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ORIGINAL PAPER

How Children with Autism Reason about Other's Intentions: False-Belief and Counterfactual Inferences

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Abstract We examine false belief and counterfactual reasoning in children with autism with a new change-of-intentions task. Children listened to stories, for example, Anne is picking up toys and John hears her say she wants to find her ball. John goes away and the reason for Anne's action changes—Anne's mother tells her to tidy her bedroom. We asked, 'What will John believe is the reason that Anne is picking up toys?' which requires a false-belief inference, and 'If Anne's mother hadn't asked Anne to tidy her room, what would have been the reason she was picking up toys?' which requires a counterfactual inference. We tested children aged 6, 8 and 10 years. Children with autism made fewer correct inferences than typically developing children at 8 years, but by 10 years there was no difference. Children with autism made fewer correct false-belief than counterfactual inferences, just like typically developing children.

Keywords Reasoning · Counterfactuals · False beliefs · Intentions · Autism

Introduction

Understanding other people's intentions is challenging for the developing child. A child who is offered a toy by a classmate may need to work out the classmate's intentions—the classmate may wish to play with the child, or they may wish the child to admire the toy and return it, or they may have been told to share by a teacher (Rasga et al. 2016). Importantly, the child may need to keep track of changes in intentions too: the offering may have originated because the classmate wanted the child to admire the toy and return it, but the classmate may now wish to play with the child. Reasoning about other people's intentions is essential for understanding their actions (e.g., Grant and Mills 2011; Juhos et al. 2015; Walsh and Byrne 2007). The ability to detect that reasons for actions can change develops between the ages of 6 and 9 years in typically developing children (e.g., Rasga et al. 2016). Our aim in the study we report is to compare the development of reasoning about other people's intentions in children with autism and typically developing children.

We examine reasoning about other people's intentions using a new unexpected change-of-intentions task (Rasga et al. 2016). We gave children different stories in which an individual has a reason for carrying out an action, but their reason for carrying out the action changes, as Fig. 1 shows. For example, in one story we told children that John hears Anne say she wants to find her ball to play with it. John goes into the kitchen. But while he is away, Anne's mother tells Anne to tidy her bedroom. When John comes back into Anne's bedroom, he sees Anne picking up toys from the bedroom floor. We asked children a false belief question, 'What does John believe is the reason that Anne is picking up the toys from the bedroom floor?' We also asked them a counterfactual question, 'If Anne hadn't wanted to find her ball to play with it, what would have been the reason that Anne was picking up the toys from the bedroom floor?' Our aim is to test at what age during middle childhood children with autism develop the ability to make false belief and counterfactual inferences about other people's intentions, and to test whether their ability to make accurate

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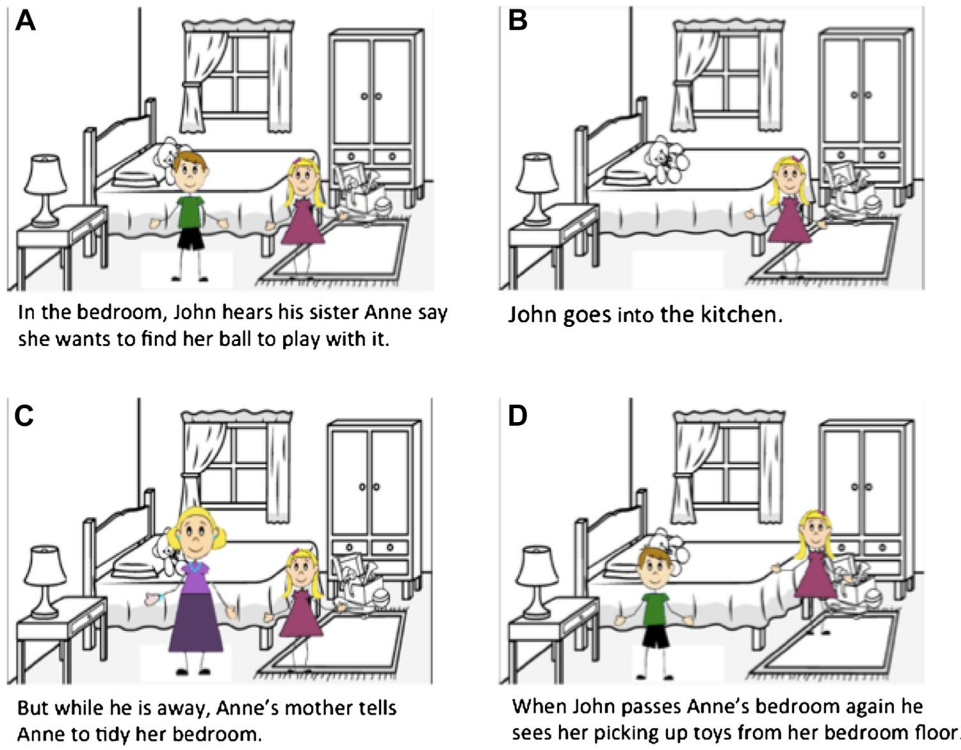

Fig. 1 Example of the novel unexpected change-of-intentions task

counterfactual inferences exceeds their ability to make false belief inferences, as it does for typically developing children.

False Belief Reasoning

Reasoning about other people's intentions requires an understanding that other people's mental states, their beliefs, desires, and knowledge, are different from one's own, that is, it requires a 'theory of mind' (e.g., Premack and Woodruff 1978). Children with autism spectrum disorder can exhibit 'mental blindness' with respect to the thoughts, beliefs, knowledge, desires and intentions of others, undermining their ability to interact socially (e.g., Baron-Cohen 1989). Their difficulties appear to result from deficits in understanding other people's perspectives and attributing mental states to others (e.g., Frith 1996; Baron-Cohen et al. 1985; Astington et al. 1988).

One demonstration of the difficulty children with autism experience in reasoning about other people's mental states is that they often make inaccurate 'false belief' inferences. By 4–5 years of age, typically developing children understand that others may have false beliefs about the physical world (e.g., Wellman et al. 2001). A standard false belief task asks children to consider two puppets, Sally and Anne, who are in the kitchen; Sally places some chocolate in the cupboard, and she leaves; Anne takes the chocolate and moves it to the fridge; Sally returns. They are asked, where will Sally look for the chocolate? Children aged 3 years usually say Sally will look in the fridge, some children at the age of 4 years and most by the age of 5 years say Sally will look in the cupboard (e.g., Wimmer and Perner 1983). Understanding that others may have false beliefs is an important developmental milestone (e.g., Miller 2009; Bloom and German 2000; Baron-Cohen et al. 1985).

The Sally–Anne task is a first-order false belief task; a further milestone is the development of second-order false belief reasoning, understanding that a person's beliefs about another person's beliefs may be inaccurate (e.g., Miller 2009). Consider John and Mary, who are both independently told about the unexpected transfer of an object to a new location, e.g., an ice-cream truck moves to another road. Hence both know where the object is, but John mistakenly believes that Mary thinks the object is at its original location. Typically developing children begin to show accuracy in answering the question 'Where does John think Mary will go for ice-cream?' at about age 6–7 years (e.g., Perner and Wimmer 1985; see also; Symons et al. 1997; Rai and Mitchell 2004).

Although understanding first-order false beliefs at 4–5 years and understanding second-order false beliefs at 6–7 years are important milestones, false belief understanding develops throughout the lifespan. Key precursors for false belief understanding emerge in infancy, e.g., typically developing infants look at where an individual mistakenly believes he or she will find an object and they spontaneously act to help the individual (e.g., Clements and Perner 1994; see also; Wellman et al. 2008; Saxe et al. 2005).

And typically developing adolescents and adults experience difficulty in advanced theory of mind tasks such as interpreting instructions to move objects on a shelf from the perspective of a director who cannot see all of them (e.g., Dumontheil et al. 2010; see also; Keysar et al. 2003; Devine and Hughes 2012; Epley et al. 2004).

In contrast, many children and adolescents diagnosed with autism have difficulty in making accurate false belief inferences, unlike typically developing children, and children with other intellectual difficulties such as Down syndrome (e.g., Baron-Cohen et al. 1985; Prior et al. 1990; Ozonoff et al. 1991). In non-verbal animations depicting interactions between geometrical shapes, individuals with high-functioning autism and Asperger syndrome do not tend to use mental state terms (Castelli et al. 2002). And in 'faux pas' tasks in which a judgment is required about an unintentional action in which a speaker accidentally hurts the feelings of a listener, individuals with high-functioning autism mistakenly judge that the speaker intended to humiliate or offend the other person (e.g., Zalla et al. 2009; see also; Baron-Cohen et al. 1999).

However, children with autism can accurately represent some mental states such as simple desires and emotions (e.g., Tan and Harris 1991; Yirmiya et al. 1992), true beliefs (e.g., Sparrevohn and Howie 1995), and intentions (e.g., Carpenter et al. 1998; Russell and Hill 2001; Grant et al. 2005). And children with high-functioning autism usually make correct false belief inferences, perhaps because they use compensatory verbal strategies (e.g., Bauminger and Kasari 1999; Bowler 1992; Happé 1994, 1995). Even in advanced theory of mind tasks, such as 'strange stories' in which children have to recognize irony, bluff and sarcasm, children with high-functioning autism are able to ascribe mental states (e.g., Happé 1994). Understanding intentions is important for many aspects of social communication, including moral judgment (e.g., Grant et al. 2005; Blair 1996; Weisberg and Leslie 2012). Importantly, individuals with autism can in many circumstances distinguish intentional from accidental harm in their moral judgments (e.g., Leslie et al. 2006; Moran et al. 2011; Buon et al. 2013).

False Belief and Counterfactual Reasoning

False belief reasoning may be related to counterfactual reasoning. Typically developing children develop the ability to think about things that did not happen, such as 'if Anne had not moved the chocolate, where would it be?' (for a review see Byrne 2016). Children's development of counterfactual reasoning develops throughout middle childhood even to young adolescence (e.g., Beck et al. 2006; Guttentag and Ferrell 2004; Rafetseder et al. 2013; see also; Beck and Riggs 2014; Rafetseder and Perner 2014). Their accuracy in counterfactual reasoning is positively correlated with their accuracy in false belief reasoning such as 'where does Sally think the chocolate is?' (e.g., Riggs et al. 1998; Peterson and Riggs 1999; see also; Robinson and Beck 2000), even when age, verbal intelligence, and other linguistic factors are controlled (e.g., Guajardo et al. 2009; Müller et al. 2007; see also; Perner et al. 2004). The two sorts of inferences activate similar brain areas, including the left temporo-parietal junction and precuneus, considered to be a mentalizing network, and the bilateral prefrontal cortex and right inferior parietal lobule, considered to be an executive control network (e.g., Van Hoeck et al. 2014).

Children with high functioning autism often make accurate counterfactual inferences (e.g., Grant et al. 2004; Peterson and Bowler 2000; Scott et al. 1999). Although they can make accurate counterfactual inferences, they differ from typically developing children in the sorts of counterfactuals they construct. They tend to create subtractive counterfactuals that delete aspects of what happened, e.g., they imagine that the kitchen floor would not have become dirty with muddy footprints if they had not gone outside to play, whereas typically developing children tend to create counterfactuals that add new aspects to what happened, increasingly so as they get older, e.g., they imagine the kitchen floor would not have become dirty if they had wiped their feet (e.g., Begeer et al. 2009, 2014; see also). Typically developing children may develop 'mindreading' abilities by relying on their ability to add as well as delete events from a mental representation of reality (e.g., Guajardo and Turley-Ames 2004).

Understanding a counterfactual such as 'if Anne hadn't moved the chocolate it would be in the cupboard' requires children to entertain two possibilities, the counterfactual conjecture 'Anne did not move the chocolate and it is still in the cupboard' and also the presupposed or known facts, 'Anne moved the chocolate and it is not in the cupboard'. Similarly, understanding a false belief such as 'Sally believes the chocolate is in the cupboard' also requires children to entertain two possibilities, Sally's belief, 'Anne did not move the chocolate and it is still in the cupboard' and the child's own knowledge of the situation, 'Anne moved the chocolate and it is not in the cupboard' (e.g., Rasga et al. 2016). Counterfactual and false belief reasoning may be linked because they both require similar abilities. They may require executive function skills, such as working memory to envisage a representation of reality and an alternative at the same time (e.g., Carlson and Moses 2001; Müller et al. 2007), inhibitory control to suppress attention to one representation (e.g., Leslie 1988; Robinson and Beck 2000), and flexibility to consider different perspectival representations of the same situation (e.g. Müller et al. 2007; Drayton et al. 2011). False belief reasoning may be the more difficult task because it requires tracking

Table 1 The ages of the children in the study

	Children with autism (n = 37)			Typically developing children (n = 37)		
	Range	Mean	SD	Range	Mean	SD
Age in months	75–131	102.8	19.9	73–131	103.1	20.3
6 year old group	75–82	78.3	2.4	73–82	78	2.7
8 year old group	97–107	102.5	2.9	98–106	103.1	2.8
10 year old group	121–131	125.7	3.8	122–131	126.3	3.1

the epistemic status of each of the possibilities, one corresponding to the other person's belief, and one corresponding to one's own knowledge of the facts.

Our aims in the current study are to examine false belief and counterfactual inferences in children with high functioning autism and Asperger syndrome, compared to typically developing children. Our first aim is to discover whether children with high functioning autism can perform above chance in false belief reasoning on the new unexpected change-of-intentions task. We hypothesized that they would show a developmental delay, that is, their performance will not be as accurate as typically developing children at younger ages, but it will be comparable at older ages (e.g., Baron-Cohen et al. 1985). We tested children aged 6, 8, and 10 years. Typically developing children make mistakes on false belief inferences on the unexpected change-of-intentions task at the age of 6 and 7 years, but their accuracy improves by the age of 8 and 9 years (e.g., Rasga et al. 2016). Our second aim is to discover whether children with high functioning autism can make counterfactual inferences about other people's intentions in the unexpected change-of-intentions task. We hypothesized that their accuracy in counterfactual reasoning would emerge earlier than their accuracy in false belief reasoning, just as it does in typically developing children.

Method

Participants

The participants were 74 children, 37 children diagnosed with high-functioning autism and 37 typically developing children. All diagnoses of children with autism were made by clinicians experienced in the field of autism, independently of the present study. The diagnoses were based on observations of the participants and interviews with parents or caregivers, using the Autism Diagnostic Observation Schedule (Lord et al. 2000) and the Autism Diagnostic Interview (Lord et al. 1994). All of the children with high-functioning autism had a clinical diagnosis of pervasive developmental disorder, according to the criteria of the diagnostic and statistical manual of mental disorders—DSM-IV (2002), and the international classification of diseases and related health problems—ICD-10 (2004).

None of the children with autism had a low coefficient of intelligence, according to the Wechsler Intelligence Scale for Children, 3rd edition—WISC III (Wechsler 2002). We established the general IQ of 70 points as a minimum cut-off point for inclusion, as in other studies (e.g., Brent et al. 2004; White et al. 2009)[1] and in fact all of the children with autism who participated had an IQ above 80 points. The 37 children in the autism group included 12 children who were recruited from the Garcia de Orta Hospital, Lisbon, 10 from the PIN Centre of Development, Lisbon, and 15 from the Portuguese Association for Asperger Syndrome (APSA). There were 12 children in the 6 year old group (11 boys and 1 girl), 12 children in the 8 year old group (10 boys and 2 girls), and 13 children in the 10 year old group (12 boys and 1 girl). Their mean ages and age ranges are provided in Table 1.

The comparison group of 37 typically developing children was recruited from a school in Lisbon. We selected children to match the ages and genders of the children with autism and so there were 12 children in the 6 year old group (11 boys and 1 girl), 12 children in the 8 year old group (10 boys and 2 girls), and 13 children in the 10 year old group (12 boys and 1 girl), as Table 1 shows.

All of the children were screened by the WISC subtest of vocabulary, which was read aloud to the children by the researcher (the first author).[2] The criterion was set that if the typically developing children scored below 1.3 SD of the score for children with autism, they would be excluded from the study. In fact, none of the children in the typically developing group were excluded.

[1] This test was administered by the child's psychologist and the scores made available to us for screening before the study was carried out.

[2] This test is part of the verbal comprehension subscale and measures children's knowledge of words and formation of concepts (Wechsler 2002). There are 36 items: 4 picture items and 32 verbal items.

The children in both groups came predominantly from middle/upper class families. In both groups, children were tested only if their parents first provided consent (97% of the parents invited to participate did so for the children with autism and 93% of the parents of the typically developing children) and if the child then agreed to participate (100% of the children in both groups did so).

Design

There were two groups of participants, children with autism and typically developing children. Within each of these groups, there were three age levels, 6, 8, and 10 year olds. Each participant listened to six stories and completed two reasoning tasks for each one—a false-belief task, and a counterfactual task. Thus the design was a 2 (group: children with autism or typically developing children) × 3 (age: 6 or 8 or 10 years) by 2 (reasoning task: false-belief or counterfactual) mixed factorial design, with repeated measures on the last factor.

Materials

All of the children completed six stories based on the novel change-of-intentions task (see the Appendix for the full set of materials). Each story was narrated by the researcher in a pre-recording played over headphones and each one was accompanied by pictures on a Macintosh Air laptop using *Open Sesame* software. Each picture was presented individually on the computer screen, with each accompanying sentence vocalised simultaneously over headphones. The stories were about simple actions. The desires were simple wants, e.g., wanting to watch cartoons. The obligations were simple instructions given by an adult, e.g., the child was told to do her homework. The stories were tested previously on a large set of typically developing children aged 6, 7, 8, and 9 years (see Rasga et al. 2016 for details). The stories were presented in a different random order to each child. After each story the children completed two reasoning tasks. Their first task was a false belief inference, for example, they were asked 'What does John believe is the reason that Anne is picking up the toys from the bedroom floor?' Their second task was a counterfactual inference, for example, they were asked, 'If Anne hadn't wanted to find her ball to play with it, what would have been the reason that Anne was picking up the toys from the bedroom floor?' They also completed a current-reason question, for example, 'What is the reason that Anne is picking up toys from the bedroom floor?', as a comprehension check. The tasks were presented in a different random order for each story to each child.[3]

Screening Test

All participants first completed a standard first order false-belief task about an unexpected change of location of objects, and they only completed the experimental task if they had succeeded in this first task. They were shown puppets and toys and told the puppet's names. They were then asked to say each doll's name. The experimenter enacted a scenario in which one puppet, Sally, placed a marble in her basket and left the scene. Then, another puppet, Anne, took the marble and put it in her own box. Sally then returned. The experimenter said aloud what the puppets were doing: *'This is Sally and Anne. Sally has a basket and Anne has a box. Sally puts a marble in her basket and then leaves the room. Anne then moves the marble from Sally's basket to her box. Sally then returns to the room.'* The child was asked a false-belief question, 'Where will Sally look for her marble?', a current-reality question, 'Where is the marble really?', and a memory question, 'Where was the marble in the beginning?'. All of the children in both groups correctly answered the three questions in this test and so no children were excluded on the basis of this task.

Procedure

For children with autism, during one of their regular therapy sessions, the child's psychologist told the child about the researcher and the experimental task, and then the researcher came into the room where the child was having the therapy session to carry out the study during the last 20 min of the session. For typically developing children, the researcher tested each participant individually in a quiet area of their school. All of the research was conducted on an individual basis, and each session lasted approximately 20 min. All children were asked to look and listen very carefully and they were told that they would be asked some questions about the stories. The children completed the screening change-of-locations task first, and then the experimental change-of-intentions task. They provided their responses verbally which were recorded by computer

[3] We included a fourth question about the conjectural future, e.g., 'What if next time Anne's mother does not tell her to tidy her room, what will be the reason that Anne is picking up toys?'. However, such conjectural inferences about future intentional relations are often not deterministic, e.g., the reason Anne picks up toys today may be to find her ball, but tomorrow the reason may be to find her doll or to look at a teddy, or any number of different reasons and so we do not include responses to these questions in the analyses.

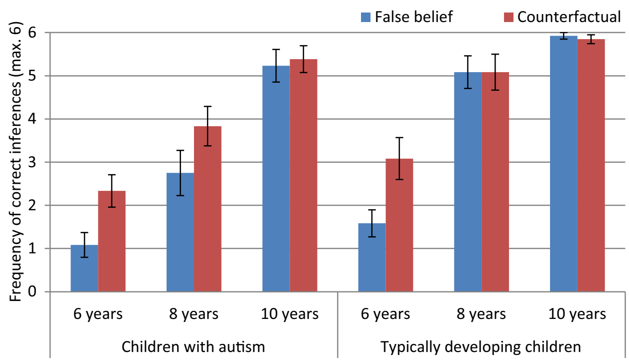

Fig. 2 Frequency of correct false belief and counterfactual inferences by children with autism and typically developing children at 6, 8, and 10 years of age. *Error bars* are standard error of the mean

software and also by the experimenter. Each child was given stickers or a pencil for their participation.

Results

Participants were given a score of 1 if they gave the correct response, and a score of 0 if they gave an incorrect response, or an alternative answer that did not refer to the desire or obligation. We carried out a 2 (group: children with autism or typically developing children) × 3 (age: 6 or 8 or 10 years) × 2 (inference: false belief or counterfactual inference) ANOVA on the correct responses, with repeated measures on the last factor. It revealed a main effect of group, F (1, 68) = 13.69, p < .001, $\eta^2_p = 0.17$, as typically developing children made more correct inferences than children with autism; a main effect of age, *F* (2, 68) = 59.92, *p* < .001, $\eta^2_p = 0.64$, as older children made more correct inferences than younger ones, and a main effect of reasoning task, *F* (1, 68) = 29.32, *p* < .001, $\eta^2_p = 0.30$, as children made more correct counterfactual inferences than false-belief ones, as Fig. 2 shows. Group did not interact with age, F (2, 68) = 2.15, p = .125, or with reasoning task, F (1, 68) = 2.17, p = .15, age and reasoning task interacted, *F* (2, 68) = 10.56, *p* < .001, $\eta^2_p = 0.24$, and the interaction of the three variables was not significant, F (2, 68) = 2.56, p = .085, $\eta^2_p = 0.07$.

We decomposed the non-significant three-way interaction (see Winer et al. 1971, for a defense of comparisons in such circumstances), with a Bonferroni corrected alpha of p = .004 for 12 comparisons. At 6 years of age, children with autism made as few correct inferences as typically developing children for false belief inferences, t (68) = 1.1, p = .321, and counterfactual inferences, t (68) = 1.40, p = .166; however at 8 years of age children with autism made fewer correct inferences than typically developing children for false belief inferences, t (68) = 4.66, p < .001, d = 1.34, but not counterfactual inferences on the corrected alpha, t (68) = 2.33, p = .02, d = 0.67; importantly, by 10 years of age, children with autism made as many correct inferences as typically developing children for false belief inferences, t (68) = 1.44, p = .15, and counterfactual inferences, t < 1. The comparisons corroborate our hypothesis that children with autism show a developmental delay in making accurate false belief inferences about other people's intentions at 8 years, but the gap is closed by 10 years of age, as Fig. 2 shows.

Furthermore, typically developing children made more correct counterfactual inferences than false belief ones at 6 years of age, t (68) = 5.02, p < .001, d = 1.45, but this gap was closed by 8, and 10 years, t < 1 in both cases. In contrast, children with autism made more correct counterfactual inferences than false belief ones at 6 years of age, t (68) = 4.18, p < .001, d = 1.21, this difference persisted at 8 years, t (68) = 3.63, p < .001, d = 1.05, but importantly, the gap was closed at 10 years, t < 1, as Fig. 2 also shows. The comparisons corroborate our hypothesis that children with autism make more correct counterfactual inferences than false belief inferences, just as typically developing children do.

To rule out the possibility that the results are due to children misunderstanding the current reason, e.g., 'What is the reason that Anne is picking up toys?', we carried out a supplementary analysis on only those responses for which the child gave the correct answer to the current-reason question, which corresponded to 99% of the full set of responses. It showed exactly the same results.[4] We also

[4] The analysis showed a main effect of group, F(1, 68) = 11.54, p < .001, $np^2 = 0.15$, age, F(2, 68) = 45.51, p < .001, $np^2 = 0.58$, and reasoning task, *F* (1, 68) = 33.59, p < .001, $np^2 = 0.33$. Group did not interact with age, F (2, 68) = 1.92, p < .155, or reasoning task, F (1,68) = 1.69, p < .198; however age and reasoning task interacted, *F* (1, 68) = 12.74, p < .001, $np^2 = 0.27$ and the interaction of the three variables was not significant, F (2, 68) = 2.69, p < .075, $np^2 = 0.07$. The decomposition of the non-significant three-way interaction, with a Bonferroni corrected alpha of p = .004, showed that at 6 years of age, children with autism made as few correct inferences as typically developing children for false belief inferences, t < 1, and counterfactual inferences t (68) = 1.25, p = .217; however at 8 years of age children with autism made fewer correct inferences than typically developing children for false belief inferences, t (68) = 4.54, p < .001, d = 1.31, and counterfactual inferences, although the latter was not significant on the corrected alpha, t (68) = 2.08, p < .04, d = 0.60; by 10 years of age, children with autism made as many correct inferences as typically developing children for false belief inferences, t (68) = 1.44, p = .15 and counterfactual inferences, t < 1. The comparisons also showed that typically developing children made more correct counterfactual inferences than false belief ones at 6 years of age, t (68) = 5.57, p < .001, d = 1.46, but this gap was closed by 8 years and 10 years, t < 1 in both cases. In contrast, children with autism made more correct counterfactual inferences than false belief ones at 6 years of age, t (68) = 4.50, p < .001, d = 1.29, this difference persisted at 8 years, t (68) = 3.61, p < .001, d = 1.04, and the gap was closed at 10 years t < 1.

Table 2 The percentages of correct inferences by typically developing children and children with autism to both the false belief and counterfactual inference, to neither, or to only one of them

	Both correct	Neither correct	Counterfactual only	False belief only
Children with autism				
6 years	15	58	24	3
8 years	46	36	18	0
10 years	76	8	8	8
Typically developing children				
6 years	24	46	28	3
8 years	78	8	7	7
10 years	97	1	1	0

note that half of the stories referred to a change from an obligation to a desire, and the other half referred to a change from a desire to an obligation (see also Rasga et al. 2016). We included this factor in a further analysis, but it showed no main effect and did not interact with any other variable and so we combined both sorts of stories in the analysis reported here.

The younger children performed at chance level whereas the older ones performed at reliably above chance, that is, they were correct on more than 2 out of the 6 inferences (chance performance was set at 0.33, as children generally answered by referring to the desire, or to the obligation, or to an alternative reason that did not mention the desire or obligation). The typically developing children performed at chance level on the false belief inferences at 6 years, binomial $p = .403$, but above chance at 8 years and 10 years, binomial $p < .001$ in both instances; and they performed above chance on the counterfactual inferences at 6 years, binomial $p = .018$, as well as at 8 and 10 years, binomial $p < .001$, in both cases. Children with autism performed at chance level on the false belief inferences at 6 years, binomial $p = .057$ and at 8 years, binomial $p = .063$, but not at 10 years, binomial $p < .001$; and they performed at chance level on the counterfactual inferences at 6 years, binomial $p = .063$, but not at 8 or 10 years, binomial $p < .001$ in both cases. The results are consistent with the observation that children with autism show a developmental delay in making accurate inferences about other people's intentions compared to the typically developing children, but the gap is closed for the older children with autism.

The children's performance on the false belief and counterfactual inferences was positively correlated, for children with autism, $r\ (37) = 0.871$, $p < .001$, and for typically developing children, $r\ (37) = 0.805$, $p < .001$. As Table 2 shows, typically developing 6 year olds rarely gave the correct response to both the false belief and the counterfactual task, instead they tended to give the correct response to neither, or to only the counterfactual task, and they very rarely gave the correct response to only the false belief task; the children with autism showed a similar pattern. In contrast, the typically developing 8 year olds tended to give the correct response to both the false belief and the counterfactual task, they rarely gave the correct response to neither, or to just one; strikingly, children with autism showed a different pattern, they gave the correct response to both the false belief and the counterfactual task, or to neither, they sometimes gave the correct response to just the counterfactual inference, and never to just the false belief inference. The typically developing 10 year olds tended to give the correct response to both the false belief and the counterfactual task, as did the children with autism at this age, although to a lesser extent. The pattern of inferences for children with autism at 10 years of age appears strikingly similar to that of typically developing children at 8 years, as Table 2 shows.

We ruled out the possibility that the results were due to differences in intelligence between the children with autism and the typically developing children. Since we did not assess IQ in the typically developing children, we relied on the vocabulary sub-test of the WISC-III, which is used as a composite verbal IQ and is a predictor of IQ in adults and children with autism (e.g., Kaufman 1990; Minshew et al. 2005; Sattler 1992). There was no difference in verbal IQ between typically developing children ($M = 11.89$, $SD = 1.41$) and children with autism ($M = 11.65$, $SD = 1.36$), $t\ (72) = 0.756$, $p = .452$. For children with autism, there was no correlation between verbal IQ and false belief reasoning, $r\ (37) = 0.267$, $p = .111$, nor between verbal IQ and counterfactual reasoning, $r\ (37) = 0.164$, $p = .333$. Similarly, for typically developing children, there was no correlation between verbal IQ and false belief reasoning, $r\ (37) = 0.018$, $p = .914$, nor between verbal IQ and counterfactual reasoning, $r\ (37) = 0.025$, $p = .882$. For children with autism, there was a correlation between overall IQ and false belief reasoning, $r\ (37) = 0.362$, $p = .027$, but none between IQ and counterfactual reasoning, $r(37) = 0.265$, $p = .113$. Overall the results suggest that the developmental delay in children with autism in their false belief inferences about other people's intentions does not arise because of differences in verbal IQ between them and the typically developing children.

General Discussion

An important challenge for young children during middle childhood, from the ages of 6–10 years, is to begin to reason accurately about unexpected changes of intention, and in particular to make accurate inferences about other people's false beliefs about the reason for a person's action when it has changed unexpectedly, and to make inferences about what the reason for the person's action would have been if the reason had not changed. Young children with autism experience difficulties in making false belief and counterfactual inferences about unexpected changes of intention, just as typically developing children do; their difficulties persist for longer than the difficulties experienced by typically developing children, but they nonetheless resolve them to succeed in making such inferences as they progress through middle childhood. An implication of the results is that it appears that children with high functioning autism and Asperger syndrome do not lack the ability to make false belief and counterfactual inferences about other people's intentions, nor do they perform qualitatively differently from typically developing children; instead their development of the necessary skills to perform these tasks, although delayed, appears to take the same general course as that of typically developing children.

One limitation of the study is that it did not include children at 12 years of age, and it may be useful for future research to examine this age group, in particular to establish whether the pattern of inferences for children with autism at 12 years is the same as for typically developing children at 10 years, that is, correct for both inferences, as Table 2 shows.

Importantly, at 6 years of age, children with autism, like typically developing children, make more correct counterfactual inferences than false belief ones, even when they both concern mental states. The finding extends the result that children find counterfactual reasoning easier than false belief reasoning, to the new change-of-intentions task in which not only false belief inferences, but also counterfactual inferences refer to mental states (Rasga et al. 2016). It corroborates the suggestion that mastery of second order false belief reasoning is a significant cognitive achievement (e.g., Miller 2009; Perner and Wimmer 1985). Children may be able to reason about false beliefs, e.g., John will think that Anne is picking up toys to find her ball to play with it, in part because they can reason about counterfactuals, if Anne's mother had not told her to tidy her room, she would be picking up toys to find her ball to play with it. Counterfactuals require children to envisage two possibilities, the conjecture, 'Anne's mother did not tell her to tidy her room and Anne was picking up toys to find her ball' and the presupposed facts, 'Anne's mother told her to tidy her room and Anne was not picking up toys to find her ball' (Byrne 2016). An implication of the results is that the difficulty that children experience in making counterfactual inferences about other people's intentions at age 6 years which persists for children with autism to age 8 years, may underlie in part their difficulty in making false belief inferences, and thus contribute to their challenges in understanding mental states (e.g., Zalla et al. 2009; Begeer et al. 2009).

Importantly, the study shows that differences between children with autism and typically developing children in their reasoning about changes of intention occur around 8 years of age. Children with autism make fewer correct false belief inferences about changes of intentions than typically developing children at this age, and the gap in accuracy between false belief and counterfactual inferences persists for them at this age, whereas it has been closed for typically developing children. An important implication of this finding is that it is at this age that children with autism may benefit most from any potential aids or compensatory strategies to help them think about other people's reasons for their actions, and to track changes in their intentions.

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Author Contributions CR conceived of the study, participated in its design and coordination, performed the measurement and performed the statistical analysis, and interpretation of the data and drafted the manuscript; RMJB conceived of the study, participated in the design and coordination, and interpretation of the data; and drafted the manuscript. ACQ conceived of the study, participated in the design and coordination; and drafted the manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Appendix: Scenarios Used in the Study

The stories were designed to have the same structure and each one had four scenes. In the desire to obligation condition, illustrated here, in scene 1, child A tells child B that he or she has a reason *X* for their action. In scene 2, child B leaves the scene. In scene 3 an adult provides child A with a different reason *Y* for the action. In scene 4, child B returns and observes child A performing the action. The obligation to desire condition was identical except that scene 1 and scene 3 were switched. The translation into English is provided first, and the original Portuguese version presented to participants is presented second. For each scenario the questions are presented in the order: current reason; false belief; counterfactual. In the desire-to-obligation condition, the correct answer to the current-reason question makes reference to the obligation, e.g., because her mother told her to tidy her room, and the correct answers to the false-belief and counterfactual inferences make reference to the desire, e.g., because she wants to find her ball to play with it. For the obligation-to-desire condition the correct answer to the current-reason question makes reference to the desire, and the correct answers to the false-belief and counterfactual inferences make reference to the obligation.

Picking Up Toys

In the bedroom, John hears his sister Anne say she wants to find her ball to play with it. John goes into the kitchen. But while he is away, Anne's mother tells Anne to tidy her bedroom. When John comes back into Anne's bedroom, he sees her picking up the toys from the bedroom floor.

What is the reason that Anne is picking up the toys from the bedroom floor? What does John believe is the reason that Anne is picking up the toys from the bedroom floor? If Anne's mother hadn't told Anne to tidy her bedroom, what would have been the reason that Anne was picking up the toys from the bedroom floor?

No quarto, o João ouve a sua irmã Ana dizer que ela quer encontrar a sua bola para brincar com ela. O João vai para a cozinha. Mas enquanto ele está fora, a mãe da Ana manda a Ana arrumar o quarto dela. Quando o João volta ao quarto da Ana, ele vê a Ana a mexer nos brinquedos no chão do quarto.

Qual é que a razão para a Ana estar a mexer nos brinquedos no chão? Qual é que o João acredita ser a razão para a Ana estar a mexer nos brinquedos no chão? Se a mãe da Ana não tivesse mandado a Ana arrumar os brinquedos, qual teria sido a razão para a Ana estar a mexer nos brinquedos no chão?

Writing on Paper

In the living room, Roy hears Betty say she wants to write a letter to send to her friend. Roy goes into the garden. But while he is away, Betty's father tells Betty to do her homework. When Roy comes back into the living room, he sees Betty writing on paper.

What is the reason that Betty is writing on paper? What does Roy believe is the reason that Betty is writing on paper? If Betty's father hadn't told Betty to do her homework, what would have been the reason that Betty was writing on paper?

Na sala de estar, o Rui ouve a Bete dizer que ela quer escrever uma carta para enviar ao seu amigo. O Rui vai para o jardim. Mas enquanto ele está fora, o pai da Bete manda a Bete fazer os seus trabalhos de casa. Quando o Rui volta para a sala de estar, ele vê a Bete a escrever no papel.

Qual é a razão para a Bete estar a escrever num papel? Qual é que o Rui acredita ser a razão para a Bete estar a escrever num papel? Se o pai da Bete não tivesse mandado a Bete fazer os trabalhos de casa, qual teria sido a razão para a Bete estar a escrever num papel?

Switching on TV

In the living room, Mary hears Tom say he wants to switch on the TV, to watch a cartoon DVD. Mary goes into the bedroom. But while she is away, Tom's grandmother tells Tom to switch on the TV to watch the news. When Mary comes back into the living room, she sees Tom switching on the TV.

What is the reason that Tom is switching on the TV? What does Mary believe is the reason that Tom is switching on the TV? If Tom's grandmother hadn't told Tom to switch on the TV to watch the news, what would have been the reason that Tom was switching on the TV?

Na sala de estar, a Maria ouve o Tomás dizer que ele quer ligar a TV para assistir a um DVD de desenhos animados. A Maria vai para o quarto. Mas enquanto ela está fora, a avó do Tomás manda o Tomás ligar a televisão para assistir ao noticiário. Quando a Maria volta para a sala de estar, ela vê o Tomás a ligar a TV.

Qual é a razão para o Tomás estar a ligar a TV? Qual é que a Maria acredita ser a razão para o Tomás estar a ligar a TV? Se a avó do Tomás não tivesse mandado o Tomás ligar a TV para ver o noticiário, qual teria sido a razão para o Tomás estar a ligar a TV?

Using a Spoon

In the kitchen, Peter hears Vera say she wants to take a spoonful of honey to taste something sweet. Peter goes into the living room. But while he is away, Vera's mother tells Vera to take her cough medicine. When Peter comes back into the kitchen, he sees Vera putting a spoon in her mouth.

What is the reason that Vera is putting a spoon in her mouth? What does Peter believe is the reason that Vera is putting a spoon in her mouth? If Vera's mother hadn't told Vera to take her cough medicine, what would have been the reason that Vera was putting a spoon in her mouth?

Na cozinha, o Pedro ouve a Vera dizer que ela quer tomar uma colher de mel para comer algo doce. O Pedro vai para a sala de estar. Mas enquanto ele está fora, a mãe da Vera diz à Vera para tomar o seu remédio para a tosse. Quando o Pedro volta para a cozinha, ele vê a Vera a pôr uma colher na boca.

Qual é a razão para a Vera estar a pôr uma colher na boca? Qual é que o Pedro acredita ser a razão para a Vera estar a pôr uma colher na boca? Se a mãe da Vera não tivesse mandado a Vera tomar o xarope para a tosse, qual teria sido a razão para a Vera estar a pôr uma colher na boca?

Going to the Lake

At the park bench, Sonia hears Michael say he wants to go to the lakeside to feed the ducks. Sonia goes to the slide. But while she is away, Michael's aunt tells Michael to fetch his boat from the lake. When Sonia comes back to the park bench, she sees Michael near the lake.

What is the reason that Michael is near the lake? What does Sonia believe is the reason that Michael is near the lake? If Michael's aunt hadn't told Michael to fetch his boat from the lake, what would have been the reason that Michael was near the lake?

No banco do parque, a Sónia ouve o Miguel dizer que ele quer ir ao lago para alimentar os patos. A Sónia vai para o escorrega. Mas enquanto ela está fora, a tia do Miguel manda o Miguel buscar o barco ao lago. Quando a Sónia volta ao banco do parque, ela vê o Miguel perto do lago.

Qual é a razão para o Miguel estar perto do lago? Qual é que a Sónia acredita ser a razão para o Miguel estar perto do lago? Se a tia do Miguel não tivesse mandado o Miguel buscar o barco no lago, qual teria sido a razão para o Miguel estar perto do lago?

Opening the Fridge

At the table, Louis hears Martha say she wants to eat an ice-cream for dessert. Louis goes to the bathroom. But while he is away, Martha's father tells Martha to eat some fruit. When Louis comes back to the table, he sees Martha opening the fridge.

What is the reason that Martha is opening the fridge? What does Louis believe is the reason that Martha is opening the fridge? If Martha's father hadn't told Martha to eat some fruit, what would have been the reason that Martha was opening the fridge?

Na mesa, o Luís ouve a Marta dizer que ela quer comer um gelado para a sobremesa. O Luís vai para a casa de banho. Mas enquanto ele está fora, o pai da Marta manda a Marta comer fruta. Quando o Luís volta para a mesa, ele vê a Marta abrir o frigorífico.

Qual é a razão para a Marta estar a abrir o frigorífico? Qual é que o Luís acredita ser a razão para a Marta estar a abrir o frigorífico? Se o pai da Marta não tivesse mandado a Marta comer uma fruta, qual teria sido a razão para a Marta estar a abrir o frigorífico?

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