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# Children with autism spectrum disorder have an exceptional explanatory drive

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## Abstract

An "explanatory drive" motivates children to explain ambiguity. Individuals with autism spectrum disorders are interested in how systems work, but it is unknown whether they have an explanatory drive. We presented children with and without autism spectrum disorder unsolvable problems in a physical and in a social context and evaluated problem-solving and explanation-seeking responses. In the physical context (but not the social context), the children with autism spectrum disorder showed a stronger explanatory drive than controls. Importantly, the number of explanatory behaviors made by children with autism spectrum disorder in the social context was independent of social and communicative impairments. Children with autism spectrum disorder did not show an exceptional explanatory drive in the social domain. These results suggest that children with autism spectrum disorder have an explanatory drive and that the explanatory drive may be domain specific.

## Keywords

explanatory drive, social cognition, systemizing

People are motivated to seek disambiguating information in ambiguous circumstances (Lewis, 1985; Morris et al., 1995). This impulse, referred to as the "explanatory drive," appears early in human development. Infants and toddlers have an understanding of abstract causal relations (Bullock and Gelman, 1979; Gopnik and Sobel, 2000; Shultz, 1982; Shultz et al., 1986), and by 4 or 5 years of age children are able to produce explicit explanations for novel events (Crowley and Siegler, 1999; Wellman and Gelman, 1998). When they fail to apprehend an explanation, children frequently ask "why?" or "how come?" (Bullock and Gelman, 1979; Crowley and Siegler, 1999; Gopnik and Sobel, 2000; Shultz, 1982; Shultz et al., 1986; Wellman and Gelman, 1998). This desire for explanation continues through adolescence and adulthood. Young children's quest for explanation has led some to liken children to scientists engaged in theory formation and hypothesis testing (Carey, 1985; Gopnik, 2012; Wellman, 1990). The explanatory drive occurs cross-culturally (Lewis, 1985; Morris et al., 1995).

This study was designed to test whether children with autism spectrum disorder (ASD) have an explanatory drive. ASDs are a group of developmental disorders characterized by (1) problems in social communication and interactions and (2) restricted patterns of behavior, activities, and interests (American Psychiatric Association, 2013).

To date, there have been no direct tests of an explanatory drive in ASD, although the systemizing view of autism (Baron-Cohen, 2003) seems to suggest that individuals with ASD might have an exceptional explanatory drive, since they are better than typically developing children at reasoning about systems, including causal relationships. Others have made a strong case for testing for an exploratory drive in chimpanzees (Andrews, 2005), and here we advocate such a test in children with ASD. Furthermore, it is unclear whether the explanatory drive, if found in the physical domain among those with ASD, will be preserved in the social domain. Because those with ASD have a deficit in social cognitive processing, and because intuitive physics and intuitive psychology are thought to be psychologically independent (Baron-Cohen et al., 2001), we sought evidence of an explanatory drive in the social and physical domains independently. We aim to test the prediction that if the explanatory drive is intact in the physical domain, it may still be impaired in the social domain, when children with ASD are required to reason

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about information with which these individuals are known to show deficits.

Social deficits are the most pronounced and reliably diagnosed symptoms in children with ASD (Leslie and Thaiss, 1992). Deficits such as poor or atypical eye contact, joint attention and joint referencing appear early during infancy (Baron-Cohen, 1989, 1995; Buitelaar et al., 1991; Mundy and Sigman, 1989). Even high-functioning individuals who pass false belief tasks may struggle with sarcasm and lying (Mathersul et al., 2013; Sodian and Frith, 1992).

With respect to the question of whether children with ASD can provide explanations for events in the social domain, some evidence suggests that compared to control participants, those with ASD are less able to explain other's behaviors and that the ability to do so is related to performance on theory of mind tasks (Tager-Flusberg and Sullivan, 2006). We sought to explore whether children with ASD effectively seek explanations in cases where social behavior was inexplicable.

Children with ASD are thought to be less creative and imaginative (Craig and Baron-Cohen, 1999; Frith, 1972; Hobson et al., 2013), and it has been suggested that the restricted behaviors and interests may be related to the impoverished imagination that is associated with ASD (Honey et al., 2011; Wing and Gould, 1979). Imagination deficits may include difficulties conjuring counter-factual thoughts or problems conceiving hypothetical or abstract circumstances. The view that ASD is characterized by imagination deficits alone would lead to the prediction that those with ASD might lack an explanatory drive; however, those with ASD are thought to have a heightened curiosity regarding how things work.

Those with ASD have been described as having a cognitive style called "systemizing." According to this view, children with ASD are driven to understand how systems work (Baron-Cohen et al., 2001; Lawson et al., 2004). Examples might include a greater interest in method than meaning when looking at art, aptitude in repairing home electrical or plumbing systems, and an interest in mathematical patterns (Baron-Cohen et al., 2003). This drive to understand physical systems might lead to a preserved or even exceptional explanatory drive. Isolated cognitive strength in intuitive physics and mathematics may be characteristic of ASD (Baron-Cohen et al., 1999) and the broader autism phenotype (Baron-Cohen et al., 1997). Some research shows evidence that high-functioning individuals with ASD have exceptional abilities in the physical domain (Baron-Cohen, 1997, 2003; Baron-Cohen et al., 1986), and there is evidence that fathers and grandfathers of those with ASD may be better than average at reasoning about physical causation (Baron-Cohen, 2000; Baron-Cohen et al., 1997). In one study, Baron-Cohen et al. (1986) found that children with ASD were better at picture sequencing than either a typical control group or a control group with Down's syndrome when given stories about mechanical causation, but not stories requiring an understanding of behavioral causation or of the role of mental states in causal sequences (Baron-Cohen et al., 1986).

## Study aim and methodological approach

Here, we replicate and extend the procedures first developed by Povinelli and Dunphy-Lelii (2001) to test whether chimpanzees and preschool-aged children have an explanatory drive. We presented children with unsolvable problems in order to evaluate their tendency to seek explanations. In the non-social Physical Task (Experiment 1), children were presented with an L-shaped block and asked to stand it on end. Because it was specially weighted at the top, the sham block could not be stood on end. If children with ASD have an explanatory drive in the physical domain, they should evince exploratory behaviors including visually or manually inspecting the different surfaces of the blocks as well as problem-solving behaviors such as trying to move the block to the opposite side of the table. In the Social Task (Experiment 2), children were asked to make a non-verbal request for a sticker from an experimental confederate who, after supplying the child with several stickers, became inexplicably unresponsive. In each case, we were interested in the child's spontaneous response to this inexplicable ambiguity, especially evidence of a drive to acquire explanatory information. Exploratory behaviors in the social domain would include making eye contact with the experimenter (i.e. using the actor's eyes as a source of information), looking at the table (in order to seek information about the availability of stickers), as well as problem-solving behaviors such as trying to place themselves in the center of the visual field of the experimenter.

## Experiment 1

### Method

#### Participants

*ASD group*. In total, 18 children (15 males, 3 females) diagnosed with ASD participated in Experiment 1. Their mean chronological age (CA) was 6 years 9 months (range: 4 years 4 months–10 years 2 months). Mean mental age (MA; assessed using the Mullen Scales of Early Learning; Mullen, 1989) was 4 years 9.3 months (range: 2 years 7 months–7 years 8 months). Mean verbal mental age (VMA) was 4 years 6.4 months (range: 1 year 6.4 months–6 years 4 months). Mean non-verbal mental age (NVMA) was 5 years 7.8 months (range: 3 years 2 months–9 years 6.8 months). They were recruited via clinicians who specialize in the treatment of children with

ASD. Clinical diagnosis of ASD following *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV) standards was independently confirmed by one of the authors (M.D.R.) using the autism diagnostic observation schedule–generic (ADOS-G) (Lord et al., 2000) and autism diagnostic interview–revised (ADI-R) (Lord et al., 1994).

*Control group*. In total, 21 (6 males, 15 females) typically developing children (mean age 4 years 9 months, range: 4 years 8 months–4 years 10 months) with no history of developmental delay served as the control group. Mean MA, assessed using the Mullen Scales of Early Learning (Mullen, 1989), was 5 years 2.4 months (range: 4 years months 4 months–5 years 9 months). Mean VMA was 5 years 4.5 months (range: =4 years 5 months–5 years 1 month). Mean NVMA was 5 years (range: 4 years 5 months–5 years 8 months). These children were recruited via an existing research database. These two groups differed significantly on CA ($t(38) = 4.2$, $p = 0.001$) and on VMA ($t(38) = 2.5$, $p = 0.01$) but were matched on overall MA ($t(38) = 1.1$, n.s.) and NVMA ($t(38) = 1.05$, n.s.).

### Stimuli and apparatus

Three yellow L-shaped blocks, identical to each other in size, color, and weight were decorated to look like dogs when stood on the long end (as an inverted "L"). Although all the blocks contained a weight that was not visible, in one of the blocks, the position of the weight prevented the block from standing upright (hereafter, referred to as the "sham" block). The functional blocks, in contrast, could be stood on end. The blocks were to be stood atop a white table that had two concentric black circles drawn on opposite ends of the table (76 cm apart). See Povinelli and Dunphy-Lelii (2001) for a complete description of the apparatus and its design.

### Procedure

After a warming up period during which the experimenter interacted with the child, the child was led to a testing area which included the two functional blocks, introduced as dogs, atop a white table. The experimenter demonstrated how the blocks were to be stood inside each circle, described to the child as the dog's yard. The experimenter placed the blocks on their side in the middle of the table, outside the circles. The children were then asked to stand the two blocks up in their respective circles. This procedure was repeated across two trials (the baseline trials) using the functional blocks. After each trial, the child was given a sticker to place on a sticker page as a reward. This served both as a reinforcer and gave the experimenter a moment to manipulate the blocks without the child observing. Prior to the start of the third trial, while the child placed a sticker onto the sticker page, the experimenter replaced one of the functional blocks with the sham block, placed both the sham and the functional blocks on their side in the center of the table and asked the child to stand the blocks in their circles "one last time."

This third trial, the test trial, started with a 120 s "manipulation period" during which the experimenter appeared distracted (arranging stickers) in order to discourage the child from seeking direct assistance. If the child insistently appealed to the experimenter, the experimenter's verbal responses took the form of general encouragement and support: "Can you stand them up on their feet?"

The manipulation period was followed by a "questioning period" which lasted for a maximum of 2 min or was terminated when it stopped being productive. The experimenter asked the child, "Why won't it stand up?" The questioning period ended once the child said repeatedly, "I don't know" more than three times, stopped responding, or refused to participate.

### Coding

All trials were video-recorded and then coded by two trained coders. Coders were blind to the group membership of the participants and the hypotheses being tested. Visual inspections consisted of (1) looking at the bottom of the block closely and deliberately, (2) observing the block outside the circle or inside of the opposite circle, and (3) observing the block placed upside down on the table. Tactile inspection consisted of (1) touching the bottom of the sham block or (2) touching the surface of the table. All measures were binary; counted as either present (1) or absent (0). This coding scheme was directly modeled after those developed by Povinelli and Dunphy-Lelii (2001). Inter-rater reliability was acceptable: kappas for each item are shown in Table 1.

## Results

We were interested in both non-verbal behaviors and verbal behaviors that evidenced a desire to seek explanatory information in this ambiguous situation. Here, we describe these observed behaviors and compare across the two groups. Table 1 lists all the items reported for Experiment 1 and the reliability of each.

### Non-verbal measures

In order to test for group differences on each specific behavior that was coded, we used the Kruskal–Wallis test. The two groups differed significantly with respect to some but not all non-verbal behavioral measures. Children in the ASD group were significantly more likely to touch the surface of the table (40%) compared to the typical group (0%; $H(35) = 9.38$, $p = 0.002$, two-tailed). In

**Table 1.** A list of each item in Experiment 1 and Cohen's kappa, and index of the inter-rater reliability, for each.

| Experiment 1: items measuring the explanatory drive in the physical domain | Cohen's kappa |
|---|---|
| Look at the bottom of the block | 1.000 |
| Touch the bottom of the block | 1.000 |
| Switch it to the other side of the table | 1.000 |
| Flip the block to the other end | 1.000 |
| Touch the surface of the table | 0.986 |
| Attempt to put the block outside the circle | 0.912 |
| Move block to other side of table | 1.000 |
| Request for help | 0.845 |
| Offer physical explanation | 0.821 |
| Ask "why" question | 0.986 |
| Refer to block as agent | 1.000 |
| Offer a description of the state of affairs | 0.791 |
| Offer folk psychological explanations | 0.827 |

addition, the children with ASD were more likely to put the block outside of the circle (33%) in an attempt to make it stand, compared to typically developing children (0%; $H(35)=7.56$, $p=0.006$, two-tailed).

The two groups did not differ in touching the bottom of the block (ASD 20%; typical 30%; $H(35)=0.44$, n.s.), in looking at the bottom of the block (ASD 27%; typical 35%; $H(35)=0.27$, n.s.), in flipping the block to the other end (ASD 13%; typical 10%; $H(35)=0.09$, n.s.), nor in moving the block to the other side of the table (ASD 40%; typical 30%; $H(35)=0.37$, n.s.). A $t$-test revealed that there was no difference with respect to the amount of time engaged in tactile and visual inspection of the sham block between the ASD group ($M=112.3$ s, $SD=31.6$ s) and the control group ($M=103.6$ s, $SD=11.5$ s; $t(35)=1.13$, n.s.). Non-verbal explanatory seeking behaviors are depicted in Figure 1(a).

### *Verbal measures*

The children with ASD were significantly more likely to make explicit requests for help than typically developing controls (ASD=61%; Control=25%, $H(38)=4.94$, $p=0.02$, two-tailed) and to offer physical explanations for the problem (ASD=67%; Control=30%, $H(38)=4.97$, $p=0.02$, two-tailed) compared to the control group. More of the children with ASD asked "why" questions compared to typically developing controls (ASD=44%; Control=15%, $H(38)=3.88$, $p=0.04$, two-tailed). In contrast, the control group was marginally more likely than the ASD group to refer to the block as an agent (ASD=0%; Control=15%, $Z=1.71$, $p=0.08$, two-tailed). The groups did not differ in terms of describing the state of affairs (ASD=89%; Control=85%, $Z=0.35$, n.s.) or offering folk psychological explanations (ASD=22%; Control $M=30\%$, $Z=0.54$, n.s.). These findings are depicted in Figure 1(b).

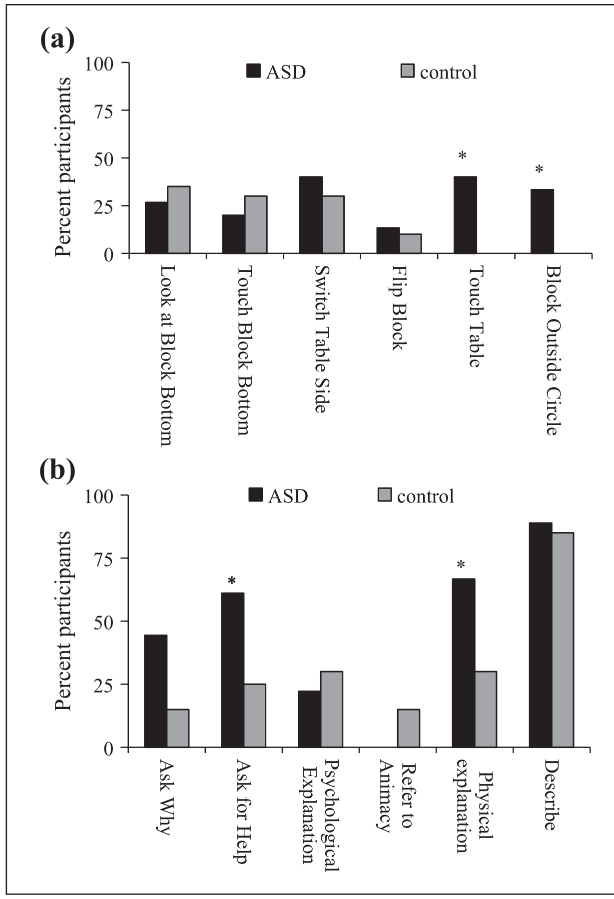


**Figure 1.** Experiment 1: The percent of each group of children who showed each behavior is represented on the y-axis. (a) Non-verbal responses to the physical dilemma and (b) verbal responses to the physical dilemma.
*Significant group difference ($p < 0.05$).

Finally, we tested the relationship between MA and CA and explanation-seeking behavior. The number of spontaneous explanation-seeking behaviors (either visual or tactile) that the children with ASD engaged in was significantly correlated with NVMA (Spearman's $r=0.65$, $p=0.003$, two-tailed), but not with either VMA (Spearman's $r=0.04$, $p=0.45$, one-tailed) or with CA (Spearman's $r=0.09$, $p=0.72$, two-tailed). Similarly, the control group's tendency to ask more questions was not correlated with VMA (Spearman's $r=0.14$, $p=0.53$, two-tailed), NVMA (Spearman's $r=0.14$, $p=0.53$, two-tailed) or with CA (Spearman's $r=0.11$, $p=0.63$, two-tailed). Considering the two groups together, there was no relationship between explanation-seeking behavior and CA (Spearman's $r=0.10$, $p=0.56$, two-tailed), though the relationship with both VMA (Spearman's $r=0.34$, $p=0.04$, two-tailed) and with NVMA (Spearman's $r=0.64$, $p < 0.001$, two-tailed) was significant.

## Discussion

Compared to typically developing controls, children with ASD evidenced more exploratory (non-verbal) and explanatory (verbal) behaviors, supporting the idea that children with ASD have an exceptional explanatory drive with respect to non-social situations. Importantly, this effect was independent of verbal mental age and chronological age, a result that is consistent with the view that a strong explanatory drive may represent a specific—perhaps, defining—cognitive style (Baron-Cohen, 2010). It is an open question whether this explanatory drive can be applied to a social problem.

In addition to clearly explanatory behaviors, the group with ASD was also more likely to verbally ask the experimenter for help. This seems anomalous given that one might, in general, expect less use of expressive language from the children with ASD. This group difference might reflect the systemizing cognitive approach on the part of the children with ASD, who assume that this physical system behaves in predictable and controllable ways, and thus seek the intervention of the apparent authority figure. If the control group is less certain of the predictability of the physical apparatus, they may not assume that the adult has a solution to the problem.

## Experiment 2

### Introduction

Can children with ASD use the apparently exceptional explanatory drive in the social domain? Experiment 2 directly addressed this question by presenting both typically developing children and children with ASD with a Social Task that was analogous to the Physical Task used in Experiment 1.

### Methods

#### Participants

*ASD group*. In total, 17 children (11 males, 6 females) diagnosed with ASD participated. Mean CA was 5 years 8 months (range: 3 years 7 months–8 years 4 months). Mean MA was 67.2 months (range: 38.8 months–87.4 months). Mean VMA was 5 years 4 months (range: 3 years 4.5 months–7 years 2 months). Mean NVMA was 65.1 months (range: 37 months–85.2 months). Participants were recruited through an existing experimental database and via public lectures given to parents' groups by M.D.R. No participant who had participated in Experiment 1 was included in Experiment 2. Children had a clinical diagnosis of ASD following DSM-IV standards, and diagnoses were confirmed by M.D.R. using the ADOS-G (Lord et al., 2000).

*Control group*. A total of 15 (9 males, 6 females) participants who had no history of developmental delay were recruited via an existing research database. Mean CA was 4 years 9 months (range: 4 years 8 months–4 years 10 months), mean MA was 5 years 3.6 months (range: 4 years 4.3 months–5 years 8.3 months), mean VMA was 5 years 5.2 months (range: 4 years 6 months–5 years 9.5 months), and mean NVMA was 5 years 2.0 months (range = 4 years 2.5 months–5 years 8.3 months). No participant who had participated in Experiment 1 was included in Experiment 2.

CA was significantly different across groups ($t(30) = 2.90$, $p = 0.007$). Groups were matched on MA ($t(30) = 1.2$, *n.s*), VMA ($t(30) = 0.87$, $p$ = n.s.), and NVMA ($t(30) = 1.0$, $p$ = n.s.).

### Stimuli and apparatus

Children were presented with the "sticker frame": an $8.5 \times 11$ in paper with four $2 \times 4$ in rectangles drawn on it. The four rectangles served as frames for stickers. This paper was placed on top of a table situated approximately 2 m from the sticker experimenter. Large, colorful stickers depicting animals, flowers, and cartoon characters were given to the children at appropriate moments throughout the experiment. Markers were also provided to decorate the paper.

### Procedure

Children were first familiarized with a caretaker experimenter and a sticker experimenter. Then, the caretaker experimenter and the child sat together and the sticker experimenter sat at a different table. The caretaker experimenter showed the child the sticker frame, and told him or her that four stickers were needed to complete it. In order to get the stickers, the child had to approach the sticker experimenter and make a request using a specific non-verbal gesture: the caretaker experimenter demonstrated holding an outstretched hand toward the sticker experimenter, with his palm facing up. The child practiced this request, and the caretaker experimenter provided feedback. Children were discouraged from making verbal requests. Once the child made the appropriate request, the sticker experimenter made eye contact with the child, smiled, and placed a large sticker in the child's hand.

Next, the caretaker experimenter and child returned to the original table with the sticker frame, where the child was instructed to place the sticker inside one of the frames. Children were encouraged to color and decorate around the sticker. After this initial familiarization with the task, the Test Phase began.

The Test Phase consisted of three trials, the third of which was the experimental trial. In trials 1 and 2, the child received a sticker from the sticker experimenter. During trial 1, the caretaker experimenter asked the child to request another sticker from the sticker experimenter, telling the child to do it "like we just did, remember to stick out your hand like I showed you." No further instructions were given to the child. Once the correct request was made, the sticker experimenter placed a large sticker in the child's hand and smiled. The sticker experimenter then continued playing with the stickers acting as though her attention was directed exclusively at the stickers she was sorting. The child returned to the caretaker experimenter and placed the sticker in another frame. After a few minutes of coloring the frame, trial 2 commenced, and was the same as trial 1.

On the third (experimental) trial, the child did not receive a sticker from the sticker experimenter. Instead, the sticker experimenter ignored the child, pretending to be engaged in sorting stickers. The caretaker experimenter also acted distracted. If the child walked to the caretaker experimenter and/or requested help, or attempted to sit back at the caretaker's table, the caretaker experimenter said, "go get a sticker from her." Or, "ask for a sticker like I showed you." The caretaker experimenter repeated this for up to 2 min, or until the child ceased novel attempts to obtain a sticker.

### *Coding*

Video recordings of each session displayed both the child's face and the sticker experimenter. Videos were coded by two coders working independently from one another. Table 2 lists the reliability of each items reported for Experiment 2.

**Table 2.** A list of each item in Experiment 2 and Cohen's kappa, and index of the inter-rater reliability, for each.

| Experiment 2: items measuring the explanatory drive in the social domain | Cohen's kappa |
|---|---|
| Behavior change significantly | 0.786 |
| Attempt to get attention of sticker experimenter | 1.000 |
| Attempt to get attention of another person | 0.862 |
| Talk to sticker experimenter | 0.918 |
| Verbal explanation for social dilemma | 0.751 |
| Looked at face/eyes | 0.783 |
| Touched experimenter | 0.783 |
| Made noise (non-words) | 0.841 |
| Looked at table/stickers | 0.839 |
| Tapped/hit/touched table | 0.795 |
| Hand moved toward experimenter | 0.796 |
| Body moved toward experimenter | 1.000 |

## Results

As with Experiment 1, we first analyzed group differences in the number of children who performed each behavior of interest.

### *Interactions with experimenter*

A Kruskal–Wallis test revealed a significant group difference in the number of attempts to get the attention of the experimenter: Only 2 of 15 children in the ASD group attempted to get the attention of the experimenter, compared to 14 of 15 in the control group; $H(30) = 18.6$, $p < 0.001$). There were also group differences in the number of times the child moved a hand toward the experimenter (Control Group, 15 out of 15; ASD Group = 4 out of 15; $H(30) = 16.79$, $p < 0.001$), but no significant group difference in the number of times the child moved (his or her entire body) toward the experimenter (Control Group = 9 out of 15; ASD Group = 4 out of 15; $H(30) = 3.28$, $p = 0.07$).

Groups did not differ significantly in the number of children that looked at the eyes or face of the sticker experimenter (Control Group = 15 out of 15; ASD Group = 13 out of 15; $H(30) = 2.07$, n.s.). There were no significant group difference in attempts to talk to the experimenter comparing the control group (6 out of 15) and the ASD group (3 out of 15; $H(30) = 1.38$, n.s.) nor in touching the experimenter, comparing the control group (2 out of 15) and the ASD group (1 out of 15; $H(30) = 0.36$, n.s.). Non-verbal and verbal explanation-seeking behaviors are shown in Figure 2(a).

### *Other information-seeking behavior*

A Kruskal–Wallis test revealed no significant difference in the number of children who looked at the stickers on the table, between the control group (15 out of 15) and the ASD group (12 out of 15; $H(30) = 3.22$, $p = 0.07$). The difference in the production of non-linguistic noises (Control group = 8 out of 15, ASD group = 2 out of 15) was not significant after Bonferroni correction ($H(30) = 5.22$, $p < 0.02$, two-tailed).

There were no significant group differences in the coders' noting an overall change in behavior between the first trial and the third trial, when comparing the control group (1 out of 15) and the ASD group (2 out of 15; $H(30) = 0.36$, n.s.). Similarly, there was no significant group difference in the number of children who attempted to get the attention of a parent, between the control group (8 out of 15) and the ASD group (5 out of 15; $H(30) = 1.18$, n.s.). There were no group differences in the number of children who touched the table between the control group (7 out of 15) and the ASD group (7 out of 15; $H(30) = 0$, n.s.). These results are shown in Figure 2(b).

Because there were group differences on many fewer items than we found in Experiment 1, we decided to follow these analyses with a test of group differences on the number of times each child performed a given behavior. Our observations during the sessions suggested that some children were more persistent at pursuing a given strategy, and a consideration of the number of times each behavior was

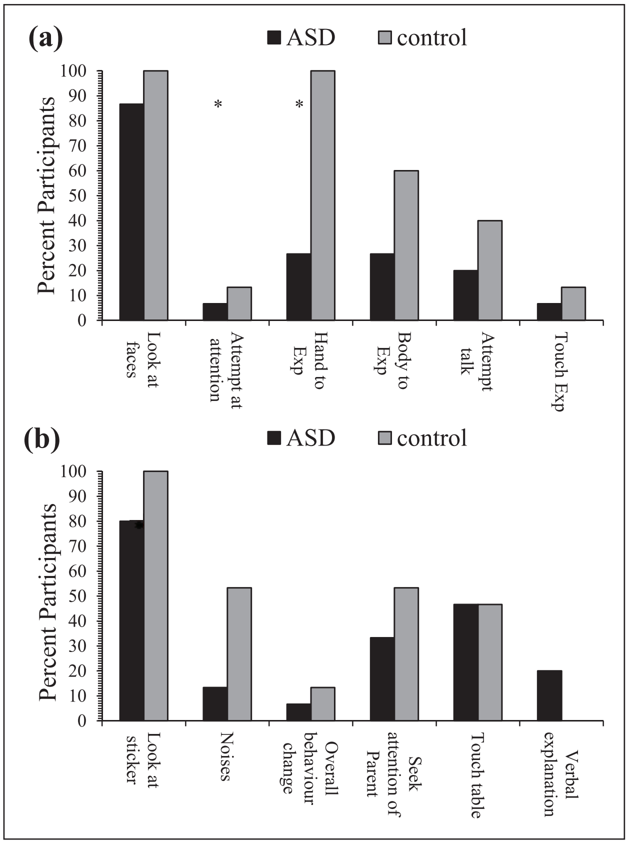


**Figure 2.** Experiment 2: The percent of each group of children who showed each behavior is represented on the y-axis. (a) Experimenter-directed behaviors, in the social dilemma and (b) other information-seeking behavior in the social dilemma.
*Significant group difference ($p < 0.05$).

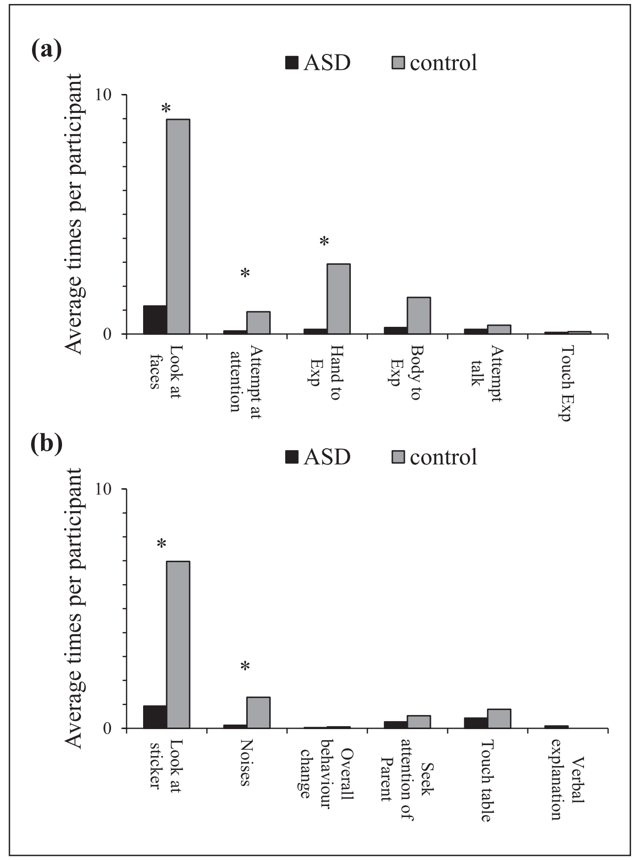


**Figure 3.** Experiment 2: The number of times children in each group showed each behavior is represented on the y-axis. (a) Experimenter-directed behaviors, in the social dilemma and (b) other information-seeking behavior in the social dilemma.
*Significant group difference ($p < 0.05$).

repeated should be more sensitive, potentially yielding group differences.

### Interactions with experimenter

Groups differed significantly in the number of times they looked at the eyes or face of the sticker experimenter. Children in the control group looked more times ($M$=8.97 times, $SD$=3.59 times) than the ASD group ($M$=1.17 times, $SD$=0.8 times) at the experimenter's face while requesting a sticker ($t(30)=8.21$, $p<0.001$, two-tailed). There was a significant group difference in the number of attempts to get the attention of the experimenter: on average, the control group made more attempts ($M$=0.93 attempts, $SD$=0.26 attempts) than the ASD group ($M$=0.13 attempts, $SD$=0.35 attempts; $t(30)=7.25$, $p<0.001$). There were also group differences in the number of times the child moved a hand toward the experimenter (Control $M$=2.93 times, $SD$=1.94 times; ASD $M$=0.2 times, $SD$=0.37 times; $t(30)=5.70$, $p<0.001$) but no group difference in the number of times the child moved (his or her entire body) toward the experimenter (Control $M$=1.53 times, $SD$=1.51 times; ASD $M$=0.27 times, $SD$=0.46 times; $t(30)=1.13$, n.s.). There were no significant group difference in attempts to talk to the experimenter comparing the control group ($M$=0.37 attempts, $SD$=0.48 attempts) and the ASD group ($M$=0.20 attempts, $SD$=0.41 attempts; $t(30)=1.08$, n.s.) nor in touching the experimenter, comparing the control group ($M$=0.1, $SD$=0.28) and the ASD group ($M$=0.07, $SD$=0.25; $t(30)=0.32$, n.s.) (see Figure 3(a)).

### Other information-seeking behavior

Groups differed in the number of times children looked at the stickers on the table. Those in the control group looked at the stickers on the table more ($M$=6.97 times, $SD$=2.29 times) than the ASD group ($M$=0.93 times, $SD$=0.68 times, $t(30)=10.5$, $p<0.001$). The control group was more likely ($M$=1.3, $SD$=1.78) than the ASD group ($M$=0.13, $SD$=0.35) to make non-linguistic noises, usually to express confusion or frustration ($t(30)=2.66$, $p=0.01$).

There were no significant group difference in overall change in behavior between the control group ($M=0.06$, $SD=0.17$) and the ASD group ($M=0.03$, $SD=0.13$; $t(30)=0.56$, n.s.). Similarly, there was no significant group difference in the number of attempts to get the attention of a parent, between the control group ($M=0.53$ attempts, $SD=0.52$ attempts) and the ASD group ($M=0.27$ attempts, $SD=0.42$ attempts; $t(30)=1.56$, n.s.). There were no group differences in the number of times the child touched the table between the control group ($M=0.8$ times, $SD=1.11$ times) and the ASD group ($M=0.43$ times, $SD=0.49$ times; $t(30)=1.24$, n.s.) (see Figure 3(b)).

Neither group was likely to offering verbal explanations for the dilemma (control group ($M=0$, $SD=0$; ASD group $M=0.1$, $SD=0.28$). None of these performance variables correlated significantly with MA in the ASD group, but in the control group alone, VMA showed a significant correlation with looking at the sticker table ($r(14)=0.91$, $p<0.001$, two-tailed) and looking at faces ($r(14)=0.76$, $p<0.001$) and a marginally significant correlation with tapping or hitting the table ($r(14)=0.51$, $p=0.08$). No other variables were significantly correlated with MA.

## Discussion

The results of Experiment 2 provide no evidence that children with ASD use an explanatory drive in the social domain. In contrast to the result reported for Experiment 1, typically developing children generated more exploratory and problem-solving behaviors and responses than children with ASD. Specifically, typically developing children evinced more exploratory behaviors such as looking at the stickers on the table and problem-solving (i.e. attention-getting) behaviors such as making noises.

Given the results of Experiment 1, where children with ASD visually inspected and actively explored the blocks, the failure of children with ASD to generate similar exploratory and problem-solving responses in the social domain suggests that children with ASD are unable to use their exceptional explanatory drive to compensate for their social cognitive deficits.

## General discussion

Experiments 1 and 2 were designed to answer two questions: (1) Do children with ASD show evidence of an explanatory drive that is similar to that of typical children? (2) Does the explanatory drive appear to function differently in the social versus the physical domain? Results support the conclusion that the children with ASD in this study had an intact explanatory drive, but only in the non-social domain. In Experiment 1, when confronted with a physical problem, children in the ASD group were more likely than the control group to ask a "why" question and were also more likely than the control group to offer a physical explanation for what was happening. The children with ASD asked for help more often and offered more physical explanations than typically developing control participants. There was also non-verbal evidence consistent with the notion that children with ASD may have an exceptional explanatory drive in the physical domain. For instance, children in the ASD group were more likely than children in the control group to touch the surface of the table and were more likely to put the block outside of the circle in an attempt to make it stand. Not only do children with ASD have an explanatory drive, but it is more robust than that of the control group. This difference cannot be explained by group differences in verbal ability.

Children with ASD were just as likely as the control children to explore the block by touching the bottom, looking at the bottom, and flipping it over. They were just as likely as control children to try standing the block up on the other end of the table, and most significantly, they spent as much time as the children in the control group inspecting the block tactilely and visually. All of these behaviors are consistent with the idea that children in the ASD group have an intact explanatory drive.

These results are consistent with the systemizing hypothesis of autistic cognition (Baron-Cohen et al., 2001; Lawson et al., 2004). According to this hypothesis, ASDs are characterized by a "systemizing" cognitive style, meaning those with ASD want to know how system works. This systematizing cognitive style may have led children with ASD in Experiment 1 to seek out explanations for puzzling physical events to a greater extent than controls.

With respect to testing in the social domain, we saw clear evidence of group differences of the type one would expect to find in any social context: those with ASD were less likely to look at the experimenter's face, attempt to get the experimenter's attention, or extend the open hand toward the experimenter. In contrast to performance in the physical domain, there was no evidence of an explanatory drive in the social domain for children with ASD. Given a social dilemma, children in the ASD group were less likely than children in the control group to look at the experimenter's face and between the experimenter's face and the stickers. This finding is consistent with the expectation that there may be group differences in the initiation of joint attention (Bedford et al., 2012; Charman and Baird, 2002; Warreyn et al., 2005).

It is possible that children with ASD have no explanatory drive with respect to the social domain. We speculate that children with ASD are accustomed to finding social situations perplexing and perhaps have no expectation of explaining social events; thus, they may not be driven to seek explanations in social situations. Alternatively, their behavior may result from an intact social explanatory drive and an inability (inhibition) to act. For example, seeking information in social contexts involve actually *initiating* a social situation (asking someone what they mean, etc.).

Such a difference between social and non-social information seeking might, in and of itself, reduce the frequency of information seeking in those with ASD. Our procedures were meant to control for this potential confound: it is for just this reason that the sticker experimenter did not interact socially, verbalize, or make eye contact with the participant. However, the less social measures such as touching the table and touching the sticker experimenter showed no significant group difference. One might think that touching was a social gesture, but the failure to find group differences in touching the experimenter may be a floor effect resulting from the fact that these behaviors were low-frequency behaviors in either group.

Note that it is possible, given these results, that children with ASD may still have an explanatory drive with respect to the social domain, and that group differences arise because children with ASD make attempts to seek explanations that rest on incorrect assumptions about the world. For example, it is possible that they are seeking explanations, but are not relying on other's mental states as information sources, so their explanatory behaviors do not look like those of the control group, incorporating eye contact and attention bids, for example. Similarly, they may not understand that the experimenter's visual attention to stickers forecloses the possibility that she is still interacting with the child. Future experiments could test the children's understanding of the relationship between visual attention and behavior, in order to aid the interpretation of these group differences.

This study is the first to report that high-functioning children with ASD have a preserved explanatory drive despite their reduced facility with respect to reasoning about psychological unobservables.Indeed, our data suggest that children with ASD may possess an exceptional explanatory drive in the physical domain. Our results suggest that the explanatory drive is present in young individuals with ASD and does not emerge late relative to typical development, which could be explained by either explicit training or practiced compensatory mechanisms.

The explanatory drive in ASD may be restricted to the non-social domain. Among those with ASD, folk psychology deficits dissociate from deficits in folk physics (for a review, see Baron-Cohen (2010)). Our results suggest that there is either no drive to seek explanations in the social domain (perhaps all social interactions are perplexing, and our experimental dilemma is no more confusing than everyday life) or the children with ASD lack the skills necessary to resolve the dilemma. The fact that the ASD group did not extend their explanatory drive in the social domain suggests that the explanatory drive might not be domain-general, but domain- or task-specific. Alternatively, the drive might be neutral with respect to domain but ineffective in the social domain because of a lack of coordination with other social abilities such as theory of mind. Such a possibility merits future research. If the explanatory drive is domain specific, intervention strategies that attempt to use a child's exceptional explanatory drive to compensate for social reasoning deficits may prove ineffective.

Humans have an "Explanatory Drive," which leads them to seek information in ambiguous circumstances, a drive that may be unique among primates (Povinelli and Dunphy-Lelii, 2001). Because those with ASD have a deficit in social cognitive processing (Baron-Cohen, 1995), in some cases concurrent with preserved cognitive functioning in other domains (Baron-Cohen et al., 1999), we sought evidence of the explanatory drive in the social and physical domains in children with ASD. We see no evidence of an ASD-specific deficit in the explanatory drive with respect to physical problems. A failure to seek explanations in the social domain is consistent with poor performance in social situations among those with ASD and could suggest that the explanatory drive is domain specific.

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