Belief-Attribution in Adults with and without Autistic Spectrum Disorders

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ABSTRACT

An important aspect of daily life is the ability to infer information about the contents of other people's minds, such as what they can see and what they know, in order to engage in successful interactions. This is referred to as possession of a 'Theory of Mind' (ToM). Past research has shown that adults with Autistic Spectrum Disorders (ASD) often show deficits in social communication abilities, although can successfully pass tests of explicit ToM. The current study utilized a computerized false-belief task to explore subtle differences (i.e., measuring response times and accuracy rates) in how efficiently ToM capacities – specifically, belief-attribution – are utilized in adults with and without ASD. In the task, participants were asked to attribute a belief-state to either themselves or another person, following establishment of a true or false-belief scenario. Results revealed comparable patterns of ToM engagement across individuals with and without ASD, with faster and more accurate responses to 'Self' versus 'Other' oriented questions, and slower response times when shifting between the 'Self' and 'Other' perspective compared to when maintaining a perspective. However, autistic individuals showed a particular deficit in correctly identifying a belief-state in false-belief trials, in which two contrasting belief-states had to be held in mind, suggesting more difficulty disengaging from current, reality based belief-states than neuro-typical individuals.

Lay Summary:

To successfully communicate, we have to think about what other people do/do not know; this is called having a 'Theory of Mind'. This study looked at how well people use their Theory of Mind when thinking about the contents of people's minds. Results showed that people with autism had difficulties considering more than one mental state at a time, suggesting they may have more trouble in stopping themselves thinking about what is happening in reality than people without autism.

Key Words: Theory of Mind; False-Belief; Belief-Attribution; Perspective-Taking; Autistic Spectrum Disorders

Introduction

Theory of Mind (ToM) refers to the ability to compute and attribute mental states to both oneself and other people. This includes the ability to understand that one's own mental states may change across time, and that other people's mental states may differ from one's own at any given point in time (Apperly, Samson, & Humphreys, 2005; Baron-Cohen, Tager-Flusberg, & Cohen, 2000; Oberman & Ramachandran, 2007; Premack & Woodruff, 1978). ToM serves a very social function, allowing individuals to successfully communicate, both verbally and non-verbally, by attributing meanings and motivations to the things that people may say or do, and allowing individuals to distinguish between different behaviours, such as goal-oriented versus non-goal oriented actions, ensuring appropriate responses to different scenarios are produced (Baron-Cohen, 2001; Frith & Frith, 2012; Wellman, 1990). Deficits in ToM can have severe repercussions on an individual's ability to relate to other people socially; for instance, difficulties in spontaneously and readily assessing what another person may or may not know can lead to difficulties in deciding what information needs to be explicitly stated, and what information is already known by a conversational partner, to ensure successful exchanges of information (Leslie & Frith, 1988; Kuroda et al., 2011; Ponnet, Buysse, Roeyers, De Clercq, 2008). In turn, these struggles in social interactions can lead to isolation and issues with depression, anxiety, and stress as a direct result of failure to engage in 'mindreading' processes (Baron-Cohen, 2001; Kim et al., 2000; Strang et al., 2012).

Prior studies have shown that in young children with Autistic Spectrum Disorders (ASD), development of ToM abilities is often delayed, with children with ASD failing tests of first-order belief-understanding that are passed by their typically developing peers (Baron-Cohen, Leslie, & Frith, 1985; Hutchins, Prelock, & Bonazinga, 2011; Leslie & Thaiss, 1992; Swettenham, 1996). However, recent research has suggested that in older individuals with ASD, ToM task abilities are less clear, with some studies finding that high-functioning ASD individuals are able to pass advanced tests of ToM (e.g., Bowler, 1992; Happé, 1994; Ozonoff, Pennington, & Rogers; 1991; Ponnet et al., 2008). In this paper, we examined belief-attribution abilities, a component of ToM, in adults with and without ASD. The study advances previous research by exploring how efficiently adults with and without ASD could attribute beliefs both to themselves and other people, and how efficiently individuals can switch between their own and someone else's perspective, as required during social interactions in daily life.

Theory of Mind in Childhood

The American Psychiatric Association (2013) describes ASD as relating to difficulties in engaging in social communication, reduced eye contact, and an egocentric focus when engaging in conversations, alongside repetitive and stereotyped patterns of behaviour (Baron-Cohen et al., 2000; Deschrijver, Bardi, Wiersema, & Brass, 2016; Gökçen, Frederickson, & Petrides, 2016). Baron-Cohen et al. (1985) proposed that difficulties in social interactions in individuals with ASD may reflect deficits in ToM. To assess ToM abilities in children, studies often utilize a false-belief paradigm in which children are required to predict a character's actions or thoughts in a scenario where the character's mental states differ from the child's own mental states (Baron-Cohen et al., 1985; Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). For instance, in a classic unexpected contents paradigm, the 'Smarties' Task (Perner, Leekman, & Wimmer, 1987), children are shown a familiar packet of sweets ('Smarties'), and asked what they think is inside the tube. On answering with 'chocolate' or 'sweeties', an experimenter reveals that the tube actually contains a pencil; the pencil is re-hidden and the Smarties tube resealed. Children are then asked two critical test questions assessing their ToM abilities: what they themselves thought was inside the tube before seeing inside (self-oriented belief-attribution), and what another person, who has not seen inside the tube, would think was inside (other-oriented belief-attribution). To successfully pass these questions, children need to understand that their current knowledge state (that there is a pencil in the Smarties tube) differs from both their own prior mental state, and also from a naive person's false-belief that the tube contains chocolate. Results with typically developing (TD) children have reliably shown a developmental shift between the ages of 3-4 years old, with rapid improvements in abilities seen from 4-years on, with children able to identify both their own prior belief states and the current belief state of another person. In contrast, prior to this age, TD children tend to incorrectly attribute their current knowledge state both to the 'other' person and also to themselves ('*I always thought there was a pencil in the tube*') (Callaghan et al., 2005; Gopnik & Astington, 1988; Hogrefe, Wimmer, & Perner, 1986; Perner et al., 1987; Wellman et al., 2001). However, in children with

ASD, results have shown that this emergence of false-belief understanding is delayed, with children continuing to fail the critical test questions until much later ages (Baron-Cohen, 2001; Charman & Baron-Cohen, 1995; Happé, 1994; Hutchins et al., 2011; Swettenham, 1996; Swettenham, Baron-Cohen, Gomez, & Walsh, 1996).

To further assess children's ToM abilities, Williams and Happé (2009) developed the 'Plasters' task, akin to the Smarties task but removing the need for participants to verbalise their belief-state prior to the creation of a false-belief. In the plasters task, children witness an experimenter injure their finger; the experimenter then asks the child to pass them a plaster/band-aid. The child is presented with three different boxes to choose from, only one of which is a plasters box. By selecting the correct box, children demonstrated their belief that the box contained plasters, without needing to verbalise this belief. Once the plasters box was selected, children were shown that it actually contained birthday candles (unexpected contents). On resealing the box, children with and without ASD were asked questions akin to those used in the Smarties task, assessing self-oriented and other-oriented belief-attributions. Interestingly, results revealed that, without the scaffolding of a previously spoken utterance, children with ASD showed a specific impairment in their ability to answer *self*-oriented probe questions, finding them more difficult than the other-person test questions (Williams & Happé, 2010; Williams, 2010). These results suggest that self-oriented and other-oriented belief-attributions are dissociable (although likely closely related) processes, and indicates that individuals can make errors when reflecting not only on the contents of other people's mental states, but also when reflecting on their own past mental states.

Theory of Mind in Adults

Despite evidence suggesting deficits in ToM abilities in individuals with ASD during childhood, studies have suggested that once children with ASD develop sufficient verbal abilities, they are able to pass tests of advanced ToM, ultimately reaching ceiling levels on ToM tasks that include binary responses (e.g., sweets/pencils in the Smarties task; Charman & Baron-Cohen, 1995; Perner et al., 1987; Peterson, Slaughter, & Paynter, 2007; Scheeren, de Rosnay, Koot, & Begeer, 2013). These findings suggest that older individuals with ASD are, at least to some extent, in possession of ToM abilities, in that they are able to pass tasks requiring consideration of contradictory mental states both of oneself and other people, under false-belief task conditions. However, individuals with ASD are still found to experience and report significant social difficulties, arguably reflecting difficulties in inferring the contents of other people's minds and use of an egocentric focus within social interactions (e.g., Baron-Cohen et al., 2001; Deschrijver et al., 2016; Gökçen et al., 2016; Laghi et al., 2016; Peterson, Garnett, Kelly, & Attwood, 2009; Scheeren et al., 2013). Given this, it has been suggested that to assess whether adults with ASD do experience deficits in ToM abilities, more sensitive measures of ToM capacities – rather than pass/fail tasks – are required to capture more subtle deficits within the ToM mechanism that may be present (Deschrijver et al., 2016; Gökçen et al., 2016; Scheeren et al., 2013). Addressing this, studies have explored differences in results when using explicit measures of ToM abilities (i.e., requiring overt responses), in which ToM capacities of individuals with ASD appear to be intact (e.g., Deschrijver et al., 2016; Roeyers, Buysse, Ponnet, & Pichal, 2001; Scheeren et al., 2013), versus using implicit measures of ToM abilities (e.g., using eye-tracking to examine spontaneous looking behaviour), in which ToM abilities appear to be impaired in individuals with ASD compared to TD individuals (e.g., Gökçen et al., 2016; Happé, 1994; Kleinman, Marchiano, & Ault, 2001; Peterson et al., 2007; Schneider et al., 2013; Senju et al., 2009).

Senju et al. (2009) explored differences in implicit versus explicit ToM task performance, recording eye-tracking measures whilst TD adults and adults with Asperger syndrome viewed videos of a puppet hiding a ball in one of two boxes, before an actor reached through one of two windows to retrieve the ball from the box. Before the actor grasped the ball, a true or false-belief scenario was created when the puppet moved the ball from its current location either whilst the actor was looking (true-belief) or whilst the actor was looking away (false-belief). The false-belief scenario created the critical test trial, in which anticipatory looking was assessed. Results showed that neuro-typical adults anticipated the actor's behaviour on the basis of their false-belief, demonstrating a bias in looking towards the correct answer target (i.e., the now empty box that the actor believes contains the ball); in contrast, individuals with Asperger syndrome did not show any anticipatory looking towards the correct target window, although there was no significant difference in explicit ToM task performance between TD and ASD individuals. Results from Schneider, Slaughter, Bayliss, and

Dux (2013) further support these findings, demonstrating that, in a similar paradigm, there were no significant differences between performance of high-functioning ASD participants and TD participants on an explicit ToM measure, whilst implicit eye-tracking measures suggested that TD participants were spontaneously tracking an actor's belief-states, but ASD participants were not.

Current Study

In this paper, we sought to establish whether differences in ToM capacities between individuals with and without ASD could be captured when using a sensitive measure of *explicit* ToM capacities. The Self/Other Differentiation task (Bradford, Jentzsch, & Gomez, 2015; Bradford et al., 2018) measures response times and accuracy to assess conditions in which ToM is most efficiently utilized (as opposed to binary pass/fail measures), allowing detection of specific deficits in ToM that may be experienced by individuals with ASD (e.g., in reporting their own prior belief-states versus the belief-states of another person; Russell & Hill, 2001; Williams & Happé, 2009). The Self/Other Differentiation task is a computerized false-belief paradigm, developed for use with adult participants, and based on the 'Smarties' task methodology. Participants are asked to identify which container they or someone else would look inside for a particular item, before being shown expected or unexpected contents. They are then asked what either they ('Self') or someone else ('Other') would think was inside a container, if they hadn't seen inside (i.e., belief-attribution). Previous research has indicated that even in TD adults, who possess fully developed ToM capacities, an egocentric bias can be seen during interactions, with a failure to spontaneously consider the perspective of another person unless explicitly prompted to do so (e.g., Apperly, 2012; Birch & Bloom, 2004; Keysar, Barr, Balin, & Braunder, 2000; Royzman, Cassidy, & Baron, 2003; Samson, Apperly, Braithwaite, & Andrews, 2010). Results from Bradford et al.'s (2015) study using the Self/Other Differentiation task demonstrated that TD individuals were faster and more accurate at responding from their own perspective than another person's perspective, suggesting an egocentric bias in processing of scenarios, even though answers from both the 'Self' and 'Other' perspective were identical (i.e., both believe there to be Smarties in the tube, before seeing inside). Moreover, there was a significant role of perspective-shifting, with participants finding it harder (taking longer and making more errors) when shifting from their own to someone else's perspective, compared to when shifting from someone else's perspective to one's own. These results suggest that even in neuro-typical individuals, ToM can be engaged in a more/less efficient manner, depending on context.

This paper utilized the Self/Other Differentiation task to assess whether, when using a sensitive explicit measure of ToM capacities, differentiations between the performance of TD individuals and individuals with ASD could be ascertained, specifically exploring how efficiently individuals with and without ASD could successfully attribute beliefs to both themselves and other people, and how efficiently individuals can switch between their own and someone else's perspective. It was predicted that ASD individuals would find the belief-attribution task harder than TD individuals, showing longer response times and more errors overall. Further, if ASD individuals find mental state attribution per se difficult, we could expect that responses would show less differentiation between 'Self' and 'Other' perspectives, compared to TD individuals, reflecting an overall deficit in mental state attribution, rather than a deficit in belief-attribution that is specific to the 'Self' or 'Other' perspective. If, however, ASD individuals experience a stronger bias towards an egocentric perspective (e.g., Baron-Cohen et al., 2001; Brent et al., 2004; Charman & Baron-Cohen, 1992), we might expect ASD individuals to show a larger difference between 'Self' and 'Other' oriented processing than TD individuals, with faster responses for the 'Self' perspective than the 'Other' perspective. It was also predicted that ASD individuals would show a particular deficit in trials requiring a perspective-shift between the self-perspective and the other-perspective, reflecting difficulties in tracking the mental states of other people in conversation-like scenarios. Finally, it was predicted that both ASD and TD participants would show longer response times and more errors following false-belief trials than true-belief trials, reflecting successful manipulation of true/false belief-states in the task.

Method

Participants

Sixty-two participants were recruited from the Autism Research at Kent (ARK) participant database, split into two groups: 32 neurotypical individuals and 30 individuals with Autistic

Spectrum Disorder. One participant with ASD was excluded from analysis due to an overall very low accuracy score (< 10%) in the Self/Other Differentiation task, suggesting a failure to engage with the task, leaving 29 participants in the ASD participant group. All participants were reimbursed for their time. All participants gave informed consent and this study was approved by the University of Kent Research Ethics committee.

Participants were statistically matched for gender, age, and IQ (see Table 1). All participants had full-scale IQs greater than 70 (measured using the Wechsler Abbreviated Scale of Intelligence (WASI); Wechsler, 2011), were over 18, native-English speakers, and did not have a diagnosis of dyslexia or reading comprehension impairment. Participants completed the Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), a 50-item self-report questionnaire that assesses ASD/ASD-like features; three neurotypical individuals were excluded from reporting of AQ results due to a failure to complete the questionnaire in its entirety. Individuals in the ASD group scored significantly higher than TD individuals on the AQ (see Table 1).

Table 1: Mean (S.D.) demographic information of participants included in analysis

	ASD (n = 29)	TD (n = 32)	t	p
Gender (m:f)	21:8	18:14	X^2 = 1.72	.19
Age (years)	30.41 (11.72)	30.22 (14.2)	.058	.954
Verbal Comprehension	103.28 (10.93)	105.19 (10.95)	-0.68	.498
Perceptual Reasoning	102.14 (18.09)	107.44 (12.31)	-1.35	.183
Full-Scale IQ	102.72 (14.30)	107.03 (10.97)	-1.33	.190
AQ*	**29.90 (10.47)**	**17.71 (7.14)**	**4.08**	**< .001*** **
ADOS Module 4 (Severity Score)	6.73 (4.47)	-		

*Note: for the AQ, three TD participants failed to complete the questionnaire in its entirety, and thus N = 29.

Participants in the ASD group had all received formal diagnoses of autistic disorder (N = 10), Asperger's Syndrome (N = 18), or Pervasive Developmental Disorder Not-Otherwise Specified (PDD-NOS; N = 1), according to DSM-V or ICD-10 criteria (American Psychiatric Association, 2013; World Health Organization, 1993), and diagnostic reports were verified by the researcher. Current ASD symptomology was assessed with Module 4 of the Autism Diagnostic

Observation Schedule (ADOS; Lord et al., 2000; see Table 1 for mean score), which was administered and coded by a research-reliable trained researcher. ADOS scores were calculated as an overall 'severity score' based on two sub-scales of communication and social interaction. Two individuals with a diagnosis of Asperger's Syndrome declined the ADOS assessment.

Measures and Procedure

The Self/Other Differentiation task, a computerized task assessing belief-attribution abilities, replicated the method described in Bradford et al. (2015; see also Bradford et al., 2018). Programmed using E-Prime software, the task consisted of 8 practice trials and 120 test trials (80 experimental trials and 40 distractor trials; see Table 2). All trials consisted of three stages: Dilemma Stage (establishing a belief-state) → Contents Revelation Stage (creating true/false belief scenarios) → Probe Stage (belief-attribution). Only test trials required belief-attribution, with practice trials referring only to reality states (e.g., '*What was in the backpack?'*). Figure 1 illustrates the three stages of each trial.

At the Dilemma Stage of the task, participants were asked to identify where either they (self-oriented) or someone else (other-oriented) would look for an object (e.g., '[*You are/Mark is] baking a cake and need(s) some eggs. Where would [You/Mark] look for them?'*). This question was presented on screen for 1500ms before three image answer options were also displayed below this sentence, for a maximum of 5000ms. The answer options were presented horizontally, with one correct answer image and two incorrect answer images. Participants indicated their selection by pressing an arrow key corresponding to the spatial location of the object (left image ←, central image ↓, right image →). If an incorrect selection was made, or there was no response within the time limit, a red 'X' was displayed for 1500ms before the Dilemma reset, until the correct answer option was selected.

Following establishment of a belief-state at the Dilemma Stage, the Contents Revelation Stage manipulated true- or false-belief states of participants. The contents of the selected container were revealed to be either expected contents (i.e., true-belief) or unexpected contents (i.e., false-belief). This image was shown for 2000ms. No response was required from participants.

Following Self or Other oriented dilemmas, half of each were followed by expected/unexpected contents.

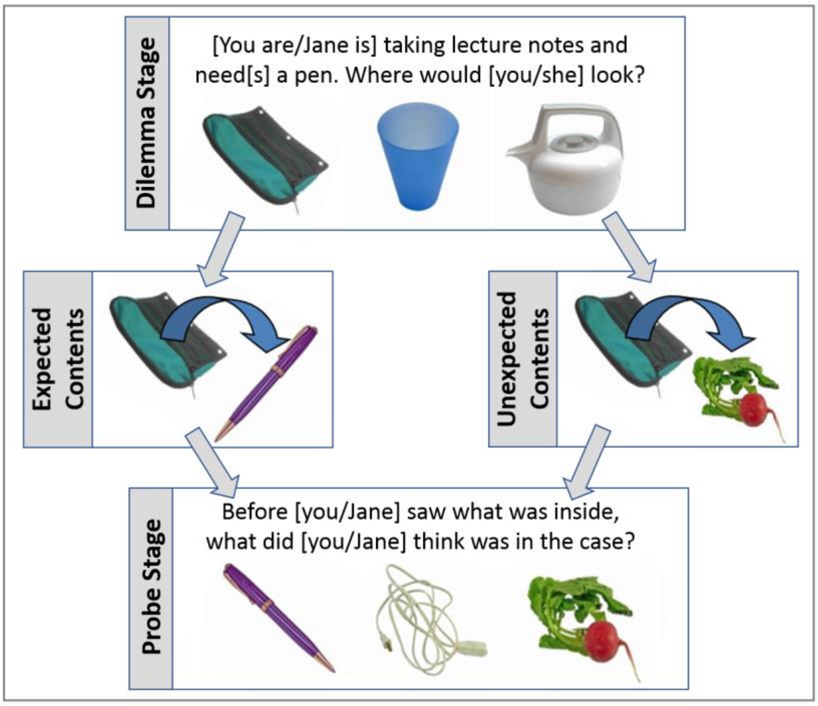

Figure 1: Example of the trial structure used in the Self/Other Differentiation Task, illustrating how a trial would be seen in a Self or Other condition at the Dilemma and Probe stage, with examples of expected and unexpected content outcomes at the Contents Revelation stage.

The final stage of each trial was the Probe Stage, in which participants saw a sentence asking them to attribute a belief-state to either themselves at a previous time point, or another person (e.g., '*Before [you/Mark] saw what was inside, what did [you/he] think was in the box?*). Answers were indicated by selecting one image from three presented horizontally, as in the Dilemma Stage. The Probe question was shown for 1500ms before the three answer options appeared. The image answer options were displayed until a response was given, or for a maximum of 8000ms if no response was recorded. Distracter questions (40) were also included at the Probe Stage (e.g., '*What colour was the egg box?*') to reduce anticipation of a correct answer until the Probe Question was presented.

The manipulation of 'Self' and 'Other' oriented questions created trials in which there was either no perspective shift (e.g., Self-Self, Other-Other) or there was a perspective-shift (e.g., Self-Other, Other-Self) across the Dilemma-to-Probe stage of each trial. Participants were instructed to respond as quickly and as accurately as possible to both the Dilemma and Probe

Stage questions. See Figure 1 for an illustration of the trial stages. Table 2 provides details of trial numbers in the task; for details on the full methodology (including sentence matching), see Bradford et al. (2015; 2018).

Table 2: Number of trials in each condition combination in the Self/Other Differentiation Task.

	Self Dilemma			Other Dilemma			
	Self Probe	Other Probe	Distracter	Self Probe	Other Probe	Distracter	
Expected Contents	10	10	10	10	10	10	*60*
Unexpected Contents	10	10	10	10	10	10	*60*
	20	*20*	*20*	*20*	*20*	*20*	*120*

Results

Dilemma Stage

A Repeated-Measures ANOVA with Dilemma Type (Self vs. Other) as a within-subjects factor, and group (ASD vs. TD) as a between-subjects factor, was conducted on accuracy and response times.

Accuracy

There was a significant main effect of group on dilemma question accuracy, F (1,59) = 4.36, p = .04, η_p^2 = .07, with more accurate responses in the TD group (M = 97.7%) than the ASD group (M = 95.8%). There was no significant main effect of dilemma type (p = .71, η_p^2 = .002) and no interaction between Dilemma Type and Group (p = .59, η_p^2 = .005).

Response Times

There was no significant main effect of group (p = .10, η_p^2 = .05), however a significant main effect of Dilemma Type, F (1,59) = 48.11, p < .001, η_p^2 = .45, revealed faster responses to Self-Oriented Dilemmas (M = 1548ms) than to Other-Oriented Dilemmas (M = 1701ms). There was no significant interaction between Dilemma Type and Group (p = .42, η_p^2 = .01).

Probe Stage

A 2 (Perspective Shift: No Shift vs. Shift) x 2 (Contents: Expected vs. Unexpected) x 2 (Probe: Self vs. Other) repeated-measures ANOVA was conducted for accuracy and response times, with group (ASD vs. TD) as a between-subjects factor. Table 3 presents the means and standard error values for each condition of the Self/Other Differentiation task; Table 4 presents the significance values of the repeated-measures ANOVA for accuracy and response times.

Table 3: Means and standard error values for each condition of the Self/Other Differentiation Task, for accuracy and response times

				ASD		TD	
				M	*SE*	*M*	*SE*
Accuracy (%)	No Shift	Expected	Self	98.3	0.8	99.7	0.8
			Other	98.6	0.6	99.1	0.6
		Unexpected	Self	82.4	3.7	95	3.5
			Other	80.7	3.8	91.9	3.6
	Shift	Expected	Self	99.3	0.5	99.1	0.5
			Other	97.2	0.8	98.7	0.8
		Unexpected	Self	85.5	3.3	94.7	3.2
			Other	81.4	3.9	93.4	3.8
Response Times (ms)	No Shift	Expected	Self	1152.5	65.1	919.0	61.9
			Other	1192.5	70.8	953.6	67.4
		Unexpected	Self	1289.0	71.5	1007.1	68.1
			Other	1355.2	85.6	1074.8	81.5
	Shift	Expected	Self	1215.6	70.9	952.3	67.4
			Other	1360.8	84.6	1096.1	80.6
		Unexpected	Self	1270.2	76.4	944.7	72.7
			Other	1364.1	72.4	1064.2	68.9

Accuracy

There was a significant main effect of group, with more accurate responses in the TD group (*M* = 96.4%) than the ASD group (*M* = 90.4 %). There was also a significant main effect of Probe Type, with more accurate responses to Self-Oriented Probes (*M* = 94.2%) compared to Other-Oriented Probes (*M* = 92.6%), and a significant main effect of Contents Type, with more accurate responses to the probe question in Expected Contents trials (*M* = 98.8%) than Unexpected Contents trials (*M* = 88.1%).

Table 4: Results from the repeated-measures ANOVA for accuracy and response time values

		F	*df*	*p*	η_p^2
Accuracy	Group	5.946	1,59	0.018 *	0.092
	Perspective Shift	0.715	1,59	0.401	0.012
	Contents	21.473	1,59	<0.001 ***	0.267
	Probe	6.81	1,59	0.011 *	0.103
	Perspective Shift x Group	0.497	1,59	0.484	0.008
	Perspective Shift x Contents	2.593	1,59	0.113	0.042
	Perspective Shift x Probe	0.248	1,59	0.621	0.004
	Contents x Group	5.213	1,59	0.026 *	0.081
	Contents x Probe	2.075	1,59	0.155	0.034
	Probe x Group	0.212	1,59	0.647	0.004
	Perspective Shift x Contents x Group	0.247	1,59	0.621	0.004
	Perspective Shift x Probe x Group	1.748	1,59	0.191	0.029
	Perspective Shift x Contents x Probe	0.109	1,59	0.742	0.002
	Contents x Probe x Group	0.018	1,59	0.895	<0.001
	Perspective Shift x Contents x Probe x Group	0.109	1,59	0.742	0.002
Response Times	Group	9.187	1,59	0.004 **	0.135
	Perspective Shift	5.892	1,59	0.018 *	0.091
	Contents	7.767	1,59	0.007 **	0.116
	Probe	29.506	1,59	<0.001 ***	0.333
	Perspective Shift x Group	0.789	1,59	0.378	0.013
	Perspective Shift x Contents	12.089	1,59	0.001 ***	0.17
	Perspective Shift x Probe	3.163	1,59	0.08(*)	0.051
	Contents x Group	0.981	1,59	0.326	0.016
	Contents x Probe	0.013	1,59	0.91	<0.001
	Probe x Group	0.024	1,59	0.878	<0.001
	Perspective Shift x Contents x Group	0.003	1,59	0.959	<0.001
	Perspective Shift x Probe x Group	0.029	1,59	0.866	<0.001
	Perspective Shift x Contents x Probe	0.7	1,59	0.406	0.012
	Contents x Probe x Group	0.056	1,59	0.813	0.001
	Perspective Shift x Contents x Probe x Group	0.015	1,59	0.902	<0.001

These main effects were modulated by a significant interaction between Contents Type and Group (see Figure 2). Post-hoc independent samples *t*-tests with Bonferroni corrections showed that when the contents were expected there was no significant difference in accuracy between ASD (*M* = 98.4%) and TD (*M* = 99.1%) participants, *t* (59) = 1.38, *p* = .35, *d* = .35, but when the contents were unexpected, accuracy was significantly reduced for ASD participants (*M* = 82.5%) compared to TD participants (*M* = 93.8%), *t* (59) = 2.38, *p* = .04, *d* = .60.

No other effects were significant for accuracy (all *p*'s > .11).

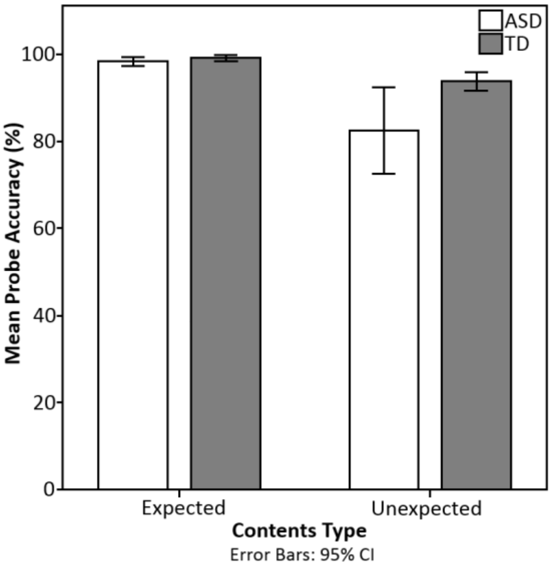

Figure 2: Mean accuracy (percent correct) to the probe question, following expected or unexpected contents revelation.

Response Time

There was a significant main effect of group, with faster responses from TD participants (*M* = 1001ms) than ASD participants (*M* = 1274ms). There was also a significant main effect of Probe Type, with faster responses to Self-Oriented Probes (*M* = 1093ms) than Other-Oriented Probes (*M* = 1182ms), and a significant main effect of Contents Type, with faster responses in Expected Contents trials (*M* = 1105ms) than Unexpected Contents trials (*M* = 1171ms). In addition, there was a significant main effect of Perspective-Shifting, with faster responses in no-perspective shift conditions (*M* = 1117ms) compared to perspective-shift conditions (*M* = 1158ms).

There was a significant interaction between Perspective-Shifting and Contents Type. Post-hoc paired samples *t*-tests, with Bonferroni corrections, revealed that responses were faster for Expected than Unexpected contents in no-perspective shift trials (*M* difference = 126ms), *t*(60)= 4.16, *p*< .001, *d*=.32, but did not differ in perspective-shift trials (*M* difference = 4ms), *t*(60)= .12, *p*= .91, *d*=.01. Finally, there was a trend towards a significant interaction between

Perspective-Shifting and Probe Type[1]; post-hoc paired sample *t*-tests, with Bonferroni corrections, revealed that responses were significantly slower for Other-Oriented than Self-Oriented Probes in Perspective-Shift trials (*M* difference = 126ms), $t(60)= 4.38$, $p< .001$, $d=.31$, and were marginally slower for Other-Oriented than Self-Oriented Probes in No-Perspective Shift trials (*M* difference = 52ms), $t(60)= 2.24$, $p= .058$, $d=.14$.

No other effects were significant for response times (all *p*'s > .33).

Discussion

This study sought to assess whether an explicit test of ToM abilities can reveal distinct belief-attribution abilities in adults with and without high-functioning ASD. In particular, we assessed how efficiently individuals could attribute beliefs to themselves and to other people, and how efficiently individuals could switch between their own and someone else's perspective, as required during everyday social interactions. Using a computerized false-belief task to assess response times and accuracy, results revealed largely comparable outcomes for TD participants and participants with ASD. First, both TD and ASD individuals were faster and more accurate to respond from the 'Self' perspective than from the 'Other' perspective, suggesting that people experienced an egocentric bias when responding to the Probe questions; this egocentric bias was equivalent between the two groups, and the ASD participants did not experience greater interference from the self-perspective than TD participants. Results also revealed a significant effect of perspective-shifting for both TD and ASD individuals, with slower and less accurate responses when a perspective-shift was required compared to when no change in perspective was required between the Dilemma and Probe stage. Similar to prior studies, participants found it harder to shift from their own perspective to that of another person (i.e., shifting from a Self-Oriented Dilemma to an Other-Oriented Probe), compared to shifting from someone else's perspective to one's own (i.e., shifting from an Other-Oriented Dilemma to a Self-Oriented Probe within a trial). Contrary to our hypotheses however, this pattern was evident for both TD and ASD individuals, suggesting

[1] Note that two ASD participants had low overall accuracy scores (*M* = 48% and 54% accuracy, respectively). Analysis of response times and accuracy did not change substantively when these participants were excluded; all main effects were replicated, and for response times the Perspective-Shifting x Probe Type interaction became significant (rather than a trend), $F(1,57) = 11.39$, $p = .001$, $\eta_p^2 = .17$.

similar engagement styles across the two participant groups and that difficulties in engaging in perspective-shifting are not specific to individuals with ASD. These results suggest that adults with high-functioning ASD are successfully able to engage ToM abilities (specifically, belief-attribution), and do so within a comparable timecourse to TD adults. The current findings support recent research that has argued that social difficulties experienced by individuals with ASD are not due to an absence of ToM capacities per se (e.g., Deschrijver et al., 2016; Schneider et al., 2013; Senju, 2013), although it is noted that the current results are interpreted with caution, as they do not tease apart use of ToM capacities themselves versus the potential engagement of compensatory strategies that individuals with ASD may be utilizing (for a recent review, see Livingston & Happé, 2017).

False-Belief Errors

Interestingly, despite the core similarities between TD and ASD participants seen in the results of this study, some clear differences in explicit ToM processing were revealed between the two groups. First, responses were overall slower and less accurate among the ASD individuals than the TD individuals, which supports the hypothesized general difficulty in engaging belief-state attribution capacities among adults with ASD. More importantly, analysis of error rates revealed a specific impairment in the ASD group on false-belief trials, with significantly more errors in unexpected contents (false-belief) trials compared to expected contents (true-belief) trials. That is, when the contents revelation stage showed expected contents (i.e., true-belief trials), ASD and TD participants were equally efficient at correctly answering the Probe question (98% and 99% accuracy, respectively). However, when the contents revelation stage showed unexpected contents (i.e., false-belief trials), ASD participants were significantly less accurate than TD participants at correctly answering the Probe question (82% versus 93% accuracy). These results indicate that adults with ASD experience a particular impairment with utilizing their ToM abilities when two contrasting belief-states need to be held in mind; i.e., the outdated belief of what they believed to be inside a container before seeing inside (the correct answer to the Probe question) and the reality state of what they know to actually be inside a container. Thus, participants with ASD were less able than TD participants to spontaneously consider multiple mental states in this task, experiencing more difficulty disengaging from current, reality based belief-states, and suggesting that ToM abilities are not utilized as efficiently in individuals with ASD compared to their TD peers.

It is important to note that both TD and ASD participants showed an effect of contents type, with more errors in false-belief trials compared to true-belief trials, suggesting that the Self/Other Differentiation task successfully manipulated belief-states of participants, and is thus a suitable measure for assessing belief-attribution abilities in adult populations. Results also showed a significant interaction between Perspective-Shifting and Contents Type for response times, indicating that in trials in which no perspective-shift was required (Self-Self, Other-Other), participants were faster to respond following expected versus unexpected contents, whereas in trials in which a perspective-shift *was* required (Self-Other, Other-Self), there was no significant difference in speed of response between expected/unexpected contents trials. This suggests that for both TD and ASD participants, the manipulation of contents type (i.e., true vs. false-belief) was particularly salient in no perspective-shift trials, compared to trials in which participants are already required to engage in extra cognitive processing to switch between perspectives across the Dilemma-to-Probe stages of the task. The results of the current study may have implications for predicting the success of social interactions in daily life; when engaging in a conversation with someone, the notion of what people know or believe can change throughout a conversation, as more information is exchanged. Perhaps individuals with ASD have a specific difficulty with tracking these updates of mental states under these circumstances, and thus have difficulties contemplating more than one mental state at a time, such as a previously held belief state versus current knowledge state, in this task.

Socio-cognitive or domain-general cognitive difficulties?

Our results highlight that adults with ASD are successfully able to utilize belief-attribution capacities, although in a less efficient way than TD individuals. Importantly, the results indicate a particular deficit experienced by ASD participants in accurately processing false-beliefs, compared to TD participants, likely due to the multiple perspectives that need to be considered at one time (i.e., what was previously believed to be inside a container vs. what is now known to be in the container). These observed difficulties may be reflective of socio-cognitive deficits specifically or more domain-general cognitive difficulties experienced by autistic individuals, such as in working memory or cognitive flexibility. Prior research has suggested that individuals with ASD experience reduced executive function abilities (e.g., Craig et al., 2016; Eylen et al., 2011; Russell, Hala, & Hill, 2003), including inhibition, cognitive flexibility, working memory, and planning, which are often cited as being required for successful engagement of social cognition capacities (e.g., Brown-Schmidt, 2009; Cane, Ferguson, & Apperly, 2017; Joseph & Tager-Flusberg, 2004; Sabbagh et al., 2006). For example, success on a false-belief task requires one to hold in mind multiple perspectives (i.e. working memory), suppress irrelevant perspectives (i.e. inhibitory control), and switch between these two perspectives depending on context (i.e. cognitive flexibility). In contrast, true-beliefs make much lower demands on executive function processes. In the current study, participants with ASD made more errors in false-belief trials than in true-belief trials, suggesting a particular difficulty in disengaging from current reality based belief-states. Future research is needed to examine the degree to which differences in explicit ToM task performance between ASD and TD adults can be explained in terms of social communication impairments associated with the disorder, or to more general executive functioning deficits (e.g., inhibition and cognitive flexibility; Pacherie, 1997; Russell, 1997).

Implicit vs. Explicit Measures

Prior research has highlighted different outcomes from studies that test explicit versus implicit expression of ToM abilities. Implicit tasks typically reveal impaired automatic belief tracking among ASD participants (e.g., Senju et al., 2009), though TD and ASD individuals tend to perform at similar levels on explicit response-based tasks, with both successfully passing even complex ToM tasks (Deschrijver et al., 2016; Ozonoff et al., 1991; Roeyers et al., 2001; Scheeren et al., 2013). In the current study, participants were required to give an explicit response, selecting an image that portrayed a previously held belief state of either the 'Self' or 'Other'. However, unlike previous tasks that have assessed explicit ToM abilities in adults with ASD, our study allowed examination of the efficiency with which ToM abilities are utilized using accuracy and response times as more sensitive measures of ToM tasks engagement, rather than simply looking at a binary pass/fail task (e.g., Baez et al., 2012; Gantman, Kapp, Orenski, & Laugeson, 2012; Happé, 1994; Schneider et al., 2013). The more sensitive approach taken here therefore demonstrates that overall adults with ASD *are* able to attribute and track beliefs for the self and others in a ToM task, and are sensitive to the same biases as TD adults. The current results highlight explicit evidence that managing these complex processes is significantly more challenging for people with ASD (reflected in longer reaction times and lower accuracy), and is subject to increased interference from conflicting mental states. It is noted that at the Dilemma Stage of the Self/Other Differentiation task, there was a significant main effect of group on accuracy, with ASD participants overall less accurate (95.8% accurate) than TD participants (97.7% accurate); this suggests that, at the Dilemma Stage, ASD participants found the scenarios more difficult to engage with than TD participants. However, there was no significant interaction between Dilemma Type and group, indicating that, despite being overall less accurate at the Dilemma Stage, accuracy of ASD participants was not influenced by perspective-type (i.e., they were equally accurate across self/other-oriented Dilemma questions), akin to TD participants.

Conclusion

In conclusion, we aimed to assess the efficiency of belief-attribution abilities – a core component of ToM – in adults with and without ASD, using a computerized false-belief task. Results revealed that TD and ASD participants performed comparably when attributing beliefs to the self and other, with faster and more accurate responses to Self-Oriented trials compared to Other-Oriented trials, and slower responses when a perspective shift was required. The results demonstrate a specific deficit for ASD participants in processing false-beliefs, suggesting increased difficulty disengaging from reality based belief-states than TD participants. Impaired ability to consider and track multiple mental states would have repercussions on how successfully an individual is able to relate to other people in a social setting, and therefore has implications for the quality of social interactions in daily life. Future research should explore this further, assessing the extent to which these difficulties reflect a purely social impairment, or whether they relate to impairments in more general cognitive mechanisms that underlie successful ToM, such as working memory or cognitive flexibility.

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