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Dissociating intuitive physics from intuitive psychology: Evidence from Williams syndrome

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ABSTRACT

Prior work suggests that our understanding of how *things* work ("intuitive physics") and how *people* work ("intuitive psychology") are distinct domains of human cognition. Here we directly test the dissociability of these two domains by investigating knowledge of intuitive physics and intuitive psychology in adults with Williams syndrome (WS) – a genetic developmental disorder characterized by severely impaired spatial cognition, but relatively spared social cognition. WS adults and mental-age matched (MA) controls completed an intuitive physics task and an intuitive psychology task. If intuitive physics is a distinct domain (from intuitive psychology), then we should observe differential impairment on the physics task for individuals with WS compared to MA controls. Indeed, adults with WS performed significantly worse on the intuitive physics than the intuitive psychology task, relative to controls. These results support the hypothesis that knowledge of the physical world can be disrupted independently from knowledge of the social world.

1. Introduction

Humans rapidly and accurately understand complex scenarios involving physical objects and social beings. For example, in a brief glance we understand whether a precarious stack of books will fall or whether a person is engaged in conversation with someone else. Philosophers and psychologists have suggested that these remarkable human capacities are supported by distinct cognitive mechanisms: one for understanding how *things* work, known as "intuitive physics" or "folk physics", and a second for understanding how *people* work, known as "intuitive psychology" or "folk psychology" (Carey, 1985; Dennett, 1987; Leslie, 1995; Wellman & Inagaki, 1997). These systems are distinguished conceptually by the kinds of information they must represent. Intuitive physics supports reasoning about inanimate objects based on physical properties of objects (e.g., size, weight, etc.) and external forces (e.g., other objects, gravity, etc.) that may be acting upon them. By contrast, intuitive psychology supports reasoning about animate agents based on the information known to be available to the agent (e.g., what or who they can currently see, what they have or have not been told, etc.) and the agent's internal goals, intentions, and desires.

However, beyond conceptual arguments for the distinction between intuitive physics and intuitive psychology, relatively little empirical evidence exists to support the independence of these cognitive domains. Indeed, while many studies have focused on questions within the domain of either intuitive physics or intuitive psychology, far fewer have directly compared the two. If intuitive physics and intuitive psychology are independent cognitive domains, then it should be possible to find cases of selective impairment in one domain, but not the other. To this end, a number of studies have explored intuitive physics and intuitive psychology in autism spectrum disorders (ASD) (Baron-Cohen, Leslie, & Frith, 1986; Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001; Binnie & Williams, 2002; Charman & Baron-Cohen, 1995; Leslie & Thaiss, 1992). Such studies reveal that individuals with ASD are impaired at intuitive psychology tasks relative to both typically developing controls and individuals with comparable, nonspecific developmental disorders (e.g., Down's syndrome), but nevertheless show typical or even superior performance on intuitive physics tasks. This single dissociation provides important initial evidence

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that intuitive physics and intuitive psychology may be independent. Critically, however, if intuitive physics and intuitive psychology are truly independent, then it should also be possible to find cases of impaired intuitive physics coupled with spared intuitive psychology. Indeed, without such evidence, it could still be the case that a single mechanism (e.g., for causal inference) underlies both kinds of reasoning, and that intuitive psychology is simply a more difficult or complex case than intuitive physics.

Here we search for this complementary profile (i.e., impaired intuitive physics, spared intuitive psychology) by studying intuitive physics and intuitive psychology abilities in adults with Williams syndrome (WS). WS is a genetic developmental disorder caused by a hemizygous microdeletion of ∼28 genes on chromosome 7q11.23 (Ewart et al., 1993). Strikingly, although WS involves moderate intellectual disability (average IQ is around 65; Mervis & John, 2010), this highly specific genetic deletion does not affect all domains equally. For example, people with WS are severely impaired compared to typically developing mental-age matched (MA) controls on a variety of visual-spatial tasks, such as block construction (Hoffman, Landau, & Pagani, 2003), spatial memory (Vicari, Bellucci, & Carlesimo, 2003), visually-guided action (Atkinson et al., 1997; Dilks, Hoffman, & Landau, 2008), and multiple object tracking (O'Hearn et al., 2005). By contrast, WS individuals perform similarly to MA controls—and sometimes even chronological age matched controls—on a variety of social tasks, including face recognition (Tager-Flusberg, Plesa-Skwerer, Faja, & Joseph, 2003), biological motion perception (Jordan, Reiss, Hoffman, & Landau, 2002), emotion expression (Tager-Flusberg & Sullivan, 2000), and theory of mind (Karmiloff-Smith, Klima, Bellugi, Grant, & Baron-Cohen, 1995; Tager-Flusberg, Boshart, & Baron-Cohen, 1998; Tager-Flusberg & Sullivan, 2000). Furthermore, people with WS are described as showing a strong interest in the social world (Klein-Tasman & Mervis, 2003; Tager-Flusberg et al., 1998), and have even been described as "hypersocial" (Jarvinen, Korenberg, & Bellugi, 2013).

Insofar as intuitive physics is an inherently visual-spatial process, while intuitive psychology is inherently social, the contrasts in performance across a variety of spatial and social tasks in WS above suggest that intuitive physics and intuitive psychology may likewise be differentially susceptible to damage in this genetic disorder. Indeed, recent studies of WS individuals suggest that specific genes within the WS deletion play distinct roles in the overall cognitive profile; for example, *LIMK-1* has been related to visual-spatial deficits, while *GTF2I* has been related to social aspects of the disorder (Dai et al., 2009; Frangiskakis et al., 1996; Sakurai et al., 2011). Thus, considering both the specific cognitive and genetic dissociations found in this disorder, it is possible that adults with WS will perform disproportionately worse on an intuitive physics task than on a comparable intuitive psychology task, relative to MA controls. To test this prediction, WS adults and MA control participants completed two tasks, each involving a high-level judgment made after viewing a complex, naturalistic six-second video. In the intuitive physics task, participants observed 6 s videos of unstable towers of blocks, and were asked to judge in which of two directions the tower would fall (e.g., "toward the red side or green side?").[1] In the intuitive psychology task, participants observed 6 s videos of children playing with toys who were either interacting with an off-screen "friend", or not, and were asked to judge whether the child was playing alone or with someone else (e.g., "one person or two people?").

Finally, following our primary analysis testing the prediction above, we conducted additional analyses addressing previous arguments that WS cannot be used as a neuropsychological model of the typical cognitive system. This argument has been leveraged on the basis that WS individuals might develop differently from typically developing children from birth, leading to qualitative differences in cognitive processes underlying their behavior (Karmiloff-Smith, 1997). Thus, in WS, it might be possible that any observed decrement in performance on the intuitive physics task results from a *qualitatively* different pattern of performance from the MA controls (e.g., WS might show a distinct pattern of performance across the trials, reflecting a distinct underlying mechanism), rather than a *quantitatively* different pattern of performance (e.g., WS might show the same overall pattern of performance across the trials as MA controls, but at reduced accuracy, reflecting a similar underlying mechanism that is less developed in the case of WS) (Musolino & Landau, 2012). To test this possibility, we compared detailed patterns of performance in people with WS compared to MA controls (around 8 years old), as well as an even younger group of typically developing children (i.e., 4 year olds)—an age at which WS adults have been observed to perform comparably on other tasks on which they show deficits (Bellugi, Bihrle, Neville, Doherty, & Jernigan, 1992; Dilks et al., 2008).

2. Methods

2.1. Participants

Sixteen adults with WS (9 females), 16 MA controls (9 females), and 16 typically developing 4 year olds (10 females) participated in the study. Participant characteristics are presented in Table 1. The WS adults were recruited through the Williams Syndrome Association, and all had been positively diagnosed by a geneticist and the FISH test, confirming a deletion in the classic WS region of chromosome 7. All adult participants and legal guardians of child participants gave informed consent.

Participants were tested on a standardized intelligence test, the Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1990). This test yields an overall IQ score, as well as scores for two components, Verbal and Non-verbal (Matrices). The Verbal subtest requires participants to match words or descriptions to pictures, and the Matrices subtest requires participants to judge which objects or patterns "go together". Each WS adult was individually matched to a typically developing control participant based on raw scores for the verbal and nonverbal subtests (Table 1). Matching was done as closely as possible, with a mode of 4 points difference for the verbal match (max difference = 8, N = 2) and a mode of 3 points difference for the nonverbal match (max difference = 12, N = 1). As a result of this procedure, no significant difference was found between the two groups for either verbal ($t_{(30)} = 0.55$, $p = 0.58$, $d = 0.20$) or nonverbal raw scores ($t_{(30)} = 0.44$, $p = 0.66$, $d = 0.16$).

2.2. Design, stimuli, and procedure

Participants performed two tasks: an intuitive physics task, in which they judged the direction in which an unstable tower of blocks was likely to fall, and an intuitive psychology task, in which they judged whether or not a child was playing/interacting with an off-screen "friend". The order of tasks was counterbalanced across participants. Both tasks were presented using custom software

[1] We used this task as a representative measure of intuitive physical reasoning for three reasons. First, this task strongly and preferentially modulates cortical regions that are also activated by a variety of other intuitive physics tasks (Fischer, Mikhael, Tenenbaum, & Kanwisher, 2016). Second, computational models using probabilistic simulations of Newtonian mechanics closely capture human performance both on this task and many other intuitive physics tasks (Battaglia, Hamrick, & Tenenbaum, 2013; Hamrick, Battaglia, & Tenenbaum, 2011). Third, this task does not rely on language abilities, unlike other intuitive physics tasks (Baron-Cohen et al., 2001, 2003), which is crucial for the study of WS individuals whose relatively spared language abilities could mask any potential intuitive physics impairment.