# Supporting Online Material for

## Mindblind Eyes: An Absence of Spontaneous Theory of Mind in Asperger Syndrome

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## Materials and Methods

***Participants***. Data from 19 participants with Asperger Syndrome (5 female, 14 male), as well as 17 neurotypical participants (5 female, 12 male), matched by age and IQ, were included in the analyses (Table 1). An additional neurotypical participant was excluded from the analyses because of a technical problem. All the participants were recruited through the autism research database at the UCL Institute of Cognitive Neuroscience, and written informed consent was obtained from each participant before the study began. The study was approved by the UCL Research Ethics Committee.

All participants in the Asperger group had previously been diagnosed with Asperger Syndrome by a qualified clinical psychologist or psychiatrist. To assess their current clinical manifestation, the Autism Diagnostic Observational Schedule-Generic (ADOS-G: (*1*)) was administered. Eight of the Asperger participants met the criteria for Autism, 5 for Autism Spectrum, and the remaining 6 scored below the cut-off point. These latter participants were significantly older (mean age 48 vs. mean age 32, $t(17) = 2.67$, $p = .02$, *Cohen's d* = 1.18, t-test) and presumably better compensated. We report the results obtained from all the participants with AS, having confirmed that they did not change when only those participants scoring above the ADOS score of 7 were included in the analyses.

Verbal, non-verbal and full-scale IQ was measured with the Wechsler Adult Intelligence Scale (WAIS-III UK: (*2*)). All participants in both the AS and neurotypical group completed the Autism-Spectrum Quotient (AQ: (*3*)) as well.

The participants also completed a battery of Theory of mind (ToM) tasks, which consisted of five first-order false belief tests and two second-order false belief tests, requiring the participant to either interpret another person's behaviour or to understand another's emotion based on the false belief of a protagonist (Sally-Ann: (*4*); Smarties: (*5*); Interpretational false belief: (*6*); Belief-emotion and Real-apparent emotion: (*7*); Ice Cream Van: (*8*); Coat Story: (*9*)). References for these tests are presented in the text.

Answers were marked as a pass or fail (1 or 0) for each task. In addition the participants were asked to justify their choice; this was marked as a correct mental state justification (e.g. 'because she doesn't know it's in the box'), a correct non-mental state justification (e.g. 'because she left it in the basket'), or an incorrect justification (e.g. 'because no-one stole it apart from Anne'). This additional scoring (1, 0.5 or 0 respectively) aimed to check for false positive responses when the participant was achieving the correct answer by guessing, and also was expected to increase the variation in responses with the aim of avoiding ceiling effects. Control questions (memory and reality questions: e.g. 'where did Sally put the ball in the beginning?') were also administered. Prompt questions (e.g. 'where did the icecream man tell John he was going?') were asked during the more complex tasks, which all participants were required to pass in order to check for comprehension of the scenario.

A composite ToM score was calculated by summing the number of correct responses and justifications (max = 14) across these 7 tests. ToM scores ranged from 4 to 13.5 in the Asperger group, and from 9 to 12.5 in neurotypical group. There was no significant difference between the two groups on the composite ToM score (Table 1). All participants with Asperger syndrome passed the two classic False Belief tasks (*i.e.* Sally-Ann and Smarties).

In addition, an 'advanced' theory of mind test (Strange Stories, (*10*) using eight ToM stories (*11*)) was also administered. After each story had been read, the participant was presented with a question about its content (e.g. Why did Brian say this?). Correct answers have to provide context-appropriate mental state explanations for the story characters' non-literal utterances. The score represents the sum total of correct answers about the mental

states of protagonists (fail = 0; pass = 1) and correct justifications (fail = 0; physical justification = 0.5; mental justification = 1; max = 16). Full test materials and detailed scoring criteria is presented in White et al. (*12*). The scores ranged from 10 to 16 in the Asperger group, and from 12 to 16 in the neurotypical group. No group differences were observed (Table 1).

***Apparatus and Stimuli***. A Tobii (Stockholm, Sweden) T120 Eye Tracker, integrated with a 17-inch TFT monitor was used to present the stimuli and record eye movements. Stimulus presentation and recording were controlled via a computer with Tobii's Studio software. Participants were seated approximately 50 cm from the monitor. A nine-point calibration was completed before the stimulus presentation.

The stimuli consisted of four familiarization trials, followed by one of two test trials (*Figure 1*, *Movies S1* and *S2*). All participants viewed the same four familiarization trials, and were randomly assigned to receive the FB1 or FB2 test trial. The stimuli were identical to those used in our previous study (*13*), with two exceptions. Firstly, in our previous study with young children, a large number of participants were excluded for failing to pass the second (final) familiarization trial. To ensure participants learnt the contingency between the cues (illumination and chime) and subsequent window opening, we added an additional two familiarization trials in the beginning in which no object was hidden, but a small toy was visible sitting on top of one of the boxes. This scene was then followed by the onset of the cues, and the actor subsequently opened the window above the box on which the toy sat. Secondly, in the single test trial presented to each participant, no action outcome was revealed. Instead, the movie was frozen for 5 seconds following the 1 second illumination and chime. The purpose of the familiarization trials was (a) to show that the actor's goal was to obtain a specific object, and (b) to teach the participant the link between the windows being illuminated together with a corresponding 'chime' sound, and the subsequent opening of one of the windows by the actor. To be included in the analysis, participants were required to understand the contingency between the cues (illumination of the windows with the simultaneous activation of a chime sound) (*Figure 1B*) and the actor's impending reaching, and had to display anticipatory looking toward the correct window by the fourth familiarization trial. These trials did not involve the actor having a false belief . All the participants met this criterion.

Two versions of the test trials, FB1 (*Movie S1*) and FB2 (*Movie S2*), were used in order to counterbalance the first and last location of the target object, as well as the last location of the actor's gaze, which could affect participants' eye movements. The same familiarization trials were presented to all the participants, in the same order, and then each participant observed a single test trial (FB1 or FB2), counterbalanced between participants. The reason why we only administered one trial per participant was to avoid the possibility that they would inadvertently learn the outcome (i.e. nothing happens for the period of 5s after the illumination and a chime), which could affect their motivation to look towards the windows on any subsequent trial. See *Movie S1* and *S2* for videos used in the current study.

***Data reduction***. Eye-tracking data was analyzed as follows: After recording, a gaze replay file showing the exact location of each participant's gaze was exported at 25 frames per second with the Tobii Studio program. From the exported data, fixation points were coded frame-by-frame starting from the point when the windows were illuminated to the end of stimulus presentation (6 seconds). Having obtained the total looking time to each of the two windows, a differential looking score (DLS) was calculated by subtracting the total looking time to the incorrect window from looking to the correct window, and by dividing it by the sum

of looking time to correct and incorrect windows. The DLS is a measure of preference for looking at one target over another, and can range between 1 and -1, being closer to 1 if the participant spent most time looking at the correct location, and closer to zero if the participant looked randomly to both windows. We also coded the direction of first saccade after the illumination of the windows.

**Supporting Text**

***Additional analyses on eye tracking data***. To further examine the group differences in the pattern of visual scanning, the total number of fixations and the mean duration of fixation during the text trial were calculated and compared between groups. Fixation was defined as the continuous gaze within the radius of 2.5º of visual angle for at least 100 ms, and extracted with the Tobii Studio program. No differences were observed between groups in the number of fixations (Asperger group: Mean±SD: 81.8±36.8; Neurotypical group: 69.4±22.9 in the neurotypical group, $t(34) = 1.20$, $p = .24$, *Cohen's d* = .40, t-test) or duration of fixation (Asperger group: Mean±SD: 639.5±253.7 ms; Neurotypical group: 934.6±625.2 ms, $t(34) = 1.89$, $p = .07$, *Cohen's d* = .62, t-test). In addition, the number of saccades toward the actor's face during the test trial was analyzed to examine the potential group difference in their attention to the actor's gaze. However, results revealed that both groups made a similar number of saccades towards the actor's face (Asperger group: Mean±SD: 8.0±4.9; Neurotypical group: 10.7±6.8, $t(34) = 1.39$, $p = .17$, *Cohen's d* = .46, t-test). Thus, differences in action anticipation based on false belief between the two groups cannot be attributed to an atypical pattern of fixation or reduced monitoring of the actor's gaze in the Asperger group.

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*Movie S1*. Stimulus sequence (FB1). The resolution of the movie was reduced for on-line presentation.

*Movie S2*. Stimulus sequence (FB2). The resolution of the movie was reduced for on-line presentation.