding to unwarranted belief items in an adolescent sample and allows assessing the reliability of an overall unwarranted beliefs total score. The model fit the data well (CFI = .94, TLI = .93, RMSEA = .05, SRMR = .05). A total score based on the unwarranted beliefs general factor had an omega of .86. Similar to the results obtained in Study One, the unwarranted-belief total score's high omega is mainly due to the paranormal items having high standardized general factor loadings (ranging from .51 to .76) in contrast to the conspiracy and anti-science items having lower standardized general factor loadings (ranging from .28 to .48); therefore, the general unwarranted beliefs factor is essentially a paranormal factor (see Eid et al., 2017). Taken together, the factor structure of the model with the three correlated general factors of paranormal, conspiracy, and anti-science beliefs and attitudes (in addition to the four specific paranormal factors) is a better representation of reliable variance in the items.

Total scale score descriptive statistics

Descriptive statistics are in Table 6 for all total scale scores, including the unwarranted beliefs scales based on the factors of the hierarchical CFA model with three general factors. All variables were approximately normally distributed with values of skewness and kurtosis near zero, except for the academic achievement and CRT variables. In the SEM, the CRT's raw score was used, assuming that the maximum likelihood estimation with robust standard errors and fit statistics adequately adjust for non-normality.

Table 6. Descriptive statistics of total scale scores in the adolescent sample

Variable	Mean	SD	Observed range	Skewness	Kurtosis
Predicted correlates					
ICAR-5	1.23	1.20	0, 5	0.83	0.10
Academic Achievement Composite	82.61	14.86	3.5,100	-2.08	5.88
CRT	1.42	2.39	0, 11	2.11	3.93

AOT	52.49	7.33	36, 71	0.08	-0.61
OCS	15.83	7.23	0, 29	-0.10	-0.51
Contaminated mindware					
Paranormal	55.90	20.45	20, 110	-0.08	-0.70
Conspiracy	27.15	8.63	8, 48	-0.11	0.20
Anti-science	15.40	4.63	5, 28	-0.30	-0.12

Note. ICAR-5 = International Cognitive Ability Resource 5-item version; *CRT* = Cognitive Reflection Test*; AOT* = Actively Open-Minded Thinking*; OCS* = Ontological Confusions Scale.

Correlations

Correlations among scale scores are presented in Table 7. First, the paranormal beliefs total score was negatively correlated with cognitive ability, academic achievement, CRT, AOT, and OCS (*r*s between -.15 and -.53; all *p*s < .05). Similarly, the anti-science beliefs total score was negatively correlated with cognitive ability, academic achievement, CRT, AOT, and OCS (*r*s between -.17 and -.49; all *p*s < .05). The conspiracy beliefs total score was negatively correlated with cognitive ability, OCS, and AOT (*r*s between -.11 and -.33; all *p*s < .05). However, the conspiracy beliefs total score was not significantly correlated with CRT ($r = -.11$, $p = .05$) or academic achievement ($r = -.10$, $p = .07$). Finally, as hypothesized, the paranormal beliefs, conspiracy beliefs, and anti-science beliefs scores were all positively associated (*r*s from .44 to .52) as were cognitive ability, academic achievement, CRT, AOT, and OCS (*r*s ranging from .13 to .52, all *p*s < .05).

Table 7. Correlations among all variables in the adolescent sample and their respective 95% confidence intervals

Variable	1	2	3	4	5	6	7	8
1. ICAR5	1							
2. Academic achievement composite	.16* (.05, .26)	1						
3. CRT	.52* (.43, .59)	.15* (.04, .25)	1					
4. AOT	.18* (.07, .28)	.31* (.21, .41)	.13* (.02, .23)	1				
5. OCS	.36* (.26, .45)	.18* (.07, .28)	.33* (.23, .43)	.34* (.24, .43)	1			
6. Paranormal	-.15* (-.26, -.04)	-.21* (-.31, -.10)	-.17* (-.28, -.07)	-.53* (-.60, -.45)	-.42* (-.50, -.32)	1		
7. Conspiracy	-.11* (-.22, .00)	-.10 (-.21, .01)	-.11 (-.21, .00)	-.26* (-.36, -.16)	-.33* (-.42, -.23)	.52* (.43,.59)	1	
8. Anti-science	-.19* (-.29, -.08)	-.17* (-.27, -.06)	-.19* (-.30, -.09)	-.49* (-.57, -.41)	-.41* (-.50, -.31)	.47* (.38,.55)	.44* (.35,.52)	1

Note. * $p < .05$. *ICAR5* International Cognitive Ability Resource 5-item version; *CRT* Cognitive Reflection Test*; AOT* Actively Open-Minded Thinking*; OCS* Ontological Confusions Scale.

Structural Equation Model Results

The structural equation model shown in Figure 4 fit the data adequately (CFI = .92, TLI = .91, RMSEA = .05, SRMR = .05). Table 8 presents the unstandardized path coefficients and their respective 95% confidence intervals. The set of individual-difference predictors (cognitive ability, CRT, AOT, and OCS) explained 37.6% of the variance in the paranormal beliefs latent variable, 17.6% in conspiracy beliefs, and 38.8% in anti-science beliefs and attitudes. AOT and OCS significantly predicted paranormal beliefs, conspiracy beliefs, and anti-science attitudes and beliefs (all *ps* < .001). Cognitive ability and cognitive reflection did not significantly predict any of the three unwarranted beliefs domains of contaminated mindware. Comparing standardized path coefficient estimates (see Figure 4), AOT was the strongest predictor of the latent variables for both paranormal beliefs and anti-science beliefs and attitudes, such that higher AOT

predicted higher disagreement with those beliefs. Overall, higher ontological confusions and less actively open-minded thinking predicted higher endorsements of all three unwarranted beliefs.

Table 8. SEM unstandardized path coefficients and 95% confidence interval

Outcome Variable	Predictor Variable	Unstandardized Path Coefficient	95% Confidence Interval
Paranormal			
	Cognitive ability	0.06	-0.07, 0.19
	CRT	- 0.03	-0.09, 0.03
	AOT	- 0.08	-0.10, -0.06
	OCS	- 0.01	-0.07, -0.03
Conspiracy			
	Cognitive ability	0.02	-0.09, 0.13
	CRT	-0.00	-0.06, 0.05
	AOT	-0.03	-0.05, -0.02
	OCS	-0.04	-0.06, -0.02
Anti-Science			
	Cognitive ability	0.01	-0.12, 0.14
	CRT	-0.04	-0.10, 0.03
	AOT	-0.08	-0.11, -0.05
	OCS	-0.05	-0.07, -0.03

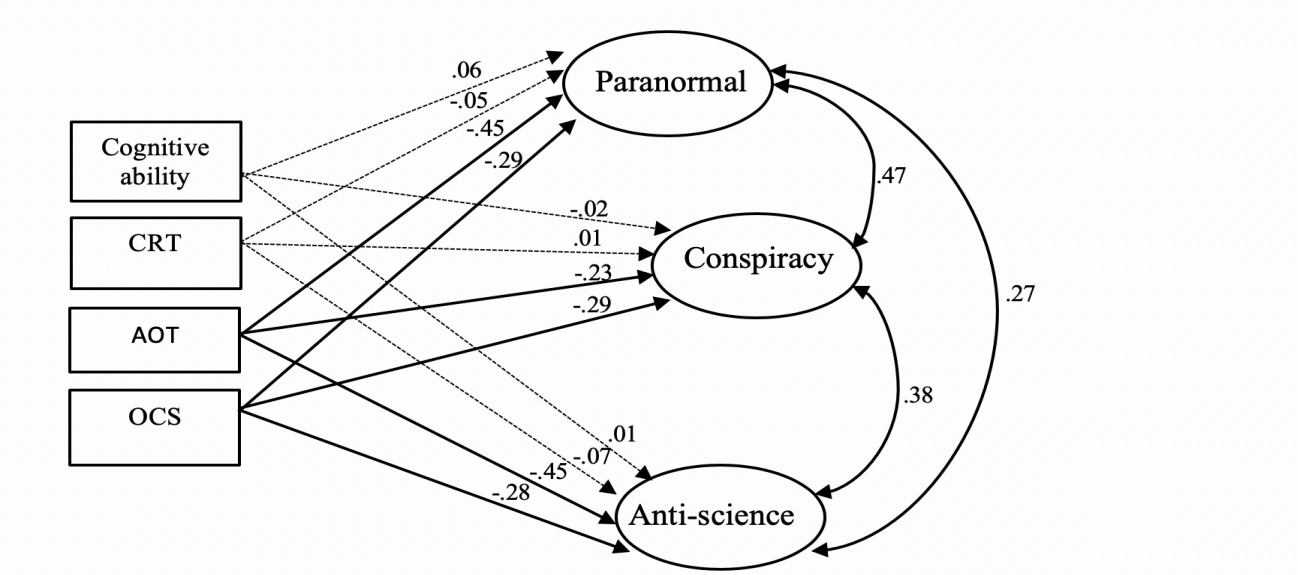

Figure 4. SEM testing the unique effect of individual difference variables on contaminated mindware. Dashed lines indicate non-significant standardized regression coefficients ($p < .05$). Double headed arrows show the correlation among the remaining variance in the three aspects of contaminated mindware. Ovals are latent variables and rectangles are observed variables. The figure omits the observed item-level indicators of the contaminated mindware latent variables, to reduce clutter.

Discussion

In Study Two, we supported the utility and psychometric properties of an unwarranted beliefs scale in the adolescent population. This endeavor is important for the development of research on contaminated mindware in adolescence. We confirmed the fit of the hierarchical model to the unwarranted beliefs scale in an adolescent sample. This is the first study with an adolescent sample to examine the dimensional structure of individual differences in three domains of contaminated mindware. Further, the results demonstrated the unique effects of ontological confusions and AOT on all three domains of contaminated mindware, irrespective of one's cognitive ability and cognitive reflection.

As outlined before, the tools in the literature that capture paranormal, conspiracy, and anti-science beliefs and attitudes are psychometrically underdeveloped in that they are either too narrow and specific or are related to but not representative of the broader constructs of interest (e.g., Bolton et al., 2002; Francis & Greer 1999;2001; Preece & Bexter, 2000; Bogart & Thorburn 2006). In this study, we provide a scale that can be used with adolescents to measure individual differences in three unwarranted beliefs that form domains of contaminated mindware. Specifically, the hierarchical model fit the data well and the reliability of the scale scores representing the three unwarranted beliefs support their utility as valid indices with little measurement error as representations of their respective factors. The results from the hierarchical model with a general unwarranted beliefs factor did not support a unitary construct of unwarranted beliefs among adolescents. These results are consistent with research using young-adult and adult samples that conceptualizes separable, yet related, domains of unwarranted beliefs (e.g., Bruder et al., 2013; Browne et al., 2015; Hartman et al., 2017).

The associations between unwarranted beliefs and their individual-difference predictors were in the expected direction, supporting the scale's criterion validity (see Table 7). Cognitive reflection and academic achievement were negatively associated with paranormal and anti-science beliefs and attitudes, but were not significantly associated with conspiracy beliefs. These results are consistent with previous research with adolescents examining paranormal beliefs (Kokis et al., 2002; Toplak et al., 2014) and with young-adult and adult samples examining all three unwarranted beliefs (e.g., Lindeman et al., 2015; Lobato et al., 2014; Pennycook et al., 2015a; Stanovich et al., 2016; Svedholm & Lindeman, 2013a; Swami et al., 2014). In addition, higher levels in all three unwarranted beliefs were associated with higher ontological confusions and lower AOT.

In the structural model, higher AOT and lower ontological confusions uniquely predicted lower levels of all three unwarranted beliefs over and above cognitive ability and ontological confusions, neither of which significantly predicted the unwarranted beliefs factors. These results are the first to examine three unwarranted belief domains and the effects of four associated correlates simultaneously in the adolescent population. These results support and extend what we found in Study One with young adults.

Summary of Findings

In Study One and Two, we tested and replicated the structure of individual differences in unwarranted beliefs. The results supported the multidimensional nature of unwarranted beliefs in adolescents and young-adults, specifically the presence of three correlated factors for paranormal, conspiracy, and anti-science beliefs and attitudes. Further, similar individual difference variables were uniquely associated with the three unwarranted beliefs in both samples. The two studies highlight the relevance of an AOT disposition and ontological understanding

and knowledge on the accumulation of contaminated mindware as early as young adolescence. In the next study, we explore whether the unwarranted belief scale functions equivalently across adolescence and early adulthood, which would allow for direct comparisons of scale scores for the three unwarranted beliefs domains between these two developmental periods.

Chapter 4: The effect of age and development on the accumulation of contaminated mindware

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With development, one becomes more cognitively sophisticated and adept in acquiring advanced scientific information and knowledge. An individual's stage of cognitive development and acquired ability to engage in reflection and deliberation impact the kinds of beliefs one accumulates (Kitchener & King, 1981). Individual differences in rational thinking, including System 2 processes and thinking dispositions, contribute to the accumulation of beliefs, including unwarranted beliefs (Pennycook et al., 2015b; Stahl & van Prooijen, 2018). Therefore, it is reasonable to expect that with the development of thinking and reasoning, one's accumulation of unwarranted beliefs and reliance on cognitive biases would be reduced or somewhat mitigated. Although unwarranted beliefs have been studied in young adulthood and adulthood (e.g. Hartman et al., 2017; Lobato et al., 2014), and to a lesser extent in childhood and adolescence (e.g., Kokis et al., 2002; Bogart & Thorburn 2006), research has yet to make a direct comparison across developmental periods, which is the purpose of the current study. Such research has been scarce in part due to the lack of measurement tools validated for use across developmental periods.

We first describe the average level of endorsement of individual items measuring individual differences in unwarranted beliefs across adolescent and young-adult samples for a preliminary investigation of the level of endorsement in the these developmental periods. To advance the study of unwarranted beliefs across development, we then examined the measurement equivalence of the unwarranted belief scale scores across the adolescent and

young-adult samples. Scores are determined to be measurement invariant if a person's observed score depends on only their true score and is independent of their group membership (Meredith & Millsap, 1992). That is, measurement invariance assesses whether a set of items measures the constructs of interest (in our case the three unwarranted beliefs) equivalently across the two groups of participants (see Reise, et al., 1993). Investigation of measurement invariance removes ambiguity about whether differences in observed scores are attributable to developmental differences or represent measurement differences. Demonstrating measurement equivalence allows researchers to use the same scales to assess cross-sectional age differences or longitudinal changes across adolescence and young adulthood. Upon confirming measurement invariance, we compared the total unwarranted beliefs scale scores between samples and examined their associations with age in the merged sample.

Unwarranted Beliefs Across Development

Pseudoscientific explanations are easier for the human mind to ascertain than scientific explanations because the latter often requires competencies beyond common reason and inclinations (Bronner, 2016). Those competencies are gained with development as individuals become more adept in their understanding of core knowledge systems (Spelke & Kinzler, 2007), how knowledge is constructed, and what is true of the world (Kuhn, Cheney, & Wienstock, 2000). Individuals also become more proficient in utilizing System 2 processes across development, demonstrating a higher tendency towards AOT, better ability to recognize bias, and superior cognitive reflection and cognitive ability (e.g., Anderson, 2001; Deary, Whalley, Lemon, Crawford, & Starr, 2000; Kokis et al., 2002; Toplak et al., 2014). Therefore, we expect that endorsement of unwarranted beliefs will decrease with age as one develops cognitively and attains higher education (Aarnio & Lindeman, 2005; Douglas, Sutton, Callan, Dawtry, &

Harvey, 2016). With cognitive development and an increased understanding of how knowledge is constructed across age, an individual is presumably equipped to distinguish warranted from unwarranted information and strong from weak evidence. In turn, individuals should be less susceptible to ideas or beliefs that rely on intuition rather than reason. Therefore, what individuals know to be true of the world (i.e., epistemic rationality) increases in accuracy across development. Nonetheless, the endorsement of unwarranted beliefs can persist independent of these developmental factors and in spite of higher education (Browne et al., 2015; Impey, 2013; Lindeman, 2018; Walker, Hoekstra & Vogl, 2002). One explanation is that individuals are likely to be exposed to more contaminated mindware with time and development because contaminated mindware is an acquired domain (Stanovich, 2009). Therefore, increased exposure to content related to contaminated mindware with age might mask the effect of cognitive development on the accumulation of unwarranted beliefs.

Age and developmental associations. Research that has specifically examined developmental trends of unwarranted beliefs has yielded mixed results. Using child and adolescent samples, some work reports age effects with respect to paranormal beliefs, whereby boys aged 12 to 13 endorse lower levels of paranormal beliefs than boys aged 7 to 10 (Bolton et al., 2002). Further, in samples of grade school students, endorsement of paranormal belief decreased across grades (Eder et al., 2011; Preece & Baxter, 2000). Peltzer (2003) found that Grade 11 students reported higher scores on superstitious and precognition belief scales compared to university students, whereas the latter reported higher scores on psi and spiritualism belief scales. In other lines of research, there were no age effects for paranormal beliefs (Chiesi et al., 2011; Kokis et al., 2002; Williams et al., 2007), with one study reporting only a weak association ($r = -.16$; Toplak et al., 2014).

Research on unwarranted beliefs with young-adult and adult samples has generally excluded age associations and developmental comparisons or has only examined age associations for secondary purposes such as identifying potential covariates. With respect to research examining the rejection of specific scientific claims and attitudes towards credibility of science, some studies report nonsignificant age effects (e.g., Browne et al., 2015; Hartman et al., 2017; Lewandowsky et al., 2013). Further, a meta-analysis on the determinants of belief in climate change indicated that age has a relatively small and negligible effect (Hornsey, Harris, Bain, & Fielding, 2016). A small positive effect was reported between age and higher belief in complementary and alternative medicine (van den Bulck & Custers, 2009). Further, some research reports negligible age effects for conspiracy ideation and belief (e.g., Lantian, Muller, & Douglas, 2016; Lewandowsky et al., 2013) and paranormal belief (Genovese, 2004; Lantian et al., 2016; Lindeman & Aarnio, 2006; Rice, 2003; van der Bulck & Custers, 2009). Other research reports that conspiracy belief and age are only weakly correlated ($r = .10$; Imhoff & Bruder, 2014). The inconsistency of these results is exemplified by a study on conspiracy beliefs in which these beliefs were weakly negatively correlated with age in a first study, but were not correlated with age in a second study (Douglas et al., 2015). Further, negative associations between paranormal beliefs and age are reported in some research (Douglas et al., 2015), whereas other research finds weak positive correlations between age and belief in alien visitation and extrasensory perception (Swami et al., 2011)

Taken together, although seemingly inconclusive, previous research suggests a negligible effect of age on unwarranted beliefs because the correlations between age and unwarranted beliefs are mixed in direction and often weak. However, most of the studies reviewed have a restricted age range, which may mask any true age effects. Research has yet to systematically

examine age effects and make direct cross-sectional comparisons across developmentally distinct samples using the same set of questionnaires. The current study furthers our understanding of the association between cognitive development and resistance and persistence of unwarranted beliefs (i.e., paranormal, conspiracy and anti-science beliefs).

Current study

The main focus of this study was to examine developmental differences for individual differences in the three unwarranted beliefs. This is the first study to have the same scale measuring unwarranted beliefs in both adolescent and young-adult participants. Therefore, we first described the average level of endorsement of individual unwarranted belief items in both samples. We then assessed measurement invariance of the scales measuring individual differences in the three unwarranted beliefs across the two samples, before testing cross-sectional developmental differences. Investigation of measurement invariance provides evidence for the utility of the unwarranted beliefs scales for future research.

Measurement invariance across the adolescent and young-adult samples was tested separately for each of the three unwarranted beliefs scales. Specifically, measurement invariance was tested using (1) a hierarchical model for paranormal beliefs with a general paranormal factor and four specific factors (i.e., precognition, psi, superstition, and spiritualism), (2) a one-factor model of conspiracy beliefs, and (3) a one-factor model of anti-science beliefs and attitudes. Once measurement invariance was established, we examined differences in the total scale scores for each domain of unwarranted beliefs across samples before merging the data to estimate the correlations between age and scale scores for the three unwarranted beliefs and ontological confusions. Table 9 presents the separate measures used in Study One and Two and highlights those used in this study (the full list of measures with their items are in Appendix A through J).

Table 9. A list of the measures used in Study One and Two

Young-adult sample (n = 321)		Adolescent sample (n = 324)	
Study One Measures	**# items**	**Study Two Measures**	**# items**
Paranormal beliefs	35	Paranormal beliefs	20
Conspiracy beliefs	12	Conspiracy beliefs	8
Anti-science	10	Anti-science beliefs	5
Actively open-minded thinking scale	30	Actively open-minded thinking scale	12
Cognitive Reflection Test	7	Cognitive Reflection Test	11
Ontological Confusions Scale	30	Ontological Confusions Scale	29
Raven's Advanced Progressive Matrices	18	International Cognitive Ability Resource	5
Vocabulary Checklist	60	Academic Achievement	4

Note. Underlined items represent measures used in Study Three.

Method

Participants

Data were taken from the first two studies. In the young-adult sample from Study One, there were 58 males and 263 females and their age ranged between 18 and 30 years (M = 19.36, SD = 2.09). In the adolescent sample from Study Two, there were 115 males and 209 females and their age ranged between 12 and 19 years (M = 15.93, SD = 1.25). When these two samples were combined, the merged dataset had an age range from 12 to 30 years (M = 17.63, SD = 2.43) and there were 472 females and 173 males.

Measures

Paranormal belief. The same 20 items used in Study One and Study Two were used in this study to measure individual differences in paranormal belief.

Conspiracy belief. The same eight items used in Study One and Study Two were used in this study to measure individual differences in conspiracy belief.

Anti-science belief. The same five items used in Study One and Study Two were used in this study to measure individual differences in anti-science belief.

Ontological confusions. The same 29 items from the Ontological Confusions Scale (Lindeman et al., 2011) used in Study Two were used in this study. See Study One and Study Two for details about the measure.

Procedure

The data used in this sample were collected as part of Study One and Study Two (see previous studies for details on the procedure employed).

Data Analysis

For descriptive purposes, we first examined the mean score for each item within the specific unwarranted belief domain across the two developmental groups. We then tested measurement invariance between the adolescent and young-adult samples separately for each of the unwarranted belief scales, using R software with the lavaan package (version 0.5-17; Rosseel, 2012). We conducted a sequential comparison of nested models, with each successive model having more stringent equality constraints (Cheung & Rensvold, 1999; Hisrchfeld & Von Brachel, 2014; Raju, Laffitte, & Byrne, 2002). First, to establish configural invariance for an unwarranted belief scale, we examined the fit of a two-group model in which the basic model specification was identical across developmental groups, but all parameters were free to vary across developmental groups. Next, to test metric invariance, we compared the fit of the configural invariance model with that of a model with all factor loadings constrained to equality across developmental groups. Metric invariance establishes that differences in covariance between observed variables in the sample are due to the latent variables. Then a scalar invariance model, also known as strong invariance model, was tested, where all factor loadings and

intercepts are constrained to equality across the two developmental groups. Scalar invariance indicates that both covariance and mean differences between observed variables in the sample are due to true score differences. Finally, strict invariance was tested by constraining all factor loadings, intercepts, and residual variances to be equal across developmental groups. Model fit was considered equivalent across models if values of CFI decreased and RMSEA increased by .01 or less (Chen, 2007).

Independent-samples *t*-tests were used to test the mean differences in paranormal, conspiracy, and anti-science belief total scores and ontological confusions between young adults and adolescents. Further, product-moment correlations were used to measure the associations among the paranormal, conspiracy, and anti-science beliefs scores along with ontological confusions and age in the merged sample.

Results

Average Level of Endorsement of Individual Unwarranted Beliefs Items

Tables 10 through 12 show the mean score of individual paranormal, conspiracy, and anti-science items, respectively, in each sample. Average level of endorsement of paranormal beliefs items ranged between 2.13 and 3.40 in the adolescent sample and 2.03 and 3.04 in the young-adult sample. Endorsement of conspiracy beliefs items ranged from 3.03 to 3.93 in the adolescent sample and between 3.10 and 4.04 in the young-adult sample. Endorsement of anti-science beliefs items was between 2.69 and 3.42 in the adolescent sample and 2.65 and 3.28 in the young-adult sample

Table 10. Mean score of paranormal items in the adolescent and young-adult sample

Paranormal Item	Adolescent sample mean score	Young-adult sample mean score
1. Some people can lift objects using the power from their minds	2.43	2.16

2. a person's thoughts can influence the movement of a physical object	2.54	2.19
3. Witches really exist and practice their magical powers in certain parts of the world	2.83	2.40
4. If you break a mirror, you will have bad luck	2.53	2.39
5. Some numbers are unlucky	2.79	2.77
6. Your mind or soul can leave your body and travel (astral projection)	2.94	2.81
7. During altered states, such as sleep or trances, the spirit can leave the body	2.90	2.76
8. It is possible to communicate with the dead	3.05	2.91
9. Astrology is a way to accurately predict the future	2.63	2.44
10. Horoscopes accurately predict the future	2.51	2.36
11. Some psychics can accurately predict the future	3.11	2.87
12. Some people have an unexplained ability to predict the future	3.40	3.04
13. You can prevent something bad from happening by just touching wood	2.13	2.35
14. Certain objects, such as rabbit's feet and four-leafed clovers, are known to bring good luck	3.37	2.83
15. Astrology is a valid explanation for the behaviours and personality of people	2.79	2.59
16. Dead people can communicate with living people through seances or Ouija boards	2.74	2.62
17. Some numbers and dates are more lucky or unlucky than others	2.94	2.80
18. Certain types of crystals have special powers	2.79	2.54
19. Hobbits really exist	2.21	2.03
20. Some people have a "sixth sense" that allows them to accurately predict the future	3.29	2.93

Table 11. Mean score of conspiracy items in the adolescent and young-adult sample

Conspiracy item	Adolescent sample mean score	Young-adult sample mean score
1. The government is secretly involved in the murder of innocent citizens	3.26	3.30
2. The spread of certain diseases is secretly caused by certain organizations	3.13	3.10
3. The government hides information and facts to trick the public	3.93	4.04
4. A secret organization is responsible for making all major world decisions, such as going to war	3.03	3.16
5. The government blames other people to hide its criminal activity	3.81	3.74
6. A small secret group of people control world events	3.10	3.12
7. The government routinely tried new drugs on people without them knowing	3.33	3.17
8. Scientists routinely hide important information from the public to protect their jobs	3.57	3.62

Table 12. Mean score of anti-science items in the adolescent and young-adult sample

Antis-science item	Adolescent sample mean score	Young-adult sample mean score
1. I tend to rely on my gut feeling even when it contradicts a scientific finding	3.42	3.28
2. Evidence from science is usually biased or wrong	2.69	2.65
3. Because scientists disagree with each other, this shows that science is about the personal opinions of scientists more than actual evidence	2.94	2.87
4. Your gut feeling is better than relying on science in making decisions	3.35	3.10
5. I don't rely on findings from science because scientific facts can be used to prove almost	3.00	2.97

Measurement Invariance of the Three Unwarranted Beliefs Scales

Upon testing the hierarchical model of paranormal items across the two developmental groups, strict measurement invariance held. Specifically, the configural invariance model had CFI = .938 and RMSEA = .069; the metric invariance model had CFI = .932 and RMSEA =.068; the scalar invariance model had CFI = .928 and RMSEA = .068; and finally, the strict invariance model had CFI = .922 and RMSEA = .069. Therefore, changes in CFI and RMSEA are less than or equal to .01 across the models and based on Chen's (2007) recommendations, these models are considered equivalent. Therefore, total scores calculated from the paranormal items measure the paranormal beliefs construct equivalently across the developmental groups.

Upon testing the one-factor model of conspiracy beliefs, strict measurement invariance held. Specifically, the configural invariance model had CFI = .965 and RMSEA = .085; the metric invariance model had CFI = .966 and RMSEA =.076; the scalar invariance model had CFI = .963 and RMSEA = .074; and finally, the strict invariance model had CFI = .964 and RMSEA = .069. Therefore, those models are considered equivalent, implying that total scores based on the conspiracy items measure the conspiracy beliefs construct equivalently across the developmental groups.

Upon testing the one-factor model of anti-science beliefs, strong measurement invariance held. Specifically, configural invariance model had CFI = .931 and RMSEA = .141; the metric invariance model had CFI = .926 and RMSEA =.120; the scalar invariance model had CFI = .924 and RMSEA = .108; and finally, the strict invariance model had CFI = .905 and RMSEA = .107. Therefore, those models are considered equivalent at the strong invariance level. However, the residual variances differed across the two developmental groups. Although some research suggests that strict invariance is required for group comparisons (Wu, Li, & Zumbo, 2007),

Geiser, Burns and Servera (2014) assert that "strict invariance is only necessary when correlated errors of measurement exist and are not properly modeled." Because strong invariance is sufficient to determine measurement equivalence and allows for a meaningful comparison of group differences in observed means (Geiser et al., 2014; Gregorich, 2006), we are confident that we can compare anti-science beliefs scores across the developmental groups.

Developmental Differences Between Samples in Paranormal, Conspiracy, and Anti-Science Beliefs

Based on the difference in unwarranted belief scale scores across the two developmental samples (see Table 13), the adolescent sample (M = 55.90, SD = 20.45) had a higher paranormal beliefs total score than the young-adult sample (M = 51.79, SD =19.08), p = .008. Conspiracy beliefs (adolescent: M = 27.15, SD = 8.63; young-adult: M = 27.26, SD = 8.04), anti-science beliefs (adolescent: M = 14.77, SD = 3.90; young-adult: M = 14.77, SD = 3.90), and ontological confusions (adolescent: M = 15.86, SD = 7.08; young-adult: M = 17.04, SD = 7.37) did not significantly differ across the two developmental samples. Further, as shown in Table 14, using the merged sample, age (in years) was not meaningfully related to any of the three unwarranted beliefs or ontological confusions total scores (r = -.04 to -.14), but ontological confusions score was negatively correlated with the three unwarranted belief scale scores (r = -.28 to -.38) such that higher confusions are associated with higher endorsement of unwarranted beliefs. Finally, the three unwarranted beliefs total scores were all positively correlated with each other (r = .38 to .44).

Table 13. Differences in unwarranted beliefs and ontological confusions between young-adults and adolescents

	Young-adult sample (n = 321)	Adolescent sample (n = 324)		
Variable	**Mean (SD)**	**Mean (SD)**	***t***	**Mean difference confidence interval**
Paranormal	51.79 (19.08)	55.90 (20.45)	2.64*	0.21, 8.01
Conspiracy	27.26 (8.04)	27.15 (8.63)	-0.16	-1.75, 1.54
Anti-science	14.77 (3.90)	15.40 (4.63)	1.88	-0.21, 1.48
OCS	17.04 (7.37)	15.86 (7.08)	-2.08	-2.61, 0.24

Note. * t-statistic significant, $p < .0125$. Bonferroni correction for 4 comparisons is alpha .012 and 98.75% confidence interval of the difference. *OCS* = Ontological Confusions Scale. Welch t-test was used because of non-homogenous variance across groups.

Table 14. Correlations among the unwarranted beliefs scales, ontological confusion scale, and age in the merged sample and their respective 95% confidence intervals

Variable	**1**	**2**	**3**	**4**	**5**
1. Age	**1**				
2. Paranormal	-.10* (-.18, -.02)	**1**			
3. Conspiracy	-.04 (-.12, .04)	.42* (.35, .48)	**1**		
4. Anti-science	-.14* (-.21, -.06)	.44* (.38, .50)	.38* (.31, .44)	**1**	
5. OCS	.05 (-.03, .13)	-.37* (-.43, -.30)	-.28* (-.35, -.21)	-.38* (-.44, -.31)	**1**

Note. * $p < .05$. *OCS* = Ontological Confusions Scale

Discussion

In this study, we demonstrated measurement equivalence across adolescents and young-adults for the scales measuring three unwarranted beliefs. By doing so, we were able to meaningfully compare observed mean scores across samples. Paranormal beliefs scores were significantly greater among adolescents than young-adults, but despite expectations, conspiracy and anti-science beliefs scores did not significantly differ between samples. Further, age was not significantly correlated with any of the three unwarranted beliefs scores nor the ontological confusions score.

Endorsement of individual items measuring unwarranted beliefs was consistent with rates reported in previous research (Angus Reid Poll, 2016; Brotherton et al., 2013; Gallup & Newport, 1990; Lantian et al., 2016). Notably, the most highly endorsed item in each unwarranted belief domain was the same in both samples, suggesting that the content of certain beliefs is similarly appealing to individuals across development. Specifically, in the paranormal domain, about 58.0% of the adolescent sample and 45.8% of the young-adult sample believe that some people can predict the future, despite the obvious erroneousness of the idea of precognition. In precognition, one ascribes the process of gaining knowledge about possible future events to a solely mental process (Lindeman et al., 2015). In the conspiracy domain, 68.8% of the adolescent sample and 75.0% of the young-adult sample endorsed the belief the government hides information and facts, with the intention of deceiving the public. At extreme levels, it can be concerning for individuals in a relatively educated and democratic society to believe that their government intentionally deceives them. Although such beliefs can sometimes be adaptive in challenging social hierarchies and for social change (Sapountzis & Condor, 2010), extreme levels of these beliefs can also negatively impact civic engagement and prosocial behaviour (e.g., Jolley & Douglas, 2014). Future research should explicate the levels of conspiracy belief that can be healthy and motivating from extreme levels that can be debilitating and deterministic. In the anti-science domain, around 50.3% of the adolescent sample and 42.5% of the young-adult sample endorsed relying on their gut feelings in making decisions, even when it contradicts scientific findings. It is alarming that even college-educated students choose not to rely on a scientific finding when it contradicts their intuition or gut feeling. This finding suggests that whatever effect education may have had in increasing understanding or appreciation of the validity of the scientific method, it is insufficient, highlighting the need for more educational

effort in teaching the scientific method of investigation. Previous research also indicates that unwarranted beliefs persist despite one's education and scientific literacy (Impey, 2013; Walker et al., 2002). Overall, these endorsement rates provide further evidence for the pervasiveness of contaminated mindware across age.

The mean difference in paranormal scores between the two groups was less than 5 points. Considering that this score ranges from 20 to 110 in the adolescent sample and 20 to 119 in the young-adult sample, this mean difference is not substantial. In other words, the 5-point mean difference translates to 0.83 on a six-point Likert-type scale. Further, unwarranted beliefs were not significantly associated with age, with these beliefs being prevalent across age. These results lend more support to the notion that higher education and superior cognitive sophistication, both of which increase with development, do not decrease the prevalence of unwarranted beliefs. Overall, the developmental effects reported in this study are consistent with research reporting weak associations between unwarranted beliefs and age (e.g., Browne et al., 2015; Chiesi et al., 2011; Hartman et al., 2017; Kokis et al., 2002; Lantian et al., 2016; Swami et al., 201; Williams et al., 2007).

The current results and those reported in the literature demonstrate that the level of endorsement of unwarranted beliefs is generally stable across development. However, because contaminated mindware is acquired with age (Stanovich 2009), it might be difficult to detect the effects of cognitive development on the accumulation of contaminated mindware; the two domains may have somewhat negating effects on each other. That is, cognitive ability can possibly attenuate the rate of contaminated mindware accumulation, but because the latter is an acquired domain, one is likely exposed to more contaminated mindware-related content with time, which inevitably leads to some accumulation. Further, it is possible that our samples were

similar in their average level of cognitive development, considering that cognitive biases (as indexed by ontological confusions) did not significantly differ across the two samples. The similarity is particularly possible with a young-adult university sample, like ours, which mainly consists of participants in the lower end of the age range of young adults. However, our data do not address this possibility directly, and future prospective research will be necessary to assess the effect of cognitive development on the accumulation of unwarranted beliefs. Further, it is possible that the young-adult sample may have not been motivated towards higher epistemic rationality, even if they possessed better abilities. Motivation towards epistemic rationality has been found to impact the endorsement of unwarranted beliefs and to mediate the effect of cognitive reflection on such beliefs (Ståhl & van Proojin, 2018). Finally, it is also possible that once unwarranted beliefs are acquired, those beliefs become resistant to falsification by nature, making it difficult to debunk or revise these beliefs. Considering the developmental stability of unwarranted beliefs, it is valuable to study contaminated mindware as early as adolescence. This research should also be applied to education.

This study's most novel contribution was the assessment of measurement invariance of the unwarranted belief scales across adolescence and young adulthood. Establishing the equivalence of these scales provides support for the feasibility of measuring unwarranted beliefs in adolescents. Researchers can be confident that any differences in scores between adolescents and young adults, on any of the three domains of contaminated mindware, result from true differences, rather than measurement artifact. For example, the invariance of the scales suggests that adolescents did not systematically interpret the items differently than did young adults. In conclusion, researchers can use the unwarranted beliefs scales from this study to further examine

belief acquisition across development. In addition, educators can use these scales to assess the effect of specific courses or interventions on belief revision and knowledge development.

Summary of the findings from Study One, Two, and Three

Taken together, we established the multidimensional nature of individual differences in unwarranted beliefs in adolescence as well as young adulthood. The unwarranted beliefs scales were also invariant across adolescent and young-adult samples, meaning that these scales can be used with samples across both developmental periods, allowing for cross-sectional comparisons and prospective research. Further, thinking dispositions and cognitive biases were unique correlates of unwarranted beliefs among adolescents and young adults. The persistence of unwarranted beliefs across age was also demonstrated.

Chapter 5: Discussion

Overall, the hierarchical model of individual differences in unwarranted beliefs with three general factors of paranormal, conspiracy, and anti-science beliefs had optimal fit in the first two studies, showing the multidimensional nature of unwarranted beliefs in adolescents and young adults. Further, similar patterns of associations between the three unwarranted belief domains and individual difference predictors were present in the adolescent and young-adult samples. Specifically, AOT and ontological confusions predicted the endorsement of unwarranted beliefs in both samples. In Study Three, unwarranted belief scales were invariant across the two samples, allowing for meaningful total score comparisons across these developmental periods. Finally, unwarranted beliefs were endorsed to a similar extent in both periods of development, although paranormal belief total score was significantly higher in the adolescent sample than the young-adult sample.

Unwarranted beliefs, including paranormal, conspiracy, and anti-science beliefs, remain prevalent in contemporary and educated societies, contributing to contaminated mindware. Such mindware can be harmful to individual decision-making (e.g., choosing unsubstantiated medical treatments) and the progression of society (e.g., skepticism toward vaccination and climate change). This research project was the first to examine the underlying dimensional structure of individual differences in three types of unwarranted belief domains. Introducing the study of contaminated mindware to adolescence is also imperative from a prevention perspective, so that researchers can understand the developmental trajectories of these beliefs and address them at a critical age before they become more resistant to change.

The dimensional structure of three contaminated mindware domains and a monological belief system

The hierarchical model fit the data well in the adolescent and young-adult samples, which implies that reliable scores can be calculated to reflect individual differences in the three separate, yet related, domains of unwarranted beliefs in adolescents and young-adults. These beliefs share an evaluation-disabling quality that may be integral to their comorbidity (Stanovich, 2009). The three correlated factors of unwarranted beliefs provide evidence that those domains form a network of beliefs characteristic of a self-sustaining worldview through which individuals process information and interact with the world, which is known as a monological belief system. The role of a monological belief system has been discussed within research on conspiracy theories: endorsing one conspiracy theory makes it more likely to endorse others with time (e.g., Brotherton et al., 2013; Swami et al., 2011; Van Prooijen & Jostmann, 2013; Wood et al. 2012). However, this idea has only begun to be discussed with respect to other unwarranted beliefs (Lobato et al., 2014). We have yet to develop and study the self-sustaining nature of such a belief system with reference to domains of contaminated mindware other than the three unwarranted beliefs studied in this dissertation, such as delusional beliefs.

We are all susceptible to being exposed to misinformation and unwarranted beliefs and everyone has likely accumulated some throughout the years. Like anxiety, at certain levels unwarranted beliefs can be healthy, normal, and motivating. But at extreme levels, unwarranted beliefs can become clinically relevant and debilitating, impacting one's daily functioning. Similarly, our reasoning and progress are partly determined by the degree to which we have cultivated a belief system based on unwarranted beliefs. Some of the harms associated with endorsing unwarranted beliefs include a decline in informed decisions and scientific literacy, financial losses due to unvalidated services, and diversion of resources and mental efforts from addressing real or imminent world problems (The National Science Board, 2000). Gleick (2012)

adds to this list the proliferation of racist myths associated with memes based on unwarranted beliefs; these memes can be persistent despite potential damage to the host (i.e., individual and society). Therefore, understanding the factors that contribute to the sustenance and perseverance of those beliefs is important.

Perseverant Beliefs

Researchers have suggested that beliefs exist in interconnected webs which cohere with each other to avoid dissonance or discord (Quine & Ullian, 1970). Our findings support the coherence of beliefs, demonstrating that three unwarranted beliefs are co-endorsed by participants and share some correlates. Cognitive dissonance theory (CDT) posits that humans have a strong preference for consistency (Festinger, 1962), which may help explain the coherence of similar beliefs and their perseverance. To maintain such consistency, people tend to seek evidence and information that confirms their beliefs over information that critiques these beliefs (Connors & Halligan, 2015), suggesting a bias towards confirmatory information (Nickerson, 2008). Through this process, individuals preserve prior beliefs and assimilate new congruent beliefs, contributing to the perpetuation of self-sustaining and stable belief systems. This process can be concerning in the context of unwarranted beliefs. A famous example of people's tendency to confirm their beliefs is the Wason Selection Task, in which participants are asked to turn over cards to verify a specific if-then statement (Johnson-Laird, 1970; Wason, 1968). In that task, participants tend to choose options that confirm the rule rather than options that invalidate or disconfirm it.

People also tend to process ambiguous or unclear information consistently with their existing beliefs. For example, people who endorse paranormal beliefs tend to seek patterns and overinterpret situations to support the paranormal (e.g., Irwin, 2009). Bronner (2016) further

explains that people are more likely to remember lucky situations rather than unlucky ones, confirming and reinforcing their superstitious beliefs and rituals. Overall, biased information processing affects the tenacity and longevity of unwarranted beliefs and attitudes (Kunda, 1990), despite disconfirming evidence (Anderson, Lepper, & Ross, 1980; Carretta & Moreland, 1982). It is also very difficult to use logical arguments and evidence to convince people who endorse unwarranted beliefs otherwise (Boudry & Braeckman, 2012). This difficulty is partly the result of the aforementioned biases that maintain those beliefs as well as inherent structural features that make beliefs immune to systematic investigation (Boudry & Braeckman, 2011).

Yet, recent research suggests that people tend to revise their beliefs upon presentation of congruent and mixed evidence that targets their beliefs (Anglin, 2019). Anglin asserts that people are receptive to evidence and willing to change or revise their beliefs, but also discusses the possibility of her findings not generalizing to other types of beliefs or to more strongly held beliefs. It is important to assess the perseverance of unwarranted beliefs in the face of disconfirming evidence empirically. In addition, we can extend this examination to determine whether individuals at different developmental periods demonstrate greater openness to belief revision than others.

Belief propagation in the age of information virality. This research aims to inform when individuals ought to be critical and reflective of their own beliefs and the information accessible to them. The study of unwarranted and self-sustaining belief systems is particularly important now that media outlets are saturated with information, requiring consumers to be critical in their interpretation and consumption of such information (Halpern, 2014; Tully & Vraga, 2017). People are typically expected to believe information presented in trusted media outlets and on the Internet and it is certainly onerous for individuals to evaluate the evidence for

all information. In reality, attempting to fact-check all beliefs and information one is presented with would be highly debilitating and dysfunctional. Nonetheless, the role of the media and the Internet have been widely implicated in the formation of belief generally (Connors & Halligan, 2015), and unwarranted beliefs specifically (Evans, 1996; Sparks & Pellechia, 1997; Sparks, Nelson, & Campbell, 1997), as well as in the content of meme propagation (Gleick, 2012). Some have even suggested that the overwhelming liberalization of information on the media and the simultaneous disregard of the skill and expertise of the contributors of information will maintain a "democracy of the gullible" (Bronner, 2016). Although our data cannot address such a claim, it seems timely to study individual differences in unwarranted beliefs and how to best measure them across development. In turn, this research project provides a basis for further examining the accumulation of contaminated mindware in an age when individuals are overloaded with information. We live in an "age of virality, with viral education, viral marketing, viral e-mail and video and networking" (Gleick, 2012, p. 316), as well as viral memes. It is unreasonable to control the virality of information at a structural or governmental level, because that would verge on censorship and authoritarianism, which opposes the virtues of democracy. To acknowledge the benefit of information accessibility is important, but to downplay the perils is imprudent. Therefore, it is important that educators, students, and responsible citizens learn informed ways of consuming information. Importantly, it is people's responsibility to recognize and acknowledge their contribution to the virality of information. This age of virality clearly maintains and propagates the beliefs and attitudes that form our culture. Such widespread propagation is particularly enriching in terms of exposure to a diverse perspectives and views, but also challenging for managing the credibility of various sources and types of information and views.

Normativity of contaminated mindware

So far, we have demonstrated and discussed the prevalence of people's exposure to and endorsement of unwarranted beliefs across adolescence and young adulthood. It is relevant to consider the normativity of instances when contemplating or engaging with content relevant to unwarranted beliefs may be harmless. For example, engaging one's imagination in paranormal-like content such as supernatural powers or extraordinary life forms, some of which can be found in fiction, is a normative aspect of development. Specifically, engaging imagination in fiction and fantasy is a normal part of young children's pretend play (Evans & Milanak, 2003). These developmental experiences contribute to children's understanding of social rules without confusing or hindering their understanding of the constituents of reality (Rakoczy, 2008), despite the paranormal-like content present in the form of supernatural phenomena and extraordinary life forms. Exposure to fiction texts in adults also appear to potential benefits, as it is also positively associated with social ability (Mar, Oatley, Hirsh, dela Pazm & Peterson, 2006) and narrative fiction may transmit social knowledge and facilitate social understanding (Mar & Oatley, 2008). For a balanced and accurate understanding of life and truth, some 19th-century philosophers have also pursued and encouraged the unification of imagination and thought (Coleridge & Foakes, 1987; Gorodeisky, 2016). Therefore, it can be harmless and sometimes beneficial to engage in imaginative fantasy, contemplating things outside of the realm of reality.

There are also times when content related to conspiracies turns out to be justified based on specific circumstance. That is, some conspiracy theories turn out to be true, and although evidence at the time of the theory's initiation would have been insufficient to support its validity, new information can substantiate the theory. It is certainly warranted for citizens to be critical and suspicious of existing covert plots or conspiratorial politics, but these suspicions should be

differentiated from a more deterministic feature of conspiracy belief and ideation that may interfere with one's judgement. In the latter, an individual only sees conspiracies across situations and time and is not open to alternatives. It is reasonable for individuals to show healthy inquisitiveness where one challenges the status quo or a scientific finding. People also regularly question a government decision or policy put forward due to possible negative repercussions or harm to society and in specific circumstances, conspiracy theories may motivate one to challenge social hierarchies (Sapountzis & Condor, 2010). Historical and societal oppression and discrimination can also lead to the perpetuation of conspiracy beliefs, which may justify individuals' current mistrust of authority. However, in certain cases conspiracy belief or ideation can harm the individual, leading to increased risky health behaviours (e.g., contraception-related conspiracies; Bogart & Thorburn, 2006; Thorburn & Bogart, 2005).

Such circumstances present some examples of when specific beliefs or information warrant contemplation, despite a lack of available evidence. Nonetheless, it is important to separate beliefs that lack necessary support when trying to reason about the real world, particularly when interacting with multiple sources of information. Especially important is recognizing that multiple sources of information can be correct, that people can have multiple interpretations of the same situation, and that some views or perspectives might have more epistemic merit or scientific evidence than others (Hallett et al., 2002; Muis et al., 2006). There are also reasons to evaluate whether certain ideas are suspicious and harmful if adopted. Individuals should be suspicious of mindware that resists evaluation and falsification (Stanovich, 2009). Stanovich warns against mindware that is self-reinforcing and has costs that are too excessive to allow for its examination (e.g., life threatening) and mindware that by default restricts a person's options for future goal pursuit or plans (e.g. joining a cult). Further research

is required to explicate the situations where it is normal and unharmful to engage beliefs that lack sufficient evidence, particularly in relation to the function of these beliefs.

Measurement of individual differences in unwarranted beliefs

We have made several advances in the measurement of paranormal, conspiracy, and anti-science beliefs and attitudes in adolescence and young adulthood. Like most constructs in psychology, unwarranted beliefs are not directly observable. Therefore, we utilized questionnaire items that were designed to measure individual differences in the three unwarranted belief domains. Observed scores based on such questionnaires typically have a degree of measurement error and, when relied upon, can lead to biased approximations of the associations among the constructs of interest (Westfall & Yarkoni, 2016). To more accurately assess these three unwarranted belief domains, we first used confirmatory factor analysis to test the underlying structure of the beliefs driving individual differences in the endorsement of the items in our questionnaires. These measurement models are optimal because they represent the associations between constructs free of measurement error and the respective questionnaire items designed to measure them (Flora, 2017). In turn, these models show how well the items represent or assess the constructs of interest. Further, we assessed the reliability of the scale scores implied by these factors, which reflects the extent to which score variance is due to the construct of interest (McDonald, 1999). It is fundamental to the progress of psychological science to examine the internal structure of questionnaires and the reliability of their scores in order to ensure accurate conclusions (Flake, Pek, & Hehman, 2017). The associations reported in the literature among unwarranted beliefs have not accounted for measurement error, but been limited to identifying bivariate associations among observed variables. Further, the scales measuring aspects of contaminated mindware in the literature have also been designed separately in young adulthood

and adolescence. Research has not assessed whether the measures yield scores that validly represent individual differences in the constructs of interest similarly in those two periods of development.

The results from this dissertation allow several conclusions regarding the measurement of individual differences in unwarranted beliefs: 1) Paranormal, conspiracy, and anti-science beliefs and attitudes are separable constructs that should be measured using separate scales; 2) constructs of paranormal, conspiracy, and anti-science beliefs are positively associated; 3) the paranormal, conspiracy, and anti-science beliefs and attitudes scores represent reliable variance in their respective domains in both adolescents and young-adults; and 4) scores on the paranormal, conspiracy, and anti-science beliefs and attitudes scales measure these beliefs equivalently across adolescence and young adulthood. Taken together, this research confirms that individual differences in these domains are measurable in adolescence and young adulthood.

We also examined individual differences in thinking and reasoning to complement the measurement of unwarranted beliefs and to identify factors associated with a susceptibility to endorsing these beliefs. Specifically, we examined the association with cognitive ability, cognitive reflection, AOT, and ontological confusions in adolescence and young adulthood. We also conducted a cross-sectional comparison of belief endorsement across adolescents and young adults.

Common correlates of contaminated mindware in young adulthood and adolescence

As can be seen in Studies One and Two, there were similar patterns of associations in adolescents and young adults between unwarranted beliefs and indices of cognitive ability, cognitive reflection, academic achievement, AOT, and ontological confusions. The associations among unwarranted belief domains were stronger in the adolescent sample (inter-factor

correlations ranged between .52 and .59) than in the young-adult sample (inter-factor correlations ranged from .34 to .43). In the adolescent sample, ontological confusions and AOT had associations with the three unwarranted beliefs, above and beyond cognitive ability and cognitive reflection. In the young-adult sample, similar patterns were present, although AOT did not have a significant unique association with conspiracy beliefs. Further, the standardized regression coefficients between ontological confusions and all three unwarranted belief domains were stronger in the adolescent sample than in the young-adult sample. It is possible that these variables have a greater impact on unwarranted beliefs earlier in development, at which point the beliefs' structure is in part self-sustaining, ensuring its persistence.

In the structural equation models, residual associations among the three unwarranted beliefs were statistically significant in both samples, and again to a greater extent in the adolescent sample than in the young-adult sample. Further, age was not correlated with individual differences in unwarranted beliefs in the merged sample, in which participants had an age range of 12 to 30 years. Level of education (i.e., secondary school students versus undergraduate university students) and development (i.e., adolescents versus young adults) also were not statistically significantly associated with individual differences in conspiracy and anti-science beliefs and attitudes, and only weakly associated with paranormal beliefs. These results are consistent with studies in which education and development have little effect on belief vitality (e.g., Bronner, 2016; Walker et al., 2002) and further speak to the longevity and perseverance of beliefs (Kunda, 1990). However, knowledge and epistemic rationality can still improve with age and education despite the perseverance of unwarranted beliefs. Notably, unwarranted beliefs and epistemically warranted beliefs, as well as knowledge, are not mutually exclusive and can be accumulated in conjunction (Shtulman & Harrington, 2015). Importantly,

we identified two unique correlates of unwarranted beliefs across two periods of development, namely ontological confusions and AOT.

Ontological confusions, actively open-minded thinking, and individual differences in contaminated mindware. We found that individuals with a disposition to think and process information that confirms their beliefs, overlooking alternative conclusions, are more likely to endorse paranormal and anti-science beliefs in young adulthood as well as conspiracy beliefs in adolescence. Furthermore, some unwarranted beliefs might represent an ontologically-confused understanding of the world, including paranormal beliefs (Lindeman, Cederstrom, Simola, Simula, Ollikainen, & Riekki, 2008), conspiracy beliefs (Brotherton and French, 2015; Lobato et al., 2014), and belief in alternative and complementary medicine (Lindeman, 2011; Lindeman & Saher, 2007; Svedholm & Lindeman, 2013b). Here we support such a conclusion and extend it to include generic anti-science beliefs and attitudes. Ontological confusions represent category mistakes when ascribing properties of the mental, physical, and biological worlds, as well as when differentiating the intentionality of the animate from inanimate and the properties of the living and lifeless (Lindeman et al., 2015). Specifically, anti-science beliefs represent a preference for intuition and gut feelings over scientific method, where one might attribute human motivation or intentionality to inanimate beings, such as physical or biological processes. These ontological domains should be clearly distinguished when reasoning about the real world and when one is required to evaluate what may be true of the world.

Taken together, these findings suggest that one should invest in thinking dispositions that promote critical thinking, belief revision, and ontological understanding to reduce the propagation of contaminated mindware. Educators can help individuals become more vigilant to ontological mistakes in information when teaching about the scientific method and the

importance of evaluating evidence when learning new information. Adding specific instruction in educational curricula at younger ages should help students develop the skills needed to differentiate aspects of reality and avoid ontological mistakes and biases (Douglas et al., 2016; Lobato et al., 2014). Instruction should also help instil a thinking disposition that allows for beliefs to be revised as well as a desire to seek and hold true beliefs about the world (Stanovich, 2009).

It is important to note, however, that even teachers demonstrate endorsement of the same unwarranted beliefs that our research proposes to mitigate (e.g., Mikuskova, 2018; Yates & Chandler, 2000). Teachers also partly disseminate aspects of unwarranted belief (Eve & Dunn, 1990). Therefore, direct instruction regarding ontology and intuitive ontological mistakes should begin with teachers in training, considering that teachers are one of the most influential sources of information for children and adolescents. If teachers partly serve as sources of unwarranted belief, it can explain why schooling and development have little effect on students' endorsement of unwarranted beliefs. Nonetheless, there is clearly more to the endorsement of unwarranted beliefs than the role of educators or teachers, especially considering the aforementioned correlates as well as the nature of belief formation and persistence. Therefore, these factors should all be considered in conjunction for a better understanding of the propagation of unwarranted beliefs across development.

Limitations and future directions

Despite the strengths and important contributions of the current research project, there are some limitations and future research directions to be considered.

Sample characteristics and diversity of education level. This research was limited to a young-adult university sample, which might not generalize to the general young-adult population

with a variety of education levels. Although our young-adult university sample had an age range of 18 to 30, most of the participants were between 18 and 22, potentially not capturing all the characteristics of the young-adult population. For instance, obtaining a sample of individuals with a graduate-level education might yield less endorsement of unwarranted belief. One study demonstrated that a higher level of education, such as that of professors, is associated with higher skepticism and lower endorsement of paranormal beliefs compared to students, with students showing greater skepticism than the general population (Genovese, 2005). Nonetheless, there is more research suggesting that the level of endorsement of unwarranted beliefs does not change between secondary school and university (e.g., Kokis et al., 2002; Lindeman, 2018; Impey 2013; Walker et al., 2002). In addition, it will be informative to include samples with distinct characteristics, such as educational field of study.

Online data collection and level of engagement. Participants in our research completed both studies online. Ample research in the social, behavioural, and health sciences uses web-based surveys and online research platforms for participant recruitment, including children, adolescents, young adults and adults (e.g., Blumenberg & Barros, 2016; McCabe, Boyd, Young, & Crawford, 2004). Research has found that online data collection methods yield similar results as paper and pencil administration (Casler, Bickel, & Hackett, 2013; Weigold, Weigold, & Russell, 2013). In addition, based on national and sample-level research, adolescents in North America between the ages of 12 and 17 are frequent and adept users of technology and the computer (Greenhow, Walker, & Kim, 2009; Lenhart, 2012; Li, Snow, & White, 2015). Therefore, we did not anticipate any problems with adolescents navigating the online study and working on a computer or tablet. Taken together, along with our validity checks throughout the studies, we are confident that online methods are valid for data collection. Specifically, online

data collection allows researchers to access participants in remote areas as well as obtain larger and more diverse samples than other methods.

However, online data collection might have negatively affected participants' engagement in the study, particularly for the performance-based measures employed. Based on the low scores for our performance-based measures and likely floor effects for these scores in the adolescent sample, it seems that some of our measures were too difficult for some participants. Specifically, although the ICAR-5 was used with secondary school students, it has shown floor effects with the younger grades (Kirkegaard & Bjerrekaer, 2016). We used the ICAR-5 because of its concision and public accessibility, which made it suitable for our time constraints and online data collection. However, in future research with adolescents, one might reconsider alternatives to the ICAR-5. Participants may also have been unmotivated in these online studies without researcher supervision, and this should be considered when designing future studies.

Additionally, the questionnaire presentation was fixed for both samples, alternating between performance-based measures and rating scales. We recognize that random presentation might have been a more ideal study design. Future projects should consider counterbalancing the presentation or using completely randomized presentation.

Measurement modality. It is notable that the AOT, OCS, and unwarranted beliefs scales shared measurement modality (i.e., rating scales), whereas cognitive reflection and the cognitive ability measures were performance-based. In particular, if there were floor effects on performance-based measures, then there was reduced variability in scores on those measures, possibly impacting their associations with rating scales. Further, the shared measurement modality might have inflated associations among the AOT, OCS, and the unwarranted beliefs scales. Where possible, future research can benefit from incorporating behavioural and

performance-based measures when assessing unwarranted beliefs. For example, some research uses laboratory simulations where the effect of introducing a superstitious ritual on reasoning and decision-making is assessed (e.g., Furlan, Agnoli, & Reyna, 2013). Finally, we discussed our results in the context of a monological belief system but did not directly measure it. Future work should directly assess individual differences in possessing a monological belief system and its effects.

Future directions. This research focused on individual differences in several domains of rational thinking, including System 2 processes and dispositions. It will be valuable for future studies to include other variables that may contribute to the endorsement of unwarranted beliefs. Variables such as need for control, tolerance for uncertainty, Big Five personality traits, and jumping to conclusions, which have all been associated with unwarranted beliefs (e.g., Hogg, Adelman, & Blagg, 2010; Moulding et al., 2016; Pennycook et al., 2015; Swami et al., 2011; Van Prooijen & Acker, 2015). Isolating the effects of such variables from those examined herein can provide a more fulsome understanding of the factors contributing to individual differences in unwarranted beliefs. It will also isolate situational factors (e.g., uncertainty) from individual differences and allow us to assess the interaction between them. Further, it may be worthwhile to develop generic paranormal items that are context-independent, representing general paranormal ideation, similar to the items used to measure generic conspiracy and anti-science beliefs and attitudes.

Aspects of unwarranted beliefs, particularly conspiracy and paranormal beliefs, have been associated with pathological beliefs, such as paranoid, schizotypal, and delusional beliefs and ideation (e.g., Barron, Furnham, Weis, Morgam, Towell, & Swami, 2018; Cella, Vellante, & Preti, 2012; Darwin et al., 2011; Hergovich, Schott, & Arendasy, 2008; van der Tempel &

Alcock, 2015). Delusional ideation has also been hypothesized to result from an individual's intolerance of uncertainty in the face of paranormal-like experiences or beliefs (Houran & Lang, 2004). Further, individuals with greater delusional ideation show greater endorsement of conspiracy beliefs, which is partly explained by a reduced tendency to possess an analytic or reflective disposition (Barron et al., 2018). Unwarranted beliefs are not conceptualized as indicators of psychopathology or pathological belief. Nonetheless, they share similar cognitive and information processing biases (e.g., Cella et al., 2018; Houran and Lange, 2004; Irwin, Dagnall, & Drinkwater, 2012; Lawrence & Peters, 2004). Unwarranted beliefs show positive associations with pathological belief and schizotypy, which is a prodromal stage to schizophrenia (Hergovich, Schott, & Arendsay, 2008). Extending the study of unwarranted beliefs to samples with schizophrenia is particularly relevant because individuals with schizophrenia present with paranoid and delusional beliefs and are often mistrustful (Warman & Beck, 2003). In the Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition (DSM–5), schizotypy or schizotypal personality disorder includes paranormal, suspicious, and paranoid ideation in its defining criteria (American Psychiatric Association, 2013). Therefore, it would be informative for an enhanced clinical conceptualization of pathological beliefs to further study the association between unwarranted beliefs and psychopathology. In addition, extending the study of the impact of unwarranted beliefs on the maintenance or formation of pathological belief could aid in earlier identification and intervention. In particular, the assessment of unwarranted beliefs such as paranormal and conspiracy beliefs, which share features with schizotypy, might serve to identify normative levels from clinically relevant levels indicating proneness to schizophrenia. It is noteworthy that schizotypy emerges in childhood and adolescence and schizophrenia typically emerges in late adolescence and young adulthood (American Psychiatric Association, 2013). The

age of onset of these clinical disorders highlights the relevance of measuring unwarranted beliefs early in development rather than later.

Finally, although this was the first cross-sectional investigation of differences in unwarranted beliefs, longitudinal or prospective designs will enable us to assess the trajectory of unwarranted beliefs. With the strong psychometric properties of the scales developed in this research, future work can use these scales in prospective designs to provide a more comprehensive representation of developmental change for unwarranted beliefs. Further, prospective designs can also more accurately uncover the mechanisms of change in endorsement of unwarranted beliefs across development.

Conclusion

Overall, the nature of belief remains understudied compared to other cognitive processes, partly because of its structural complexity and the multitude of factors that impact it as well as a lack of consensus on what constitutes a belief (Connor & Halligan, 2015). This was the first to study the dimensional structure of individual differences in three unwarranted belief domains, supporting a hierarchical model in both adolescent and young-adult samples. Ontological confusions and AOT were uniquely associated with the endorsement of unwarranted beliefs, holding constant one's level of cognitive ability and cognitive reflection capacity. The consistency of unwarranted beliefs across the two samples speaks to the early and resistant nature of those beliefs and the need for research and educational intervention at earlier periods of development. These findings inform psychological research on the nature of belief and individual differences in rational thinking, which can also inform educational research. The current results point to further examination of the consequences of unwarranted beliefs on society and should be considered in the development of science curricula that can help students

identify and assess ontological confusions. In this research, we focused on developing and utilizing appropriate measurement scales for assessing unwarranted beliefs as well as examining individual-difference predictors of these beliefs. We employed a cognitive-developmental approach to studying three domains of contaminated mindware along with their correlates and predictors. This research program can be developed further to incorporate interactive factors at the interpersonal, social, and environmental levels as well as extend it to the study of pathological belief formation. With the tools we offer in this research project, it can be possible to pursue those research avenues across developmental periods.

In conclusion, this research has implications for science, literacy, reasoning, and rational thinking. We hope to have instilled and highlighted the importance of upholding a critical perspective, flexible learning and unlearning, and warranted and substantiated beliefs in an age of information virality. We would be remiss, however, to end the discussion without acknowledging that a little bit of magic never hurts.

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Appendix A. Contaminated Mindware Questionnaire Items used in Study One and Two

Rating scale
1 = strongly disagree, 2 = moderately disagree, 3 = disagree, 4 = agree, 5 = moderately agree, 6 = strongly agree

Scoring
Higher scores indicate higher endorsements of contaminated mindware beliefs
(R) indicates items need to be reverse scored

Paranormal

Psi
1. Some people can lift objects using the power from their minds
2. The movements of objects through mental powers is impossible (R)
3. A person's thoughts can influence the movement of a physical object
4. Mind reading is not possible (R)

Witchcraft
5. Black magic can be used for evil and selfish purposes
6. Witches really exist and practice their magical powers in certain parts of the world
7. Actual cases of witchcraft have been documented in some parts of the world
8. It is impossible to cast spells on persons using magic charms or hexes (R)

Superstition
9. Black cats can bring bad luck
10. If you break a mirror, you will have bad luck
11. Some numbers are unlucky
12. Bad things happen when you step on a crack on the pavement
13. Bringing lucky mascots or lucky charms are effective at sporting events
14. You can prevent something bad from happening by *just* touching wood
15. Certain objects, such as rabbit's feet and four-leafed clovers, are known to bring good luck
16. Some numbers and dates are more lucky or unlucky than others

Spiritualism
17. Your mind or soul can leave your body and travel (astral projection)
18. During altered states, such as sleep or trances, the spirit can leave the body
19. Reincarnation does occur
20. It is possible to communicate with the dead
21. Dead people can communicate with living people through séances or Oijua boards
22. Certain types of crystals have special powers
23. Astrology is a valid explanation for the behaviors and personality of people
24. A full moon causes people to behave oddly

Precognition
25. Astrology is a way to accurately predict the future
26. Horoscopes accurately predict the future
27. Some psychics can accurately predict the future
28. Some people have an unexplained ability to predict the future

29. Some people have a “sixth sense” that allows them to accurately predict the future

Contemporary fiction

30. Zombies can really be found in graveyards after midnight.
31. Werewolves are real living people during the daytime.
32. Mermaids really live in the ocean, near the South Pacific.
33. There are historical documents showing that fire breathing dragons really existed.
34. Hobbits really exist.

Other paranormal beliefs

35. Extraterrestrial life forms have visited Earth and abducted human beings

Conspiracy

1. The government is secretly involved in the murder of innocent citizens.
2. Secret organizations communicate with aliens from space
3. The spread of certain diseases is secretly caused by certain organizations
4. The government hides information and facts to trick the public
5. A secret organization is responsible for making all major world decisions, such as going to war
6. Evidence of alien contact is being hidden from the public
7. Technology can be used for mind control
8. The government blames other people to hide its criminal activity
9. A small secret group of people control world events
10. The government routinely tries new drugs on people without them knowing
11. Scientists routinely hide important information from the public to protect their jobs
12. Most sports competitions are rigged, that is, winners are chosen before the competition

Anti-science

1. When science and common sense disagree, science is usually correct (R)
2. I tend to rely on my gut feeling even when it contradicts a scientific finding
3. Science helps us figure out what is true about the world (R)
4. When my mind and gut disagree, I tend to go with my gut when making decisions
5. Evidence from science is usually biased or wrong
6. Scientific understanding gets better over the years (R)
7. Because scientists disagree with each other, this shows that science is about the personal opinions of scientists more than actual evidence
8. Your gut feeling is always the best guide in making decisions
9. I don't rely on “scientific facts”, because scientific facts can be used to prove almost anything
10. The scientific method of measuring observable events in the world has led to important knowledge (R)

Appendix B. Ontological Confusions Scale used in Study One and Two

Rating scale
literally true = 1, not literally true = 0

Natural, lifeless objects are living
1. Stars live in the sky
2. Stones live in the forest
3. A rock lives long
4. Water lives in nature
5. The moon lives at night

Force is living and animate
6. Force lives in the universe
7. Force senses a human
8. Force wants to move
9. Force aims to influence
10. Force knows its direction

Lifeless objects are animate
11. The sun can see a long way
12. The moon aims to move forward
13. Stones sense the cold
14. Planets know things
15. Earth wants water

Living inanimate entities are animate
16. Trees aim to move upwards
17. Trees sense the wind
18. Flowers want light
19. Flowers feel the cold in autumn
20. Plants know the seasons

Artificial objects are animate
21. A home knows its residents
22. A home misses people
23. Furniture wants a home
24. A house senses its environment
25. A house knows its history

Mental states are material objects
26. Grief moves in the stomach
27. A mind touches another
28. A thought grows by concentrating
29. A mind breaks when it is ill
30. A plan lives in nature

Appendix C. Actively Open-minded Thinking Scale used in Study One

Rating scale
1 = strongly disagree, 2 = moderately disagree, 3 = disagree, 4 = agree, 5 = moderately agree, 6 = strongly agree

Scoring
Higher scores indicate higher endorsements of contaminated mindware beliefs
(R) indicates items need to be reverse scored

1. Changing your mind is a sign of weakness. (R)
2. What beliefs you hold have more to do with your own personal character than the experiences that may have given rise to them. (R)
3. If a belief suits me then I am comfortable, it really doesn't matter if the belief is true. (R)
4. A person should always consider new possibilities.
5. It is a noble thing when someone holds the same beliefs as their parents. (R)
6. My beliefs would not have been very different if I had been raised by a different set of parents. (R)
7. One should disregard evidence that conflicts with your established beliefs. (R)
8. If I think longer about a problem I will be more likely to solve it.
9. Someone who attacks my beliefs is not insulting me personally.
10. Basically, I know everything I need to know about the important things in life. (R)
11. Even if my environment (family, neighborhood, schools) had been different, I probably would have the same religious views. (R)
12. Considering too many different opinions often leads to bad decisions. (R)
13. It is important to persevere in your beliefs even when evidence is brought to bear against them. (R)
14. People should always take into consideration evidence that goes against their beliefs.
15. Difficulties can usually be overcome by thinking about the problem, rather than through waiting for good fortune.
16. Certain beliefs are just too important to abandon no matter how good a case can be made against them. (R)
17. I think I would vote more intelligently if I had more knowledge of social and political issues.
18. There is nothing wrong with being undecided about many issues.
19. Abandoning a previous belief is a sign of strong character.
20. When reading a book on history I like knowing that I am reading something that actually happened.
21. Coming to decisions quickly is a sign of wisdom. (R)
22. Beliefs should always be revised in response to new information or evidence.
23. People who hold contradictory ideas without being bothered at all by it really frustrate me.
24. It makes me happy and proud when someone famous holds the same beliefs that I do. (R)
25. It doesn't really matter if I get some facts wrong because the facts are always changing anyway. (R)
26. I like to gather many different types of evidence before I decide what to do.
27. I don't feel I have to have reasons for what I do. (R)
28. I like to think that my actions are motivated by sound reasons.

29. I like to have reasons for what I do.
30. I don't like to have to justify my actions. (R)

Appendix D. Cognitive Reflection Test used in Study One

1. A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost? ____ cents
   correct answer = 5 cents, intuitive answer = 10 cents
2. If it takes 5 machines 5 min to make 5 widgets, how long would it take 100 machines to make 100 widgets? ____ min
   Correct answer = 5 minutes, intuitive answer = 100 minutes
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ____ days
   Correct answer = 47 days, intuitive answer = 24 days
4. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together? (In days)
   Correct answer = 4 days, intuitive answer = 3 days
5. Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class? (In students)
   Correct answer = 29 students, intuitive answer = 30 students
6. A man buys a pig for $60, sells it for $70, buys it back for $80, and sells it finally for $90. How much has he made? (In dollars)
   Correct answer = 20, intuitive answer = 30 or 10
7. Simon decided to invest $8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has: a) broken even in the stock market, b) is ahead of where he began, c) has lost money
   Correct answer = c, intuitive answer = b

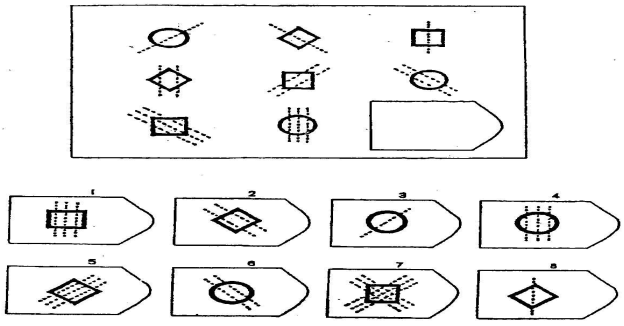
Appendix E. Raven's Progressive Matrices Nonverbal Reasoning Measure Used in Study One

Instructions

Below is an example of a spatial matrix problem. In the top box is a pattern with a piece missing. Your task is to choose from the eight alternative pieces below the box and identify the correct one that completes the pattern at the top.

Take a look at this example and see how it can be solved. First, you can see that each of the top two rows contains one circle, one square, and one diamond shape. Since the last row already contains a square and a circle, the missing piece must have a diamond shape. Thus, the answer must be either #2, #5, or #8. Looking further, you can see that the pieces in the top row have one line going through them, the pieces in the middle row have two lines going through them, and the pieces in the bottom row have three lines gong through them. Therefore, since you have eliminated all alternatives except #2, #5, and #8, the answer must be #5. You can check this by noting that in each row the lines are vertical in one piece, slanted to the left in one piece, and slanted to the right in another. You can confirm that #5 is the correct example by noting that its lines are slanted in the correct direction.

Study the example below. Ask the experimenter for help if you do not understand why #5 is the correct answer.



The experimenter will give you the rest of the matrix problems. Please raise your hand to let the experimenter know that you are ready for this part of the study. There are 18 problems in all. The problems will get harder and harder as you go along, but the task is always the same, to pick the piece that you think best fits the pattern. No one should expect to solve all the problems, because some of them are very difficult and you will be working under a time limit. Just try to do as well as you can. <u>You will have fifteen minutes to complete the 18 problems, so do not spend all of your time on one that you cannot answer.</u> If you run out of time, please do NOT simply guess at problems you have not yet looked at. Write your responses to the problems in the spaces provided below.

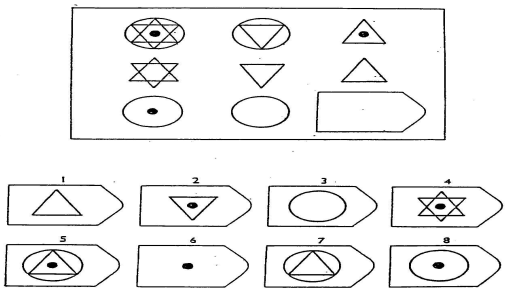
Answer Key:

Practice. 5

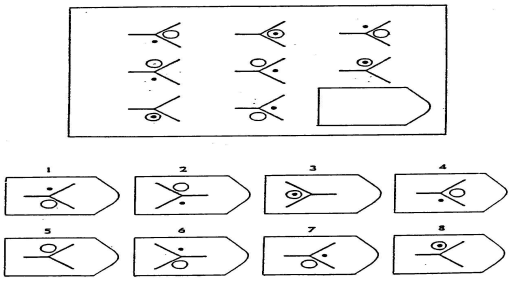
1. 6
2. 1
3. 2

4. 4
5. 6
6. 7
7. 3
8. 8
9. 8
10. 7
11. 6
12. 3
13. 7
14. 2
15. 7
16. 5
17. 6
18. 5

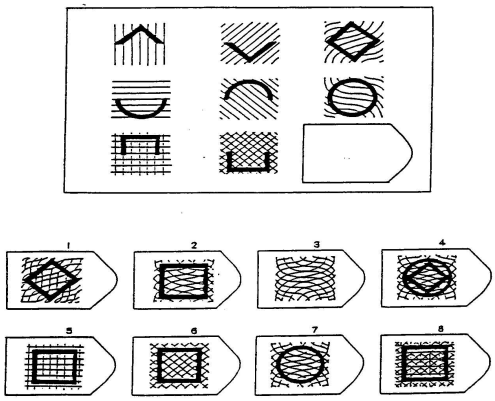
Problem #1



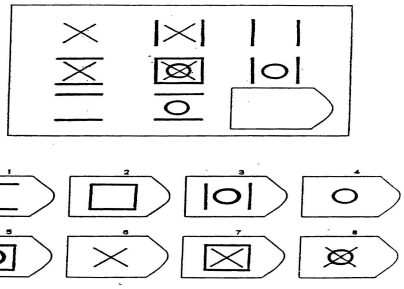
Problem #2



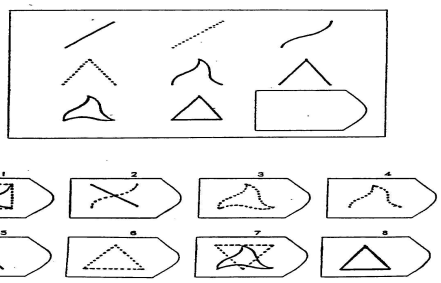
Problem #3



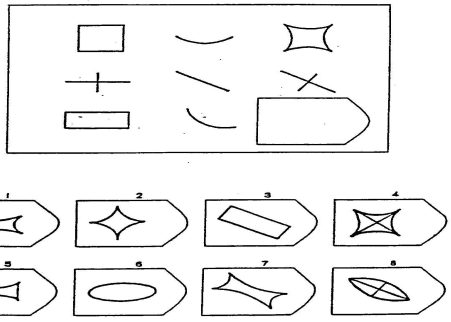
Problem #4



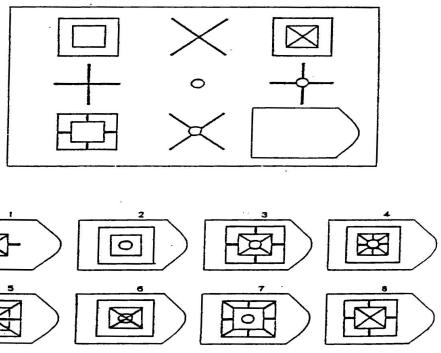
Problem #5



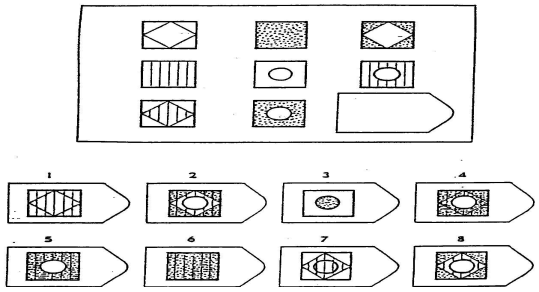
Problem #6



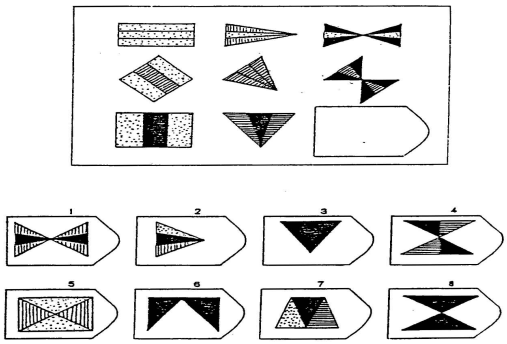
Problem #7



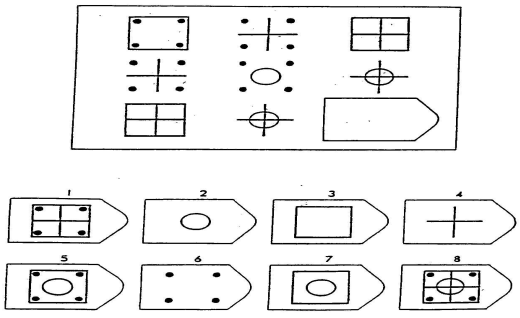
Problem #8



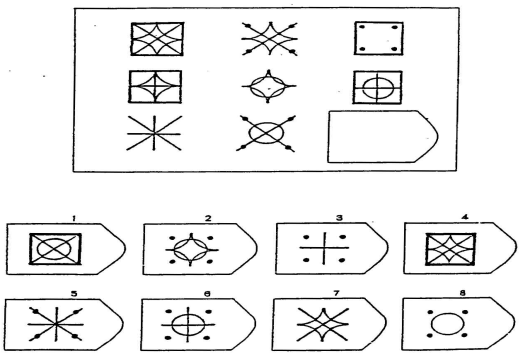
Problem #9



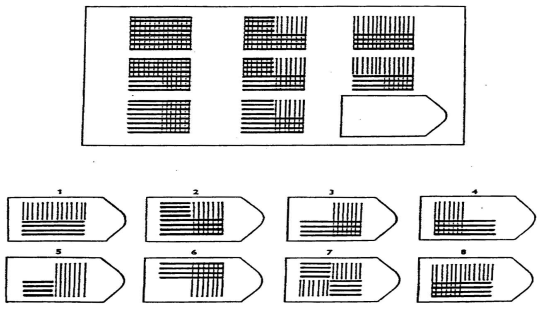
Problem #10



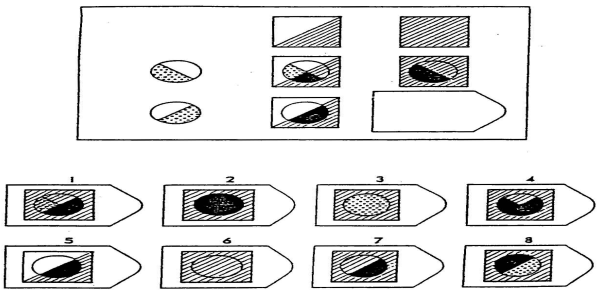
Problem #11



Problem #12



Problem #13



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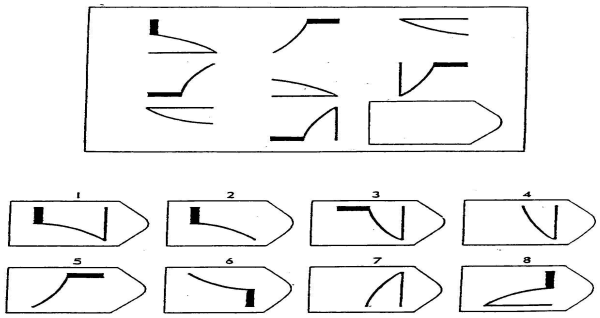

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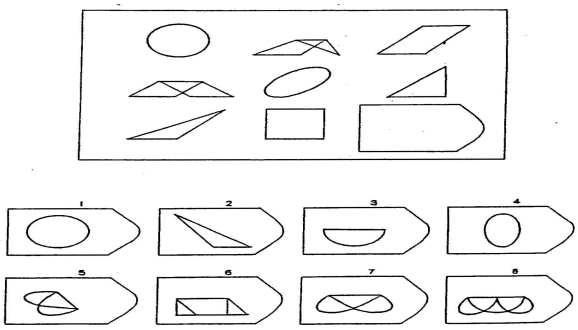

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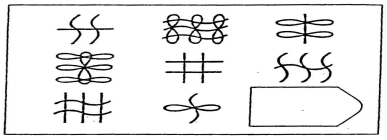

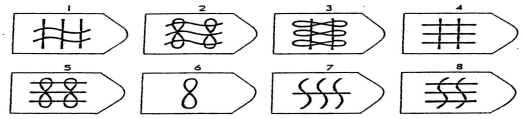

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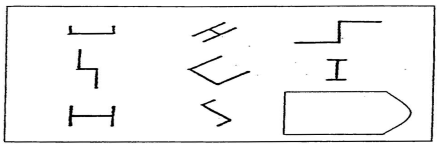

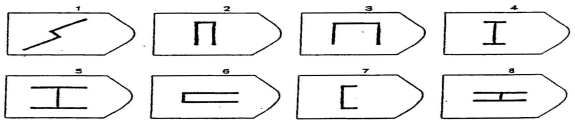

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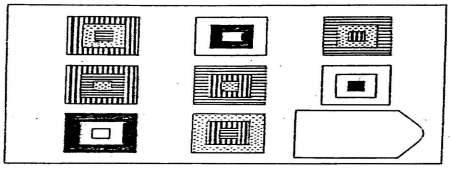
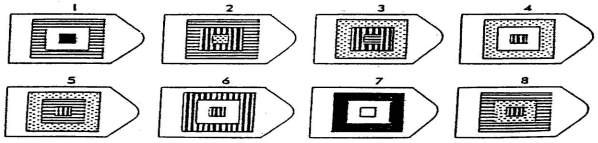




Appendix F. Vocabulary Reasoning Measure used in Study One

Instructions
Below you will see a list of 60 letter strings. Some of the strings are actual words and some are not. You are to read through the list of items and indicate whether or not you think the letter string is a word by putting a check mark next to those that you know to be words. Do not guess, but only check those who you know to be words.
***Foils are bolded (there are 40 real words and 20 foils/nonwords)**

Scoring
Sum correct number of words checked off, and subtract off number of foils checked

1. absolution _____
2. **arrate** _____
3. asinine _____
4. audible _____
5. **ceiloplaty** _____
6. clandestine _____
7. **comectial** _____
8. concurrent _____
9. confluence _____
10. connote _____
11. denotation _____
12. denouement _____
13. disconcert _____
14. **disler** _____
15. **dropant** _____
16. epicurean _____
17. eventuate _____
18. **fusigenic** _____
19. gustation _____
20. heuristic _____
21. **hyplexion** _____
22. **ineffity** _____
23. inflect _____
24. inundate _____
25. irksome _____
26. lacuna _____
27. languor _____
28. laudatory _____
29. litany _____
30. **metenetion** _____
31. **neotatin** _____
32. niche _____
33. **nonquasity** _____
34. nuance _____
35. nitrous _____
36. optimize _____
37. **plabage** _____
38. polarity _____
39. **potomite** _____
40. purview _____
41. recidivism _____
42. reportage _____
43. reverent _____
44. **rochead** _____
45. **seblement** _____
46. **sheal** _____
47. **sparkhouse** _____
48. stratagem _____
49. subjugate _____
50. substratum _____
51. suffuse _____
52. tenacious _____
53. **tradured** _____
54. **tumcier** _____
55. ubiquitous _____
56. unction _____
57. **unmanal** _____
58. wanderlust _____
59. waterfowl _____
60. xenophobia _____

Appendix G. Cognitive Reflection Test used in Study Two

1. A shirt and a pair of socks cost $120 in total. The shirt costs $100 more than the socks. How much do the socks cost?
   Correct answer = 10, intuitive answer = 20
2. A class of students was lined up in a single-file line. Jerry was the 10th student from the front and the 10th from the back of the line. How many students were lined up?
   Correct answer = 19, intuitive answer = 20
3. The number of bacteria in a container doubles each hour. If it takes 32 hours to completely fill the container, how many hours would it take for the bacteria to fill half of the container?
   Correct answer = 31, intuitive answer = 16
4. If it takes one minute to make each cut, how long will it take to cut a 25-foot wooden plank into 25 equal pieces?
   Correct answer = 24, intuitive answer = 25
5. If a town has 3 girls for every 4 boys, what fraction of the children are girls?
   Correct answer = 3/7 or 3 seventh, intuitive answer = 3/4
6. If it takes 5 carpenters 5 seconds to hammer in 5 nails, how long would it take 100 carpenters to hammer in 100 nails (in seconds)?
   Correct answer = 5, intuitive answer = 100
7. A snail starts at the bottom of a well that is 16 feet deep. He crawls up 4 feet each day, but each night he slips back 3 feet. How long will it take the snail to reach the top of the well?
   17 days, 16 days (intuitive answer), 15 days (intuitive answer), 14 days, 13 days (correct answer)
8. The number of dandelions in a lawn doubled each year. If the lawn started out with a single dandelion in the first year and became completely covered by dandelions at 10 years, when was the lawn half covered with dandelions (in years)?
   Correct answer = 9, intuitive answer = 5
9. You can get a combo of a hamburger and french fries for $12. The hamburger costs $10 more than the french fries. How much do the french fries cost (in dollars)?
   Correct answer = 1, intuitive answer = 2
10. A farmer has a barn that is 100 metres wide. He would like to divide it into10 stalls that are each 10 metres wide. How many walls separating the stalls will he need to build?
    Correct answer = 9, intuitive answer = 10
11. Lisa was in a cross country race. She finished the race with both the 35st fastest and 25st slowest time. How many students were in the race?
    Correct answer = 59, intuitive answer = 60

Appendix H. Actively Open-minded Thinking Scale used in Study Two

Rating scale
1 = strongly disagree, 2 = moderately disagree, 3 = disagree, 4 = agree, 5 = moderately agree, 6 = strongly agree

Scoring
Higher scores indicate higher endorsements of contaminated mindware beliefs
(R) indicates items need to be reverse scored

1. Changing your mind is a sign of weakness. (R)
2. A person should always consider new possibilities.
3. If I think longer about a problem I will be more likely to solve it.
4. Basically, I know everything I need to know about the important things in life. (R)
5. Considering too many different opinions often leads to bad decisions. (R)
6. Solutions to problems usually happen by thinking about them, rather than by waiting for good luck.
7. It's OK to be undecided about some things.
8. It’s bad to change how you think about something. (R)
9. Coming to decisions quickly is a sign of wisdom. (R)
10. It doesn’t really matter if I get some facts wrong because the facts are always changing anyway. (R)
11. I like to gather many different types of information or evidence before I decide what to do.
12. I don't feel I have to have reasons for what I do. (R)

Appendix I. 5-item International Cognitive Achievement Resource used as a cognitive ability index in Study Two

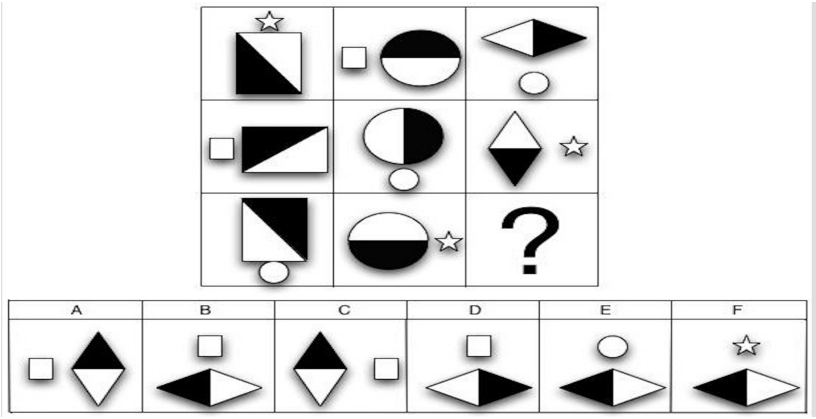
Instructions: Answer the following five questions to the best of your ability.

1. What number is one fifth of one fourth of one ninth of 900?
   2, 3, 4, 5 (correct answer), 6, 7, None of these

2. If the day after tomorrow is two days before Thursday then what day is it today?
   Friday, Monday, Wednesday, Saturday, Tuesday, Sunday (correct answer), None of these

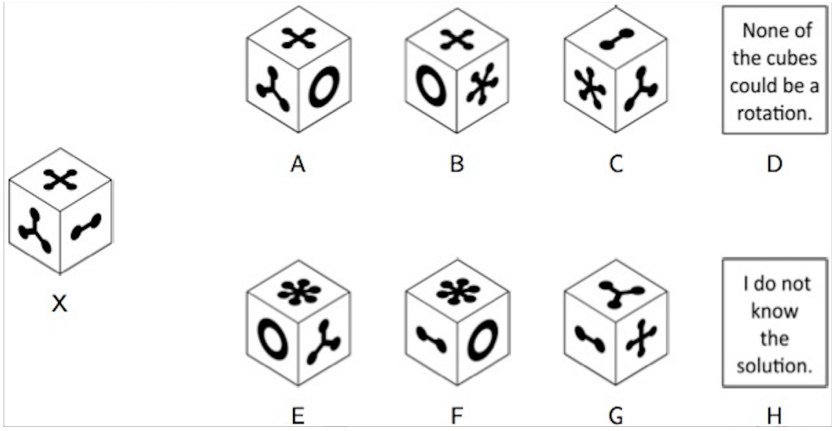
3. In the following alphanumeric series, what letter comes next? Q, S, N, P, L, ...
   J, H, I, N (correct answer), M, L, None of these

4. Please choose which figure best fits in the picture below



   Correct answer = B

5. All the dice have a unique image on each side. Select the dice that could represent a rotation of the dice marked X:



Correct answer = B

Appendix J. Academic Achievement Measure used in Study Two

Instruction
What is your average in school in each of following subjects? If you are not taking this subject this year, please provide the last final grade you had for each subject in percent out of 100.

English _____%
Sciences _____ %
Math _____ %
Social Studies or History_____ %