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

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ABSTRACT

Eye movements during false-belief tasks can reveal an individual's capacity to implicitly monitor others' mental states (theory of mind – ToM). It has been suggested, based on the results of a single-trial-experiment, that this ability is impaired in those with a high-functioning autism spectrum disorder (ASD), despite neurotypical-like performance on explicit ToM measures. However, given there are known attention differences and visual hypersensitivities in ASD it is important to establish whether such impairments are evident over time. In addition, investigating implicit ToM using a repeated trial approach allows an assessment of whether learning processes can reduce the ASD impairment in this ability, as is the case with explicit ToM. Here we investigated the temporal profile of implicit ToM in individuals with ASD and a control group. Despite similar performance on explicit ToM measures, ASD-diagnosed individuals showed no evidence of implicit false-belief tracking even over a one-hour period and many trials, whereas control participants did. These findings demonstrate that the systems involved in implicit and explicit ToM are distinct and hint that impaired implicit false-belief tracking may play an important role in ASD. Further, they indicate that learning processes do not alleviate this impairment across the presentation of multiple trials.

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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; Kovács, 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.

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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 distinct 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 attention differences and visual hypersensitivities relative to neurotypicals (Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009; Dakin & Frith, 2005; Samson, Mottron, Soulières, & Zeffiro, 2012) their eye-movement patterns may be influenced by low-level elements of the visual display or by its novelty (Asplund, Todd, Snyder, & Marois, 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 involved 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.

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