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8. A. Paukner, J. R. Anderson, E. Borelli, E. Visalberghi, P. F. Ferrari, *Biol. Lett.* **1**, 219 (2005).
9. E. Visalberghi, D. M. Fragaszy, in *Imitation in Animals and Artifacts*, K. Dautenhahn, K. Nehanic, Eds. (Massachusetts Institute of Technology Press, Cambridge, MA, 2002), pp. 247–273.
10. S. Perry *et al.*, *Curr. Anthropol.* **44**, 241 (2003).
11. I. Agostini, E. Visalberghi, *Am. J. Primatol.* **65**, 335 (2005).
12. A. N. Meltzoff, K. M. Moore, in *Intersubjective Communication and Emotion in Early Ontogeny*, S. Braten, Ed. (Cambridge Univ. Press, Cambridge, 1998), pp. 47–62.
13. B. Agnetta, P. Rochat, *Infancy* **6**, 1 (2004).
14. Materials and methods are available as supporting material on *Science* Online.
15. D. M. Fragaszy, E. Visalberghi, L. M. Fedigan, *The Complete Capuchin* (Cambridge Univ. Press, Cambridge, 2005).
16. Y. Hattori, H. Kuroshima, K. Fujita, *Anim. Cogn.* **10**, 141 (2007).
17. E. Addessi, L. Crescimbene, E. Visalberghi, *Proc. R. Soc. London Ser. B* **274**, 2579 (2007).
18. S. S. Wiltermuth, C. Heath, *Psychol. Sci.* **20**, 1 (2009).
19. N. Herve, B. L. Deputte, *Primates* **34**, 227 (1993).
20. F. B. M. de Waal, *The Ape and the Sushi Master: Cultural Reflections of a Primatologist* (Basic Books, New York, 2001).
21. J. L. Lakin, V. E. Jefferis, C. M. Chang, T. L. Chartrand, *J. Nonverbal Behav.* **27**, 145 (2003).
22. F. B. M. de Waal, K. Leimgruber, A. R. Greenberg, *Proc. Natl. Acad. Sci. U.S.A.* **105**, 13685 (2008).
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Mindblind Eyes: An Absence of Spontaneous Theory of Mind in Asperger Syndrome

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Adults with Asperger syndrome can understand mental states such as desires and beliefs (mentalizing) when explicitly prompted to do so, despite having impairments in social communication. We directly tested the hypothesis that such individuals nevertheless fail to mentalize spontaneously. To this end, we used an eye-tracking task that has revealed the spontaneous ability to mentalize in typically developing infants. We showed that, like infants, neurotypical adults' (n = 17 participants) eye movements anticipated an actor's behavior on the basis of her false belief. This was not the case for individuals with Asperger syndrome (n = 19). Thus, these individuals do not attribute mental states spontaneously, but they may be able to do so in explicit tasks through compensatory learning.

Impairment in reciprocal social interaction and communication is a core feature of autism spectrum disorders, regardless of age and ability. This core feature is manifest in a wide range of social impairments, including characteristic deficits in comprehension and use of pretend play, expressive gestures, deception, and irony (*1*). One influential account that can explain these varied and characteristic impairments proposes that they are a consequence of a failure in the neurologically based capacity to "mentalize," that is, the automatic ability to attribute mental states to the self and others. The first evidence for this hypothesis, which is also known as a deficit in theory of mind (ToM) or "mindblindness" (*2*, *3*), comes from the finding that children with autism fail the verbally instructed Sally-Anne false-belief task (FBT), whereas 4-year-old neurotypical children pass, as do children with Down syndrome of similar verbal mental age (*4*).

In this task, which is considered a stringent test of ToM (*5*), one character (Sally) places a marble in a basket and leaves the room. In her absence, another character (Anne) moves the marble to a box. When Sally returns, children are asked where she will look for her marble. If children understand that Sally's actions will be based on what she believes to be true, rather than the actual state of affairs, they should answer that she will look in the basket, rather than the box. This correct answer requires the child to predict Sally's behavior based on her now false belief.

Despite still exhibiting atypical social features characteristic of autism, individuals of higher verbal ability, in particular those with Asperger syndrome, can pass such false-belief attribution tasks (*6*–*9*). This competence presents a puzzle for the mindblindness hypothesis (*10*) and has prompted the proposal that these high-ability individuals have acquired the ability to reason explicitly about false beliefs by compensatory learning, whereas difficulties in spontaneous mental-state attribution may nevertheless persist (*11*). To date, there is only indirect evidence in support of this hypothesis (*12*–*16*). In this study, we seek to provide direct evidence by contrasting the ability to pass the standard FBT with spontaneous looking behavior during a nonverbal form of this task.

In a groundbreaking study, Onishi and Baillargeon (*17*) used an FBT scenario to exploit infants' tendency to look longer at events that they do not expect. The authors showed that 15-month-old infants looked substantially longer when an actor searched in a location where an object was hidden that she could not know about (that is, when her behavior was incongruent with her belief). Southgate *et al.* (*18*) extended this paradigm so that, rather than measuring whether young children look longer at unexpected outcomes, they measured whether children actually anticipate the outcomes before they happen. They designed a task that made it possible to assess directly whether children had an understanding of the content of an actors' belief. Briefly, 25-month-old children were familiarized to an event in which a puppet hid a ball in one of two boxes (Fig. 1A), and then an actor reached through one of two windows to retrieve the ball from the box (Fig. 1C). Before she reached, a light and simultaneous chime signaled that the actor was about to open a window to retrieve the hidden object (Fig. 1B). In the test trial, the puppet transferred the ball from one box to another and then removed it altogether while the actor was looking away (Fig. 1D). An eye tracker was used to assess whether children expected (by making anticipatory eye movements) the actor to open the door, which would be consistent with her having a false belief about the location of the ball. Southgate *et al.* found that these typically developing children made eye movements toward the window above the box, which was consistent with the actor's belief about the location of the ball, despite the fact that it no longer contained the ball. These children, who would not be able to perform the traditional verbally instructed FBT, thus correctly anticipated the actor's behavior in line with her false belief.

It is this task (detailed above) that we used for the present study (see also movies S1 and S2). We asked whether adults with Asperger syndrome would, through their anticipatory looking, reveal a similar spontaneous capacity for false-belief attribution. At the same time, we had to establish that neurotypical adults would show the same anticipatory looking as young

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children. Before the main analyses, we confirmed that all the participants showed anticipatory looking toward the correct location during familiarization trials (*19*). Written informed consent was obtained from each participant before the study began. The study was approved by the University College London Research Ethics Committee.

As shown in Table 1, the Asperger and neurotypical groups in our study were very similar in age and intelligence quotient (IQ). As no sex differences were shown in any of our measures, we pooled results over gender in each group. We found that the participants with Asperger syndrome performed at the same level as neurotypical adults on verbally instructed versions of a variety of standard ToM tests, including the previously described Sally-Anne task. There were no group differences in the composite ToM score or in the Strange Stories test (both *t*s < 1.61, both *p*s > 0.1, *t* test). All participants with Asperger syndrome passed the two standard FBTs.

However, the eye-tracking version of the FBT revealed a very different picture. We used differential looking score (DLS) (*20*), which is considered a highly reliable measure of looking bias (*21*, *22*), compiled over a 6-s period (*19*). The Asperger group showed significantly less looking bias toward the correct window than did the neurotypical group [Fig. 2A, main effect of group: $F_{1,32} = 4.93$, $P = 0.003$, $\eta_p^2 = 0.13$, analysis of variance]. Follow-up *t* tests revealed that the neurotypical group scored significantly above zero [mean = 0.42, $t(16) = 2.76$, $P = 0.014$, Cohen's $d = 0.67$, *t* test], meaning that this group showed a significant bias toward the correct target, in line with the actor's false belief. This was not the case for the Asperger group, whose bias did not differ from zero [mean: –0.001, $t(18) = -0.010$, $P = 0.99$, Cohen's $d = 0.002$, *t* test].

We also coded the direction of first saccade (Fig. 2B). Here, 13 out of 17 neurotypical participants made their first eye movement toward the correct location, which was significantly above chance ($P = 0.049$, binominal test). In contrast, only 8 out of 19 individuals in the Asperger group made a correct saccade first, but this did not significantly differ from chance ($P = 0.647$, binominal test). These results are consistent with the DLS reported above. However, the first saccade, which represents a broad categorical response, did not differentiate significantly between the groups ($P = 0.30$, Fisher's exact test, two-tailed).

Could our results be due to gaze abnormalities in the Asperger group? It is important to note that they could not be attributable to an avoidance of eye gaze because the actor's eyes were hidden beneath a visor. However, the duration of fixations to the actor's face was significantly shorter in the Asperger group (mean = 1.9 s) than in the neurotypical group (mean = 3.1 s) [$t(34) = -2.48$, $P = 0.018$, Cohen's $d = 0.827$, *t* test]. This was not due to overall shorter fixations in the Asperger group, as the duration of fixations toward the windows (correct and incorrect combined) did not differ between groups [mean = 2.5 s in Asperger group and 1.9 s in neurotypical group; $t(34) = 1.53$, $P = 0.14$, Cohen's $d = 0.506$, *t* test]. The correlation between DLS and the duration of face fixation was not significant in either the Asperger or neurotypical group. Furthermore, total time spent looking at the five regions of interest (face, two windows, and two boxes) did not differ between groups (4.8 s in Asperger group and 5.1 s in neurotypical group, see supporting online material text for further details). Thus, the lack of bias toward the "correct" target in the Asperger group is not explained by gaze abnormalities.

Our study demonstrates that adults with Asperger syndrome do not spontaneously anticipate others' actions in a nonverbal task, closely modeled on the standard FBT that they pass with ease. In particular, the contrast with neurotypical 2-year-olds who show spontaneous looking to the correct location on the same task (*18*) is quite notable. It is unlikely that differences in motivation are to blame, because neurotypical adults showed the same bias as typically developing children, and the Asperger group exhibited correct anticipatory looking on familiarization trials

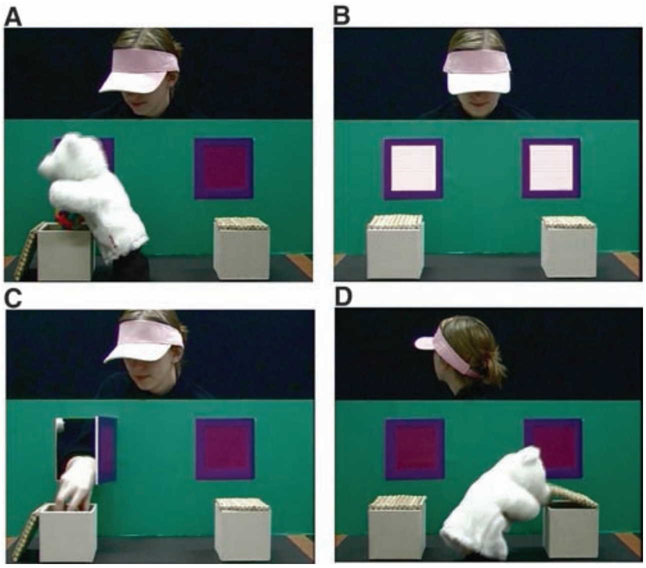

Fig. 1. Selected scenes from stimulus movies (see also movies S1 and S2). In familiarization trials, participants were familiarized to an event in which (**A**) the puppet placed a ball in one of two boxes, (**B**) both windows were illuminated and a chime sounded, and (**C**) an actor reached through the window above the box in which the ball was placed and retrieved the ball. The participants were familiarized to the contingency between (B) and (C). In (**D**), the puppet moves the ball while the actor is looking away. This operation induces a false belief in the actor about the location of the ball.

Table 1. Mean chronological age (CA), verbal IQ (VIQ), performance IQ (PIQ), full-scale IQ (FIQ) (WAIS-III UK), composite ToM score (ToM), Strange Stories test score (SS), scores of autism quotient (AQ), and autism diagnostic observation schedule–generic (ADOS-G).

Group	Asperger syndrome			Neurotypical		
	Mean	SD	Range	Mean	SD	Range
CA	36.8	14.3	21–67	39.6	11.7	26–63
VIQ	116.8	14.4	85–144	116.1	13.2	91–138
PIQ	109.6	13.0	80–132	111.5	10.6	97–132
FIQ	115.6	14.9	89–144	115.3	11.0	95–129
ToM*	9.7	2.0	4–13.5	10.6	1.3	8.5–12.5
SS†	13.2	1.8	10–16	13.6	1.3	12–16
AQ‡	34.9	7.6	17–48	16.5	7.6	6–37
ADOS-G	7.9	4.7	0–17	–	–	–

*The ToM tests consisted of five first-order FBTs [Sally-Anne (*4*), Smarties (*23*), interpretational false belief (*24*), belief-emotion and real-apparent emotion (*25*)] and two second-order FBTs [ice cream van (*26*) and coat story (*6*)]. †The Strange Stories test was taken from (*27*) and required the participant to either interpret another's behavior or understand another's emotion. ‡AS and NT groups differed significantly on the autism-spectrum quotient confirming their diagnostic status [AQ: (*28*), $t(34) = 7.23$, $P < 0.001$, Cohen's $d = 2.41$, *t* test]. No other variables were significantly different between the two groups.

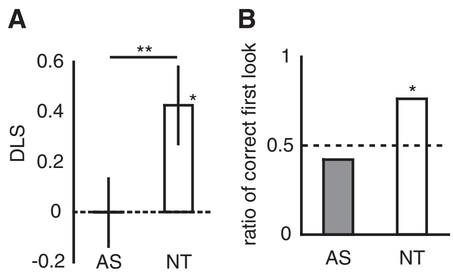

Fig. 2. (**A**) Mean (± SEM) DLS (*19*) and (**B**) the ratio of the number of participants who made correct first saccades in each group. AS, participants with Asperger syndrome ($n = 19$); NT, neurotypical participants ($n = 17$). *$P < 0.05$; **$P < 0.01$. Dotted lines indicate chance level. Statistical test used: (A), *t* test; (B), binominal test.

when no belief reasoning was required. The current results confirm indirect indications (*12–15*) that individuals with Asperger syndrome have a persistent impairment in spontaneous mentalizing and are also consistent with a previous finding (*16*) that children with autism are more likely to give a correct verbal answer than a correct anticipatory look when asked to infer someone's preference.

Although it is plausible that the documented early emerging spontaneous capacity to mentalize (*17*, *18*) is a prerequisite for the later ability to justify behavior in terms of mental states in verbal tasks, our results suggest that this need not necessarily be the case. Instead, our data raise the surprising possibility that an early developing form of the cognitive ability to mentalize, evident in spontaneous looking behavior, is not a necessary precursor of the later developing form of mental-state attribution, which supports explicit reasoning. The former would require spontaneous encoding of socially relevant information and automatic online computation of others' mental states, whereas the latter could also be achieved by verbally mediated reasoning prompted by explicit task structure and instructions.

We suggest that compensatory learning can circumvent neurophysiological limitations, even without removing the original cause of the limitation. Such compensatory learning might explain the apparent paradox between success on explicit FBTs and continued difficulty in everyday social interaction for individuals with Asperger syndrome.

References and Notes

1. U. Frith, *Autism: Explaining the Enigma* (Blackwell, Oxford, ed. 2, 2003).
2. S. Baron-Cohen, *Mindblindness: An Essay on Autism and Theory of Mind* (Massachusetts Institute of Technology Press, Cambridge, MA, 1995).
3. U. Frith, *Neuron* **32**, 969 (2001).
4. S. Baron-Cohen, A. M. Leslie, U. Frith, *Cognition* **21**, 37 (1985).
5. D. Dennett, *Behav. Brain Sci.* **1**, 568 (1978).
6. D. M. Bowler, *J. Child Psychol. Psychiatr.* **33**, 877 (1992).
7. F. G. Happé, *Child Dev.* **66**, 843 (1995).
8. C. C. Peterson, V. P. Slaughter, J. Paynter, *J. Child Psychol. Psychiatr.* **48**, 1243 (2007).
9. S. G. Shamay-Tsoory, *J. Autism Dev. Disord.* **38**, 1451 (2008).
10. A. Klin, W. Jones, R. Schultz, F. Volkmar, D. Cohen, *Am. J. Psychiatr.* **159**, 895 (2002).
11. U. Frith, *J. Child Psychol. Psychiatr.* **45**, 672 (2004).
12. F. Abell, F. Happé, U. Frith, *Cogn. Dev.* **15**, 1 (2000).
13. A. Klin, *J. Child Psychol. Psychiatr.* **41**, 831 (2000).
14. F. Castelli, C. Frith, F. Happé, U. Frith, *Brain* **125**, 1839 (2002).
15. R. K. Kana, T. A. Keller, V. L. Cherkassky, N. J. Minshew, M. A. Just, *Soc. Neurosci.* **4**, 135 (2009).
16. T. Ruffman, W. Garnham, P. Rideout, *J. Child Psychol. Psychiatr.* **42**, 1083 (2001).
17. K. H. Onishi, R. Baillargeon, *Science* **308**, 255 (2005).
18. V. Southgate, A. Senju, G. Csibra, *Psychol. Sci.* **18**, 587 (2007).
19. Materials and methods are available as supporting material on *Science* Online.
20. A. Senju, G. Csibra, *Curr. Biol.* **18**, 668 (2008).
21. V. Corkum, C. Moore, *Dev. Psychol.* **34**, 28 (1998).
22. H. M. Wellman, S. Lopez-Duran, J. LaBounty, B. Hamilton, *Dev. Psychol.* **44**, 618 (2008).
23. J. Perner, S. R. Leekam, H. Wimmer, *Br. J. Dev. Psychol.* **5**, 125 (1987).
24. T. Luckett, S. D. Powell, D. J. Messer, M. E. Thornton, J. Schulz, *J. Autism Dev. Disord.* **32**, 127 (2002).
25. H. M. Wellman, D. Liu, *Child Dev.* **75**, 523 (2004).
26. J. Perner, H. Wimmer, *J. Exp. Child Psychol.* **39**, 437 (1985).
27. P. C. Fletcher *et al.*, *Cognition* **57**, 109 (1995).
28. S. Baron-Cohen, S. Wheelwright, R. Skinner, J. Martin, E. Clubley, *J. Autism Dev. Disord.* **31**, 5 (2001).

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Movies S1 and S2

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