Do autistic adults spontaneously reason about belief? A replication study

Hannah Partington, Maryna Nosyk, Gillian Hughes, Ruihan Wu, Ishita Chowdhury, and Sarah J White*

University College London, Institute of Cognitive Neuroscience, London, UK

Author Note

Corresponding author is Sarah J. White, University College London, Institute of Cognitive Neuroscience, Division of Psychology and Language Sciences, London, WC1N 3AZ, UK. Email: s.white@ucl.ac.uk

Abstract

To overcome the criticisms of earlier work using anticipatory-looking paradigms to investigate implicit mentalizing in autism, Wu et al. (2024) recently presented a multi-trial paradigm with matched true-belief and false-belief conditions. This study is a replication of Wu et al.'s work using a novel set of stimuli and a separate group of participants, all of whom were naïve to this paradigm. Fifty-four (26 autistic) participants completed an implicit mentalizing task with both high- and low-demand false-belief conditions with two corresponding true-belief control conditions, alongside an explicit mentalizing task. In accordance with Wu et al. (2024), our findings support the presence of spontaneous mentalizing difficulties in autistic adults, despite strong explicit mentalizing abilities. Therefore, we provide further evidence that whilst some autistic adults with high-IQs may have developed compensatory strategies that mask mentalizing difficulties on explicit tasks, implicit tasks reveal differences in the underlying spontaneous mechanism.

Keywords: Autism, spontaneous mentalizing, theory of mind, anticipatory-looking, eye-tracking, false-belief

Do autistic adults spontaneously reason about belief? A replication study

As autism is often evaluated by clinicians at the behavioural level, its diagnosis is both subjective and susceptible to compensation. There is therefore a need for objective assessments of autism that are sensitive across a range of ages and abilities by tapping into cognitive processes, and implicit mentalizing tasks are a promising candidate. Indeed, work using Southgate et al. (2007)'s anticipatory-looking paradigm has provided evidence for the presence of implicit mentalizing differences in autism (Senju et al., 2009). However, this paradigm has been criticised and thus, the conclusiveness of these findings challenged.

Recently, Wu et al. (2024) developed Southgate et al. (2007)'s paradigm to address its criticisms. Firstly, they implemented a multi-trial design, increasing power and improving the signal-to-noise ratio. Whilst Wu et al. were not the first to extend Southgate et al.'s single-trial paradigm to a multi-trial one, they argue that methodological limitations, such as lengthy task durations and deviations to the story and set-up of the false-belief (FB) videos, hinder the extent of the conclusions that can be drawn from these studies (e.g. Schneider et al., 2013; Schuwerk et al., 2015). Secondly, Wu et al. extended Southgate et al.'s paradigm by introducing a well matched true-belief (TB) control condition to verify that autistic people struggle specifically with spontaneous mentalizing. Again, whilst others have endeavoured to improve upon Southgate et al.'s paradigm by including a control condition (e.g. Gliga et al., 2014; Schneider et al., 2013), Wu et al. argue that these modifications were not sufficiently comparable to the FB condition to make such verifications. Finally, Wu et al. chose to include both high- and low-demand FB conditions. Prior work in non-autistic participants has suggested that the greater cognitive resource required for high-demand FB conditions compromises anticipatory-looking (Wang & Leslie, 2016); yet several of the earlier studies which extended Southgate et al.'s paradigm by including multiple trials and a control condition also only included high-demand FB conditions (e.g. Schneider et al., 2012, 2013).

Using this updated paradigm, Wu et al. (2024) found that, unlike non-autistic people, autistic people's gaze behaviour was not biased by the protagonist's beliefs, suggesting that autistic people do not spontaneously attribute mental states. Critically, an analysis of gaze patterns over time enabled Wu et al. to dismiss other non-mentalizing explanations for this result, such as differences in attention or difficulties predicting actions. Furthermore, Wu et al.'s results suggest that their anticipatory-looking paradigm is sufficiently sensitive to overcome compensation strategies, as the autistic group performed comparably to the non-autistic group on a test of explicit mentalistic reasoning.

To further validate Wu et al. (2024)'s paradigm, we conducted a replication of their work using a novel set of FB and TB videos with different participants.

Methods

Participants

Fifty-four adults (26 autistic) gave informed consent to take part in this study, which had been approved by the local research ethics committee. The two groups were recruited through a local participant database and were matched on gender, age and IQ (Table 1). All autistic participants had a prior diagnosis of either Autism Spectrum Disorder (5) or Asperger syndrome (21), and 20 met the ADOS criteria for autism/autism spectrum. The remaining six participants were not excluded because they provided a written clinical diagnosis and the ADOS is less sensitive in people with higher IQs (Kamp-Becker et al., 2013). Participants completed the Autism-Spectrum Quotient (AQ) and the autistic group reported significantly higher autistic traits (Table 1).

Materials

Explicit Mentalizing

Participants completed the Mental State set from Happé's Strange Stories Task (SST). See White et al., 2009 for test materials, administration and scoring criteria.

Implicit Mentalizing – An Anticipatory-Looking Paradigm

Following Wu et al. (2024), the task had two types of trials: familiarisation and experimental. Both started with a protagonist stood behind a screen with two windows in it. Below each window was a box with the lid open and one contained a pop-up toy (see Figure 1). During the familiarisation trials, a puppet appeared on screen and closed the lids of both boxes (empty box first). Once the puppet left the scene, the windows illuminated for 1000ms and a chime sounded simultaneously. Afterwards, the protagonist reached through the window and opened the lid of the box containing the toy. These trials aimed to habituate participants to the sequence of events, and to the contingency between the chime/flash and the protagonist's subsequent reach through the window to retrieve the toy. The location of the toy and handedness of the puppeteer were counterbalanced, resulting in four familiarisation trials, all 15s long.

This task had two pairs of matched experimental trial conditions: TB short turn (TBST) and FB high-demand (FBHD), and TB long turn (TBLT) and FB low-demand (FBLD). Up until the point the puppet left the scene, the experimental trials were identical to the familiarisation trials. After this, a telephone rang and the protagonist turned away from the scene. In all except the TBST condition, the puppet re-appeared at this point. In the TBLT condition, the puppet opened and closed the lid of the box containing the toy. In the FBHD condition, the puppet swapped the boxes around and in the FBLD condition, the puppet replaced the box containing the toy with an empty box. Afterwards, the puppet left the scene, a telephone engaged tone was heard, and the protagonist turned back to the scene. The windows then illuminated and a chime sounded for 1s whilst the scene froze for 6s to the end of video. The TBST condition was exactly the same as the FBHD condition except the protagonist turned back to the scene before the puppet re-appeared so that she witnessed the puppet swap the boxes. The direction the protagonist turned, the position of the toy and the

handedness of the puppeteer were counterbalanced, resulting in eight trials for each condition, all 30s long.

As described, the puppet in our videos swaps the boxes containing the toy, instead of opening the boxes and transferring the toy as in Wu et al.'s (2024) videos. However, this is the only fundamental difference between our and Wu et al.'s stimuli. A Tobii X3-120 eye-tracker with a sampling rate of 120 Hz was used to record gaze data. Participants sat circa 70cm away from the eye-tracker and a nine-point calibration was conducted.

Procedure

The SST task was completed first followed by the implicit mentalizing task, which consisted of one familiarisation and four experimental blocks, with a short break between blocks. Contrary to Wu et al. (2024), the blocks were not split into sections with a longer break in-between as this did not seem to help maintain attention. The familiarisation block was presented first and consisted of all four familiarisation trials in a randomised order. Each experimental block began with one familiarisation trial followed by two experimental trials from each condition presented in a randomised order. The familiarisation trial and experimental trials in each block were randomly selected but each was only presented once across the four experimental blocks. Participants were instructed to watch the videos carefully as questions would be asked about them at the end of the task. Questions were included to encourage participants to pay attention and queried basic features of the videos.

Data Analysis

Two areas of interest (AOIs) were identified: the window and box area that was consistent (belief-congruent AOI) and inconsistent (belief-incongruent AOI) with the protagonist's belief about the toy's location. The total fixation duration to each AOI from the onset of the windows illuminating to the end of the video (approximately 6s) was extracted through Tobii Pro Studio. From this data, differential looking scores (DLSs; Senju & Csibra,

2008) were calculated as a measure of looking preference, with values ranging from 1 to -1. A DLS close to 1 indicates a strong preference for the belief-congruent AOI, while a DLS close to -1 indicates a strong preference for the belief-incongruent AOI.

Thirteen of the participants (9 autistic) were not above chance in the experimental block familiarisation trials despite the protagonist revealing the toy. As excluding these participants did not alter statistical outcomes, all 54 participants were included in all analyses.

Results

Explicit Mentalizing Task

There was no significant difference between the autistic (M=11.96, SD=2.66) and non-autistic (M=12.54, SD=2.01) participants' performance on the SST ($t(52)=-0.90$, $p=0.37$, $d=0.24$) and thus, their ability to explicitly infer mental states.

Implicit Mentalizing Task

One sample t-tests (see Table 2) indicated that the non-autistic group showed a significant looking preference towards the belief-congruent AOI in the TBLT and FBLD condition whereas the autistic group did not perform above chance in either condition. Neither group performed above chance in the FBHD or its control condition (TBST), indicating that these conditions may not have successfully detected belief monitoring. Therefore, subsequent analyses focus only on FBLD and TBLT conditions, which corresponds with the analyses performed in Wu et al. (2024).

As expected from Wu et al. (2024), a 2(belief: TB vs FB) x 2(group: autistic vs non-autistic) ANOVA showed a significant main effect of group ($F(1, 52)=3.54$, p(one-tailed)$=.03$, $d=0.04$) and no significant interaction between belief and group ($F(1, 52)=1.21$, $p=.28$, $d=0.01$). This indicates that the autistic group showed less preference for the belief-congruent AOI than the non-autistic group, and that the effect of belief on looking preference was comparable across the autistic and non-autistic groups (see Figure 2). Unlike Wu et al.

(2024), we found no significant effect of belief ($F(1, 52)=0.02$, $p(\text{one-tailed})=.44$, $d<0.01$), indicating that participants showed a similar looking bias towards the belief-congruent AOI in the TB and FB conditions (see Figure 2).

Discussion

This study investigated implicit mentalizing in autistic adults. Specifically, a replication of Wu et al. (2024) was performed: anticipatory-looking was investigated using a multi-trial paradigm with well-matched TB and FB conditions. Of note, a novel stimuli set was used and all participants were naïve to the paradigm. Our results closely matched those of Wu et al., as we also found evidence for the presence of spontaneous mentalizing difficulties in autistic adults. Despite the autistic group displaying good explicit mentalizing abilities, our findings showed that only the non-autistic group showed a clear looking preference towards the belief-congruent AOI during the FBLD condition. Thus, the autistic participants did not seem to spontaneously anticipate the protagonist's actions based on her false-belief.

We also replicated results from Wu et al. (2024), who found no interaction between group and belief. Alongside the main effect of group, this indicates that autistic adults spent considerably less time looking at the belief congruent AOI than the non-autistic adults across both TB and FB conditions. Whilst an initially unexpected result, Wu et al. concluded that it may be a result of the TB trials requiring visual perspective taking, itself a mentalizing-dependent process (Hamilton et al., 2009). Thus, the TB trials may not act as the mentalizing-free control as intended. Our replication of this finding further highlights the need for the development of a new TB condition without a visual perspective change. This would verify that autistic people's performance is limited solely by a difference in spontaneous mentalizing.

Whilst our results largely replicated those of Wu et al. (2024), we did not find an effect of belief on DLSs, meaning that participants showed a similar looking bias towards the belief-congruent AOI across the TB and FB conditions. We also found overall smaller effect sizes. These findings may be a consequence of the higher working memory load of our stimuli set (Wang & Leslie, 2016). In Wu et al. (2024) and in Southgate et al. (2007)'s original work, the toy was shown to the participants as it was moved from one box to the other. However, in this study, the participants only saw the toy in its original location, requiring them to remember which box it was in, as the boxes were moved. Therefore, working memory load may have compromised our anticipatory looking paradigm, contributing to the lack of an effect of belief. This divergence from Wu et al. (2024)'s findings, and the higher number of our participants performing at chance in the familiarisation trials, suggest that Wu et al.'s stimuli design is more suitable for future work.

In conclusion, we have demonstrated that the core finding from Wu et al. (2024), the lack of a belief-congruent looking bias in a group of autistic adults, is maintained across participant samples and stimuli. More generally, these findings provide further evidence for the presence of mentalizing differences in autism and highlight the need for tests of mentalizing that tap into the underlying spontaneous cognitive mechanism. Furthermore, non-verbal implicit tasks, such as this anticipatory-looking paradigm, hold promise for facilitating the inclusion of people who are often under-represented in autism research.

References

Gliga, T., Senju, A., Pettinato, M., Charman, T., Jackson, M., & The BASIS Team. (2014). Spontaneous Belief Attribution in Younger Siblings of Children on the Autism Spectrum. *Developmental Psychology*, *50*(3), 903–913. https://doi.org/10.1037/a0034146

Hamilton, A. F. de C., Brindley, R., & Frith, U. (2009). Visual perspective taking impairment in children with autistic spectrum disorder. *Cognition*, *113*(1), 37–44. https://doi.org/10.1016/j.cognition.2009.07.007

Kamp-Becker, I., Ghahreman, M., Heinzel-Gutenbrunner, M., Peters, M., Remschmidt, H., & Becker, K. (2013). Evaluation of the revised algorithm of Autism Diagnostic Observation Schedule (ADOS) in the diagnostic investigation of high-functioning children and adolescents with autism spectrum disorders. *Autism*, *17*(1), 87–102. https://doi.org/10.1177/1362361311408932

Schneider, D., Bayliss, A. P., Becker, S. I., & Dux, P. E. (2012). Eye movements reveal sustained implicit processing of others' mental states. *Journal of Experimental Psychology: General*, *141*(3), 433–438. https://doi.org/10.1037/a0025458

Schneider, D., Slaughter, V. P., Bayliss, A. P., & Dux, P. E. (2013). A temporally sustained implicit theory of mind deficit in autism spectrum disorders. *Cognition*, *129*(2), 410–417. https://doi.org/10.1016/j.cognition.2013.08.004

Schuwerk, T., Vuori, M., & Sodian, B. (2015). Implicit and explicit Theory of Mind reasoning in autism spectrum disorders: The impact of experience. *Autism*, *19*(4), 459–468. https://doi.org/10.1177/1362361314526004

Senju, A., Csibra, G. (2008). Gaze Following in Human Infants Depends on Communicative Signals. *Current Biology*, *18*(9), 668-671. https://doi.org/10.1016/j.cub.2008.03.059

Senju, A., Southgate, V., White, S., & Frith, U. (2009). Mindblind Eyes: An Absence of Spontaneous Theory of Mind in Asperger Syndrome. *Science*, *325*(5942), 883–885.

Southgate, V., Senju, A., & Csibra, G. (2007). Action Anticipation through Attribution of False Belief by 2-Year-Olds. *Psychological Science*, *18*(7), 587–592.

Wang, L., & Leslie, A. M. (2016). Is Implicit Theory of Mind the 'Real Deal'? The Own-Belief/True-Belief Default in Adults and Young Preschoolers. *Mind & Language*, *31*(2), 147–176. https://doi.org/10.1111/mila.12099

White, S., Happé, F., Hill, E., & Frith, U. (2009). Revisiting the Strange Stories: Revealing Mentalizing Impairments in Autism. *Child Development*, *80*(4), 1097–1117.

Wu, R., Lim, J. T., Ahmed, Z., Berger, R., Acem, E., Chowdhury, I., & White, S. J. (2024). Do autistic adults spontaneously reason about belief? A detailed exploration of alternative explanations. *Royal Society Open Science*, *11*(7), 231889.

Table 1

Group descriptive statistics, mean (standard deviation), and comparisons

	Autistic (n = 26)	Non-Autistic (n = 28)	Comparisons
Gender (Female: Male)	5: 21	7: 21	$X^2(1)=0.26$, $p=.61$
Age	34.88 (7.71)	32.21 (10.70)	$t(52)=1.05$, $p=.30$
Performance IQ [a]	110.54 (14.43)	114.64 (13.33)	$t(52)=-1.09$, $p=.28$
Verbal IQ [a]	115.85 (10.13)	117.75 (10.53)	$t(52)=-0.68$, $p=.50$
Full-scale IQ [a]	114.69 (11.59)	117.64 (11.54)	$t(52)=-0.94$, $p=.35$
AQ [b]	33.16 (8.74)	13.75 (5.67)	$t(51)=9.69$, $p<.001$

[a] Measured using the Wechsler Abbreviated Scale of Intelligence-II or Wechsler Adult Intelligence Scale - III

[b] One autistic participant did not complete

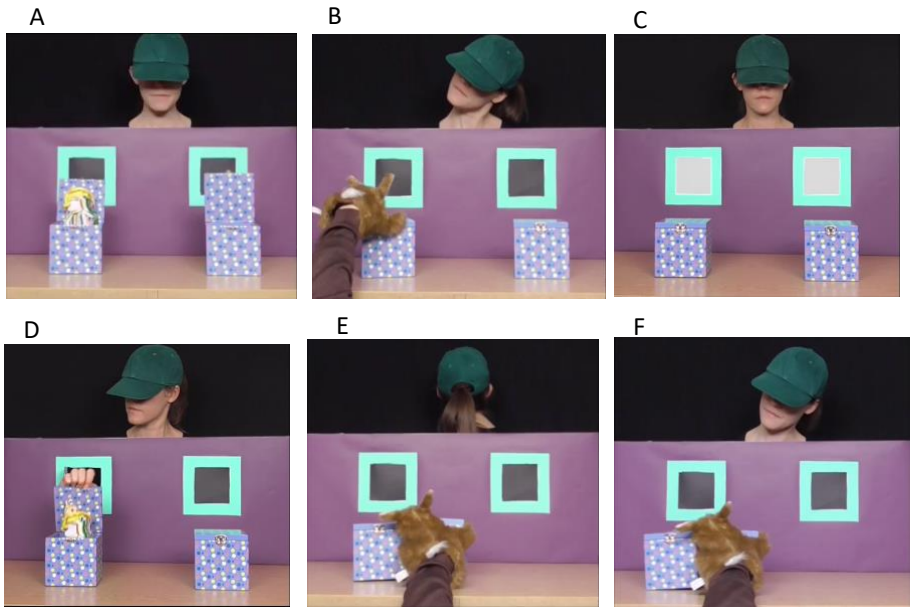
Table 2

One sample t-tests against chance level performance (0)

Condition	Autistic		Non-Autistic	
	M(SD)	*t*-test	M(SD)	*t*-test
TBLT	0.02(0.37)	*t*(25)=0.27, *p*=.79, *d*=0.05	0.21(0.42)	*t*(27)=2.70, *p*=.01*, *d*=0.51
FBLD	0.08(0.23)	*t*(25)=1.77, *p*=.09, *d*=0.35	0.13(0.29)	*t*(27)=2.43, *p*=.02*, *d*=0.46
TBST	0.06(0.24)	*t*(25)=1.34, *p*=.19, *d*=0.26	0.11(0.33)	*t*(27)=1.80, *p*=.08, *d*=0.34
FBHD	-0.03(0.33)	*t*(25)=-0.51 , *p*=.62, *d*=0.10	-0.02(0.36)	*t*(27)=-0.23 , *p*=.83 *d*=0.04

Figure 1

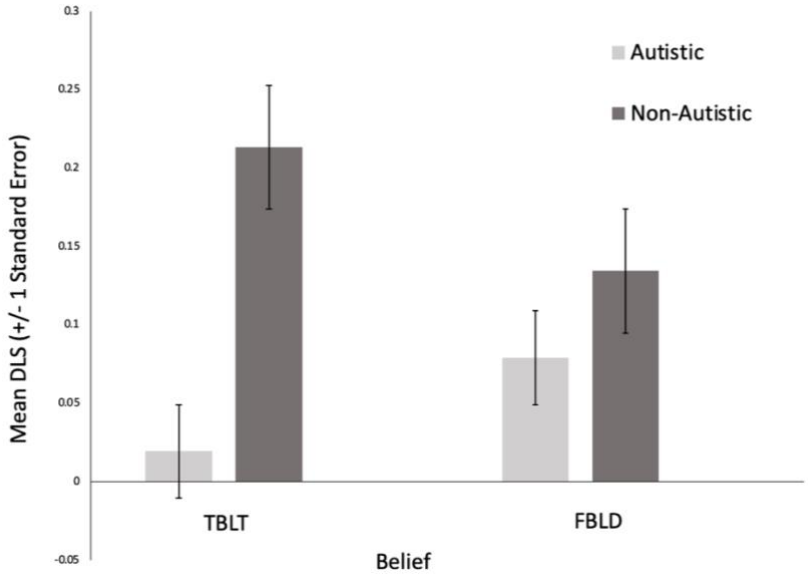
Sequence of events in familiarization and experimental trials in implicit mentalizing task



Note. Images A to D depict the sequence of events that occur in the familiarization trials: image A shows the initial set-up, image B shows the puppet closing the lids of the boxes, image C shows both windows illuminated (at this point a chime sounded) and image D shows the protagonist reaching through the window above the box with the toy in it and opening its lid. Images E and F depict events from the experimental trials: image E shows the puppet moving the boxes while the actor looks away and Image F shows the puppet moving the boxes while the actor watches. As seen in these images, the protagonist's head followed the movement of the puppet to indicate that she was paying attention to the scene.

Figure 2

Mean DLS for TBLT and FBLD conditions for autistic and non-autistic groups



Note. A main effect of group but not belief was found and there was no belief*group interaction.