A temporally sustained implicit theory of mind deficit in autism spectrum disorders

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1. Introduction

Individuals with an autism spectrum disorder (ASD) are thought to be impaired at processing the mental states of others. This is also described as a deficit in theory of mind (ToM) or ‘mindblindness’ (Baron-Cohen, 1995; Frith, 2001). Evidence for this limitation comes from findings that children with autism typically fail explicit (e.g., verbal response format) false-belief tasks, a crucial test for ToM abilities (Baron-Cohen, Leslie, & Frith, 1985; Happé, 1995; Wimmer & Perner, 1983), whereas 4-year-old neurotypical children, of a similar verbal mental age, pass such tasks (Baron-Cohen et al., 1985). For example, in the now classic Sally-Anne false-belief paradigm (performed with still images, movies, or ‘live’ with puppets and actors), Sally places a ball in a container and then leaves the room. Anne then hides the ball in a different container. Sally returns and participants are asked where she will search for her ball. The correct answer is to predict Sally’s behaviour based on her false-belief about the ball’s location, which differs from the actual location of the ball.

Alongside these explicit ToM abilities, measured with tasks in which participants make overt responses to stimuli that require mentalizing, there appears to be a capacity for implicit ToM processing (Clements & Perner, 1994; Kovacs, Téglás, & Endress, 2010; Low & Watts, 2013; Onishi & Baillargeon, 2005; Schneider, Bayliss, Becker, & Dux, 2012; Schneider, Lam, Bayliss, & Dux, 2012; Senju, Southgate, Snape, Leonard, & Csibra, 2011; Senju, Southgate, White, & Frith, 2009). In implicit ToM tests, no instructions to process the mental state of a character/actor are given.
Instead researchers measure spontaneous behaviour during false-belief tasks, such as predictive eye-movements that reflect participants’ expectations about the actor’s beliefs (Southgate, Senju, & Csibra, 2007). As such it is possible to assess whether participants keep track of an actor’s mental state without using an explicit response format. Such research has lead to the hypothesis that implicit and explicit ToM abilities reflect the operation of different functional cognitive systems (Apperly & Butterfill, 2009). Implicit ToM abilities have been described as operating efficiently and in the absence of awareness. In contrast, explicit ToM abilities have been proposed to operate slowly, to be flexible and consciously accessed.

Although children with ASD typically fail explicit false-belief tasks, some older children and adults with high-functioning autism or Asperger’s syndrome (a related social-deficit disorder, without language impairments) can usually pass such tasks (Bowler, 1992; Larson, South, Krauskopf, Clawson, & Crowley, 2011; Peterson, Slaughter, & Paynter, 2007; Scheeren, de Rosnay, Koot, & Begeer, in press). Competence demonstrated in these paradigms has prompted the proposal that high-functioning ASD individuals acquire the capability to reason explicitly about others’ false-beliefs via compensatory learning. Put differently, they develop rules in order to pass such tests and, indeed, interact more effectively in social settings (Baez et al., 2012; Gantman, Kapp, Orenski, & Laugeson, 2012; Krieger, Kinébanian, Prodinger, & Heigl, 2012).

Despite these ‘learned’ explicit ToM abilities in individuals with high-functioning ASD, it appears that difficulties in implicit ToM processing nevertheless persist (Frith, 2004). Striking evidence comes from a recent study of adults with high-functioning ASD (Senju et al., 2009). Senju et al. (2009) administered a variety of explicit ToM tasks and measured implicit ToM abilities with an anticipatory looking false-belief task, similar to the one used by Southgate et al. (2007). Individuals with high-functioning ASD as well as neurotypical controls watched movies, which showed an actor standing behind a half wall containing two windows. Two identical boxes were located just underneath the windows. In the familiarization trials, a puppet placed a ball in one of the two boxes. After the ball was placed, both windows lit up and a chime sounded, and then the actor reached a hand through one of the windows to retrieve the ball from the adjacent box. These familiarization trials established the contingency between the light and chime cues and the actor’s subsequent reach to retrieve the ball. In the test trial, everything was identical except that while the actor’s back was turned before the reach, the puppet moved the ball from one box to the other. Following the light and chime cue in the test trial, an eye-tracker was used to assess if participants looked to the box consistent with the actor’s false-belief about the location of the ball. Senju et al. (2009) found that neurotypical individuals displayed eye-movement patterns (first fixations and fixation durations) suggesting that they represented the actor’s belief about the location of the ball. Thus, they anticipated the actor’s behaviour in line with her false-belief. For the ASD group, however, the authors were unable to find evidence for such behaviour. Importantly, this lack of implicit ToM processing in the ASD group, despite neurotypical-like explicit ToM abilities, supports the hypothesis that implicit and explicit ToM systems are distinct (Apperly & Butterfill, 2009).

The results of Senju et al. are provocative and important, however there are limitations in this study that require extension. On a theoretical level, we cannot clearly infer from the work of Senju et al. whether differences in memory and learning processes are relevant for both the implicit and explicit ToM systems. Specifically, it is unknown whether the learning observed for explicit ToM task performance influenced implicit ToM as the former was measured multiple times while the latter was probed only once. Put differently, currently, a definitive statement cannot be made regarding whether learning processes can alleviate the ASD impairment in implicit ToM. This is also relevant as there is considerable debate regarding whether implicit and explicit ToM mechanisms develop along a developmental trajectory or in a parallel fashion (Apperly & Butterfill, 2009; Baillargeon, Scott, & He, 2010; Perner & Roessler, 2012).

Methodologically speaking, employing a single trial to assess implicit false-belief processing has also a number of limitations. One would predict implicit false-belief tracking to be continuous and temporally sustained (Schneider, Bayliss, et al., 2012), if it indeed reflects a form of social analysis which humans constantly engage in. The single-trial design did not allow the temporal profile of implicit belief processing to be assessed. Further, given that individuals with ASD show attentional differences and visual hypersensitivities relative to neurotypicals (Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009; Dakin & Frith, 2005; Samson, Mottron, Soulières, & Zefferi, 2012) their eye-movement patterns may be influenced by low-level elements of the visual display or by its novelty (Asplund, Todd, Snyder, & Marr, 2010). Therefore, after increased periods of measurement exposure (>1 test trial), these influences may attenuate. Further, a single-trial design does not allow the assessment of whether individuals with ASD show spontaneous learning in implicit ToM tasks. Schneider, Bayliss, et al. (2012) recently demonstrated that neurotypical adults show sustained eye-movement patterns that are indicative of implicit ToM processing. The current study therefore uses the same multi-trial paradigm to test whether the implicit ToM deficit observed by Senju et al. (2009) in individuals with ASD extends over a prolonged time period.

Another issue arising from Senju et al. (2009) is the lack of a baseline condition for viewing behaviour such as a true-belief condition (Meinhardt, Sodian, Thoermer, Doehnel, & Sommer, 2011; Schneider, Bayliss, et al., 2012; Sommer et al., 2007). As mentioned earlier, the authors used familiarization trials and those did involve true belief situations. But, the authors’ critical experimental manipulation did not include a true-belief condition, which was directly compared to a false-belief condition. This is important because the altered attention processes and visual sensitivities typically observed in individuals with ASD might lead to unusual default eye-movement patterns relative to neurotypicals. Without a baseline condition, it is impossible to conclude with certainty that the eye-movement patterns exhibited by individuals with ASD are specific to false-belief conditions that require implicit ToM processing.
A final question that was not addressed by Senju et al. (2009) is whether or not individuals in their implicit ToM task were unaware of the belief manipulation. When adult individuals are observing social scenarios, such as the ones described above, it may trigger the explicit ToM system along with an implicit system. Thus, currently we cannot be confident that Senju’s eye-movement measure assessed a ToM process that operates in the absence of awareness.

To address these issues, we tested a group of adults with ASD and a group of matched neurotypical control participants using a multiple-trial implicit false-belief task. We presented both false- and true-belief scenarios over the course of approximately an hour, to examine the temporal profile of implicit ToM processing. In addition, to ensure that the current task indeed taps into implicit, rather than explicit ToM processes, we employed an extensive debriefing procedure (see also, Schneider, Bayliss, et al., 2012; Schneider, Lam, et al., 2012).

2. Method

2.1. Participants

Forty-four participants took part in this study, of which 20 were typical control volunteers (TC; mean age: 31.40 years, SD = 6.72 years, 16 males) and 24 individuals with high-functioning ASD (mean age: 27.67 years, SD = 7.71 years, 19 males). Participants received payment in return for their participation and The University of Queensland Ethics Review Committee approved the experimental protocol. Those with ASD were recruited through local ASD organizations (e.g., Autism Queensland), ASD clinics as well as the local press and needed to present a formal diagnosis by a registered clinician in order to qualify for the study. We confirmed ASD diagnoses using the Autism Diagnostic Observation Schedule (ADOS-G) Module 4 (Lord et al., 2000), the Ritvo Autism-Asperger’s Diagnostic Scale-Revised (RAADS-R; Ritvo et al., 2010) and the Autism-Spectrum Quotient questionnaire (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). TC individuals were recruited through the School of Psychology participation schemes, flyers, e-mail lists and the local press. Each potential control participant was interviewed and only those without any history of psychiatric, developmental or neurological conditions qualified for the study. These individuals were assessed in an intake interview and had to score below 32/50 on the AQ to be included in the study. Six ASD and 4 TC participants were excluded due to our selection criteria: Eight (5 ASD; 3 TC) participants showed explicit ToM processing during the implicit task (see below) and 2 (1 ASD; 1 TC) failed the diagnostic criteria (1 ASD participant did not show ASD according to the ADOS; 1 TC participant exceeded the AQ clinical threshold of 32/50). Thus, the final group numbers were n = 16 for TC and n = 18 for ASD participants.

2.2. Procedure

At the beginning of the testing day all participants first took part in the implicit ToM task. After being familiarized and set-up for the eye-tracking session participants were instructed to watch the displayed movies and detect a hand-wave from the actor towards the hand puppet (cover task). Following the eye-tracking paradigm, participants were taken through the funnelled debriefing procedure. The implicit ToM testing component was always undertaken first to avoid participants establishing an awareness of the belief manipulation/experimental purpose. Following implicit ToM testing all participants undertook the auxiliary measures and explicit ToM tasks in a randomized order. The auxiliary measures included the ADOS-G, administered by a research assistant trained in the application of this measure. Participants also completed the following self-report instruments: the RAADS-R, the AQ, the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004) and the Systematizing Quotient (SQT; Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). The latter two self-report instruments assess individual differences in empathetic traits (i.e., the capacity to recognize another person’s feelings and emotions) and systematic traits (i.e., the capacity to analyze and construct rules). Lastly, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) provided Verbal, Performance and Full Scale IQ scores.

2.3. Materials

2.3.1. Explicit ToM measures

In order to assess explicit ToM processing in both groups, all the participants completed a ToM scale (Wellman & Liu, 2004) and the advanced Strange Stories test (Happé, Brownell & Winner, 1999). The ToM scale included 7 separate simpler tasks in which the experimenter described or acted out social scenarios and asked test questions about characters’ mental states. In the more challenging Strange Stories task, participants read narratives and then answered questions about the mental viewpoint of a character (e.g., a girl is being polite and appreciative about a gift that she really did not want in order to not hurt the gift-giver’s feelings). This was contrasted to physical reasoning scenarios (e.g., participants have to describe that a man is making meringues out of egg-whites because he does not want to waste any food, even though he has easily enough food already). Both of these explicit ToM tests have been widely used to assess ToM abilities in children and adults (Benson, Sabbagh, Carlson, & Zelazo, in press; Martins-Junior, Sanvicente-Vieira, Grassi-Oliveira, & Brieutzke, 2011; Senju et al., 2009).

2.3.2. Implicit ToM measure and funnelled debriefing

All participants viewed implicit ToM movies intermixed with distracter filler trials for approximately 50 min. These movies are identical to those employed by Schneider, Bayliss, et al., 2012. The stimuli were controlled with Presentation software (Neurobehavioural Systems, Albany, CA) on a 17-in. LCD display. Viewing distance (58 cm) was constrained using a chin rest and eye-movements were measured with an Eyelink 1000 (sweep rate: 500 Hz; SR Research, Mississauga, Ontario, Canada). Forty ‘filler’ and 20 experimental movies were presented in a random order. In filler trials participants saw an actor sitting in a
chair behind a desk with two opaque boxes on it. In one filler movie type, a red ball was on top of one of the boxes (duration: 3 s) and in another a puppet placed the red ball in one of the boxes (duration: 29 s). Each of these concluded with a bell sounding and the actor then reaching towards the ball. Crucially one of the longer filler trials contained the hand-wave, which participants needed to detect. This task was employed to keep participants engaged and distracted from the main manipulation in the movies.

There were two types of experimental trials (duration between 66 and 73 s). In false-belief scenarios the puppet hid the ball in one of the boxes and then moved it into the other box. At this stage, the actor was present and watched these actions. The actor then left the room and the puppet moved the ball back to the initial box. This resulted in the actor’s belief mismatching the ball’s actual location when she returned (Fig. 1; http://youtu.be/yf2vVSaaF9Q). The true-belief scenarios were identical to the false-belief trials except that the actor was not present after the first ball movement (the actor did not see the ball being moved to the other box and back to the initial box). Thus, upon her return, her belief was consistent with the ball’s actual location (Fig. 1; http://youtu.be/HMaLIBRwN-Q).

In each experimental trial, once the actor re-entered the room and sat behind the desk a bell sounded and the final movie frame froze for 5 s. This frame was divided into three areas of interest (face, ball box and no-ball box) for the eye-tracking analysis. This allowed us to examine our key question: whether participants were more likely to have a viewing preference for the empty box (no-ball location) when the actor falsely believed the ball was at that location (false-belief condition), compared with when she correctly believed it was not at that location (true-belief condition). Two versions of the experimental trials were employed (true-belief-right and left and false-belief right and left) counterbalancing the initial and final locations of the ball and the actor’s gaze. Note that our actor wore a visor to avoid gaze-cueing effects (Frischen, Bayliss, & Tipper, 2007).

To ensure we were examining implicit ToM processing at the end of each session participants were taken through a funneled debriefing protocol used to assess implicit higher mental processes (Bargh & Chartrand, 2000, adjusted to our study, see Appendix A). This probed, with increasing specificity, whether participants engaged in conscious processing of the actor’s belief states. As 8 participants were identified as being conscious of the belief of the actor this procedure appears sensitive for explicit ToM screening.

3. Results and discussion

3.1. Group characteristics

The ASD and neurotypical groups were matched for gender, age and years of education. With respect to the additional measures, the two groups did not differ on the SQ or intelligence measure. There were, as expected, significant group differences on the AQ, EQ and RAADS-R (Table 1).

3.2. Explicit ToM measures

On the scaled ToM tasks both groups were at ceiling performance: TC M = 7.00/7 (SD = .00); ASD M = 6.72/7 (SD = .57). On the Strange Stories test the TC group showed high accuracy for the mental stories (M = 15.00/16, SD = 1.21) and physical stories (M = 15.75/16, SD = 0.45). Here a significant difference was revealed for the TC group between these conditions, t(15) = 1.42, p = .03, which confirmed that advanced mental and physical reasoning abilities were high, however also that mental reasoning was more challenging than physical reasoning. The ASD group also showed high accuracy for the mental stories (M = 13.78/16, SD = 2.44) and the physical stories (M = 14.67/16, SD = 1.71). However, in the ASD group no difference was found between the two story types (p = 0.11). This confirmed that advanced mental and physical reasoning abilities were high in the ASD group, with both types of reasoning being similarly challenging for this group. A significant group difference was found on the physical stories (p = .02). However, no significant group difference was found for the mental stories (p = .08). Overall, in line with previous research (Senju et al., 2009) both groups were able to ‘pass’ explicit ToM tests.

![Fig. 1. Belief processing scenarios: false- and true-belief. Upper stream: False-belief scenario (with ball finishing in the box to the right of the actor) – the hand puppet transfers a ball from one box to another, then the actor leaves the room and the hand puppet transfers the ball back to the initial box. The returning actor has the false-belief that the ball is in the box on her left side. Lower stream: True-belief scenario (with ball finishing in the box to the right side of the actor) – once the ball is placed in one box the actor leaves the room then a hand puppet transfers a ball from one box to another and then back to the initial box. The returning actor has the true-belief that the ball is in the box on her right side. After the human actor is seated, approximately at the 60 s mark of each movie, a bell sounds and the movie is frozen for 5 s.](http://youtu.be/yf2vVSaaF9Q)
3.3. Implicit ToM measure

To assess eye-movement behaviour the percentage of first fixations upon the three regions of interest (face, ball box, no-ball box) were submitted to a 2 (belief: false vs. true) × 3 (location: face vs. ball vs. no-ball) × 2 (group: ASD vs. TC) mixed factorial ANOVA. The 3-way interaction was significant, $F(2,64) = 3.62$, $p = .03$, $\eta^2_p = .101$, demonstrating that first fixations to the face, ball and no-ball locations in the false- and true-belief conditions differed as a function of group. To further investigate this interaction these fixation data from each group were submitted to separate 2 (belief: true vs. false) × 3 (location: face vs. ball vs. no-ball) repeated-measures ANOVAs.

For the TC group there was a significant 2-way interaction, $F(2,30) = 5.18$, $p = .012$, $\eta^2_p = .257$. Follow-up $t$-tests revealed a higher percentage of first fixations at the no-ball location under false-relative to true-belief conditions, $t(15) = 3.61$, $p = .003$, however the difference observed at the ball- ($p = .571$, Fig. 2) or the face-location did not reach significance (false-belief: 69.25% vs. true-belief: 77.57%, $p = .065$). These results replicate the pattern of results observed by Schneider, Bayliss, et al. (2012) and Schneider, Lam, et al. (2012) demonstrating eye-movement behaviour consistent with false-belief processing.

Table 1

<table>
<thead>
<tr>
<th>Measure</th>
<th>ASD (n = 18)</th>
<th>TC (n = 16)</th>
<th>$p$-Value$^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronological age (in years)</td>
<td>27.78</td>
<td>31.81</td>
<td>.12</td>
</tr>
<tr>
<td>Male: Female</td>
<td>15:3</td>
<td>13:3</td>
<td>1.00</td>
</tr>
<tr>
<td>Years of education</td>
<td>14.17</td>
<td>13.53</td>
<td>.46</td>
</tr>
<tr>
<td>Full IQ$^a$</td>
<td>112.61</td>
<td>113.94</td>
<td>.76</td>
</tr>
<tr>
<td>Performance IQ$^b$</td>
<td>111.56</td>
<td>110.75</td>
<td>.87</td>
</tr>
<tr>
<td>RAADS-R (out of 227, ASD cut off: 65)$^b$</td>
<td>115.35</td>
<td>52.19</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>AQ (out of 50)</td>
<td>29.61</td>
<td>16.06</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>EQ (out of 80)</td>
<td>27.67</td>
<td>44.75</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>SQ (out of 150)</td>
<td>69.22</td>
<td>63.19</td>
<td>.46</td>
</tr>
<tr>
<td>Communication (COM) – (ASD cut off: 2)$^c$</td>
<td>4.19</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Reciprocal Social Interaction (SOC) – (ASD cut off: 4)$^c$</td>
<td>9.13</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Imagination/creativity (ASD cut off: 1)$^c$</td>
<td>1.56</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Stereotyped behaviours and restricted interests (RRB) – (ASD cut off: 2)$^c$</td>
<td>2.94</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

$^a$Wechsler abbreviated scale of intelligence (Wechsler, 1999).

$^b$Ritvo Autism-Asperger’s Diagnostic Scale—Revised (Ritvo et al., 2010), ASD $n = 17$.

$^c$Autism Diagnostic Observation Schedule, Module 4 (Lord et al., 2000), $n = 16$.

$^d$Independent-groups $t$-test (2-tailed) or Fisher’s Exact test as appropriate.

No evidence of implicit belief processing was observed for the ASD group as the 2-way interaction between belief type and location was not significant ($p = .703$). Planned $t$-tests revealed no differences in the percentage of first fixations at the no-ball location between the false- and true-belief conditions ($p = .753$). In addition, no difference was observed at the ball ($p = .470$; Fig. 3) or the face location (false-belief: 78.34% vs true-belief: 79.34%, $p = .587$).

The primary result of interest for the current study was the extent to which both groups implicitly tracked the belief state of the actor across the entire time-course of the experiment. To assess this, for every two consecutive trials of the false- and true-belief conditions first fixations at the no-ball location were summed across all participants. This resulted in a total sum of first fixations to the no-ball loca-
tion as a function of the actor’s belief state for all participants in the ASD and TC group across 5 trial bins (Figs. 2 and 3). To assess the fixation behaviour at the no-ball location, data were submitted to a 2 (group: ASD vs. TC) × 2 (belief: false vs. true) × 5 (bin: 1 vs. 2 vs. 3 vs. 4 vs. 5) mixed factorial ANOVA. Crucially, a 2-way interaction between belief and group was significant, $F(1,32) = 7.89$, $p = .008$, $\eta^2_p = .198$, demonstrating that fixation patterns in the false- and true-belief conditions differed as a function of group at the no-ball location.

Based on this finding and our a priori hypotheses we then submitted both belief conditions’ data separately to two 2 (group: ASD vs. TC) × 5 (bin: 1 vs. 2 vs. 3 vs. 4 vs. 5) mixed factorial ANOVAs. Under false-belief conditions, we found a group effect, $F(1,32) = 6.13$, $p = .019$, $\eta^2_p = .18$, indicating that ASD individuals made fewer first fixations ($M = 18$, $SE = .05$), relative to neurotypicals ($M = .35$, $SE = .05$), towards the no-ball location. No such effect was to be found under true-belief conditions, $F(1,32) = .15$, $p = .701$, $\eta^2_p = .005$. This demonstrates that the group effects at the no-ball location were attributable to differences in the false- rather than the true-belief condition (Figs. 2 and 3). Lastly and of key relevance, for both groups this first fixation behavior at the no-ball location did not change over time (bin × group interaction for false- and true-belief conditions, $F < 1$). This confirms that false-belief tracking was found for the TC group over the entire time period of the experiment. Further, it indicates that at no point in time over the experiment did the ASD group show eye-movements consistent with false-belief tracking. This demonstrates that even over a prolonged time period, individuals with high-functioning ASD show no evidence of implicit ToM processing.

4. Conclusions

We investigated implicit ToM processing over a prolonged time period in individuals with high-functioning ASD and compared this group to neurotypical matched controls. Across the course of approximately an hour we found that neurotypical controls implicitly and continuously tracked the false-beliefs of an actor. However, we were unable to find any evidence for this behaviour in our ASD group.

Our findings provide important advances to previous work (e.g., Senju et al., 2009). Firstly, our debriefing procedure ensured we were measuring implicit ToM processes, which had not been previously assessed in ASD participants. Secondly, our use of multiple test trials ruled out that attention-differences or visual hypersensitivities (Baron-Cohen et al., 2009; Dakin & Frith, 2005; Samson et al., 2012) gave rise to previously observed implicit ToM deficits in ASD. In addition, it appears that over a prolonged time period individuals with ASD do not get more comfortable with the experimental setting to the extent that ‘neurotypical’ implicit ToM behaviour emerged. Also, and importantly, spontaneous learning did not occur in the ASD group over the course of one hour’s implicit ToM processing. Thirdly, our findings indicate that the deficit in implicit ToM processing observed in individuals with high-functioning ASD are specifically driven by behaviour differences displayed under false-belief conditions. As we found very similar behaviour in both groups on our implicit ToM eye-tracking measure under true-belief conditions ($p = .701$), we can be confident that default eye-movement differences in individuals with high-functioning ASD are not responsible for their observed differences, relative to neurotypicals, in implicit ToM processing (Senju et al., 2009).

Finally, and of key theoretical relevance, we found over repeated measurements, sustained group differences for false-belief trials in our implicit ToM task but similar explicit ToM performance in both groups. This suggests that learning processes associated with both explicit and implicit ToM systems are distinct (Apperly & Butterfill, 2009) with learning on one (explicit) not influencing performance on the other (implicit). Such dissociations have been observed for other cognitive domains (e.g., agency learning: Moore, Middleton, Haggard, & Fletcher, 2012). Thus, our findings provide further support for the proposal that explicit and implicit ToM functions develop in parallel (Perner & Roessler, 2012; Apperly & Butterfill, 2009) rather than in a continuous developmental trajectory (Baillargeon et al., 2010) and represent distinct systems (Apperly & Butterfill, 2009).
terfill, 2009). However, there is some evidence in healthy individuals, which suggests implicit ToM is a precursor for explicit ToM functions (Clements, Rustin, & McCallum, 2000; Thoermer, Sodian, Vuori, Perst, & Kristen, 2012). In addition, our previous work has indicated working memory resources are necessary for implicit ToM processes (Schneider, Lam, et al., 2012), which may suggest some overlap between the implicit and explicit ToM systems. Then again, previous work on implicit learning (Frensch & Rünger, 2003; Seger, 1994), suggests some involvement of attention and working memory resources (Mitchell, De Houwer, & Lovibond, 2009). Thus, future research should further investigate whether the implicit and explicit ToM systems indeed tap separate learning mechanisms.

In sum, the present study showed that individuals with high-functioning ASD do not implicitly track false-belief states of others even over a prolonged time period. As this was found alongside neurotypical-like explicit ToM performance, this may be a clinically significant deficit in this disorder and requires more investigation. In addition, the current results suggest that the system responsible for implicit ToM processes is indeed to some degree distinct from an explicit ToM system, which may even apply to its associated learning mechanisms.

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Appendix A.

A.1. Funneled debriefing procedure (adapted from Bargh and Chartrand, 2000)

1. What do you think the purpose of the experiment was?
2. What do you think this experiment was trying to study?
3. Did you think that any of the tasks you did were related in any way?

(If 'yes') in what way were they related?

4. Did anything you did on one task affect what you did on any other task?

(If 'yes') How exactly did it affect you?

5. When you were completing the wave detection task, did you notice anything unusual about the movies?

6. Did you notice any particular pattern or theme to the movies that were included in the wave detection task?

7. What were you trying to do while watching the movies and detecting the wave? Did you have any particular goal or strategy?

8. If thinking about the two boxes on the desk, what box do you think you spent most time on?

9. What do you think was the story in the movies?

10. Did you notice that the actor sometimes had a true belief about the ball location and sometimes a false belief about the ball location when coming back into the room?

(If participant is unsure ask: Did you notice that the actor sometimes was tricked about the ball location when coming back into the room and sometimes wasn't tricked about the ball location when coming back into the room?)

(If 'yes') How did those beliefs become true or false/how was the actor tricked?

References


