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Article: Recognition memory, self-other source memory, and theory-of-mind in
children with autism spectrum disorder

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Running head: Recognition memory, source memory and theory-of-mind in ASD

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Abstract

This study investigated semantic and episodic memory in autism spectrum disorder (ASD), using a task which assessed recognition and self-other source memory. Children with ASD showed undiminished recognition memory but significantly diminished source memory, relative to age- and verbal ability-matched comparison children. Both children with and without ASD showed an “enactment effect”, demonstrating significantly better recognition and source memory for self-performed actions than other-person-performed actions. Within the comparison group, theory-of-mind (ToM) task performance was significantly correlated with source memory, specifically for other-person-performed actions (after statistically controlling for verbal ability). Within the ASD group, ToM task performance was not significantly correlated with source memory (after controlling for verbal ability). Possible explanations for these relations between source memory and ToM are considered.

Keywords: Autism spectrum disorder; episodic memory; recognition memory; semantic memory; source memory; theory-of-mind.

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Recognition memory, self-other source memory, and theory-of-mind in children with
autism spectrum disorder

Autism spectrum disorder (ASD) is characterised by a particular profile of strengths and weaknesses in memory (see Boucher & Bowler, 2008). For example, whilst semantic memory appears to be relatively undiminished, episodic memory appears to be significantly impaired (e.g., Bowler, Gardiner, & Gaigg, 2007). The semantic memory system is responsible for the encoding, storage, and retrieval of impersonal, factual information and general knowledge. The episodic system is responsible for the encoding, storage, and retrieval of personally experienced events (e.g., Wheeler, Stuss, & Tulving, 1997). Thus, a child with ASD might, for instance, be able to name the capital city of every country in the world, whilst encountering considerable difficulties when asked questions such as “What did you do at school today?”

One of the key differences between semantic and episodic retrieval is that each is associated with a different level of conscious awareness – *noetic* (knowing) and *autonoetic* (self-knowing) awareness, respectively (Wheeler et al., 1997). Autonoetic awareness involves focusing attention directly onto one’s own *subjective* experience, whereas noetic awareness involves thinking *objectively* about something that one knows. Perner (2000) proposes that autonoetic episodic memory relies on a theory-of-mind (ToM). According to this approach, episodic remembering involves understanding that what is being brought to mind during the act of remembering is a mental representation of a past experience. Supporting this suggestion, studies of typical development have shown there to be a relationship between episodic memory and ToM (e.g., Perner, Kloo, & Gornik, 2007). Although it has not previously been investigated, it is possible that the well-established difficulty that children with ASD

have in representing mental states (e.g., Happé, 1995) impacts upon their capacity for auto-noetic awareness and hence their capacity for episodic remembering.

Source memory involves identifying the context under which a memory was acquired. It is considered to be a function of the episodic memory system because only *episodic* retrieval involves “re-experiencing” the spatio-temporal context of the recollected episode (Johnson, Hashtroudi, & Lindsay, 1993; Wheeler et al., 1997). For example, remembering not only *what* was said in a conversation, but also *who* said what, may require episodic retrieval. Johnson et al. (1993) have distinguished between three types of source memory: *internal* (e.g., judging whether one actually performed an action or merely imagined performing that action); *external* (e.g., judging which of two individuals performed an action); and *internal-external* or *self-other* (e.g., judging whether it was oneself or another person who performed an action).

Given that individuals with ASD show reduced episodic memory capacity, they should show diminished performance on tasks requiring them to make source judgments. Although there are some discrepancies in the literature, the majority of the evidence suggests that individuals with ASD show impaired internal and external source memory (Bennetto, Pennington, & Rogers, 1996; Bowler, Gardiner, & Berthollier, 2004; Hala, Rasmussen, & Henderson, 2005; O’Shea, Fein, Cillessen, Klin, & Schultz, 2005; Russell & Jarrold, 1999). However, results from studies of self-other source memory are less consistent, with a number of contradictory findings. Two studies have found self-other source memory to be significantly diminished (Hala et al., 2005; Russell & Jarrold, 1999) and three studies have found it to be intact (Farrant, Blades & Boucher, 1998; Hill & Russell, 2002; Williams & Happé, 2009).

How can these discrepancies be accounted for? In typical populations, self-other source judgments are easier to make than internal or external source judgments (e.g., Hashtroudi, Johnson, & Chrosniak, 1989). Thus, if self-other source memory is diminished in ASD, this diminution is likely to be less marked than the diminution of internal or external source memory. Therefore, group differences might yield only relatively small effect sizes, which may not reach significance with small samples. Indeed, the three studies of self-other source memory that failed to find ASD-specific deficits, each involved small samples ($n = 15$ to 20). Thus, it is unclear whether or not individuals with ASD would show a diminution in self-other source memory if larger samples were tested.

It has been suggested that ASD may entail a particular problem with *personal* episodic memory (Powell & Jordan, 1993) or memory for experiences directly involving the *self* (Hare, Mellor, & Azmi, 2007). It is established that typical adults and children over the age of approximately 6 years show better memory for self-performed tasks than other-person-performed tasks (e.g., Engelkamp, 1998; Roberts & Blades, 1998). This memory advantage, associated with being a participating agent rather than an observer, is known as the *enactment effect*. One explanation for the enactment effect is that memory traces for self-performed actions are more salient because they involve an additional motoric component. Thus, the effect depends on the capacity for action-monitoring. Action-monitoring involves distinguishing between internally and externally caused changes in perceptual experience. Despite past speculations that ASD might involve action-monitoring impairments (e.g., Russell, 1996), subsequent research has demonstrated that this is unlikely to be the case (e.g., Williams & Happé, 2009). Thus, children with ASD should show the enactment effect to the same extent as children without ASD.

Findings regarding whether or not children with ASD show the enactment effect are inconsistent. Only one study to date has found the effect amongst participants with ASD (Williams & Happé, 2009). Other studies have either failed to show a significant effect (Farrant et al., 1998; Hare et al., 2007) or have found an “observer effect”, with participants with ASD demonstrating significantly better memory for another person’s actions than for their own (Millward, Powell, Messer, & Jordan, 2000; Russell & Jarrold, 1999). The reliability of the findings of each of these studies may be questioned, however, given that once again small sample sizes ($n = 12$ to 22) were used.

Thus, the current study had three main aims. The first was to assess self-other source memory in a relatively large sample of children with ASD in order to overcome the problem of low power, associated with previous studies. The second was to establish whether individuals with ASD are subject to the enactment effect to the same extent as individuals without ASD. The final aim was to test whether impaired ToM might account for the episodic memory difficulties experienced by individuals with ASD.

In order to address these questions, a memory task involving both old/new item recognition and self-other source memory components was devised. Following Wheeler et al. (1997), recognition memory was used as an index of semantic memory and source memory was used as an index of episodic memory. Although recognition memory is thought to invoke both the episodic and semantic systems amongst typical individuals, successful item recognition can potentially be achieved using purely semantic processes. Source memory, on the other hand, is thought to depend upon the episodic memory system because it requires one to recall contextual elements of the learning episode. Thus, individuals with ASD should be able to compensate for any

episodic memory difficulties by using their relatively intact semantic memory system on the recognition element of the task but not on the source element of the task.

The basic task procedure involved experimenter and child picking up and naming picture cards and then, after a short delay, testing the child's item recognition and source memory. ToM was assessed using a standard unexpected-contents false-belief task (Perner, Leekam, & Wimmer, 1987). It was predicted that (a) children with ASD would show significantly diminished source memory but undiminished recognition memory, (b) children with ASD would show the enactment effect to the same extent as children without ASD, and (c) false-belief task performance would be significantly correlated with source memory performance within each group.

Methods

Participants

Approval for this study was obtained from City University Senate Research Ethics Committee. Participants were recruited through schools in South-East England. The parents of all participants gave their informed, written consent for their children to take part. Two groups of participants were tested: an ASD group and a comparison group. All of the participants in the ASD group attended specialist autism schools or units, for which entry required a formal diagnosis of autistic disorder, Asperger's disorder, pervasive developmental disorder not otherwise specified, or atypical autism (American Psychiatric Association, 2000; World Health Organization, 1993). A thorough review of the participants' Statements of Special Educational Needs confirmed that they had all received formal diagnoses from qualified clinicians of autistic disorder or Asperger's disorder. The comparison group consisted of children

with general intellectual disability of unknown origin (to act as matches for those children with ASD who also had intellectual disability) and typically developing children (to act as matches for those children with ASD who did not have intellectual disability). Potential comparison participants were excluded if they had received specific diagnoses, such as dyslexia, Down syndrome, or attention deficit hyperactivity disorder. Any mention of social communication difficulties in any comparison child's Statement of Special Educational Needs resulted in exclusion from the comparison group, as this may have been indicative of ASD-related symptoms or even undiagnosed ASD.

Verbal ability was assessed using the British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Burley, 1997). This measure was selected for the purposes of matching because the experimental task involved picture naming and therefore depended on vocabulary knowledge to a considerable extent. All participants completed both the memory¹ and false-belief tasks. However, the results are presented in two sections, which include overlapping but not identical samples of participants. Firstly, in Section 1, the performance of an ASD group on the memory task was compared to the performance of a comparison group, who were matched on age and verbal ability. The ASD group consisted of 53 children/adolescents with autistic disorder ($n = 49$) or Asperger's disorder ($n = 4$). The comparison group consisted of 50 children/adolescents with general intellectual disability of unknown origin ($n = 27$) and typically developing children ($n = 23$). The characteristics of each group are presented in Table 1.

[place Table 1 about here]

The primary aim of the second part of the study was to explore any within-participant relation between source memory and ToM task performance. For this purpose, larger groups of participants with ASD and comparison participants were included. This had the effect of increasing the power of analyses to detect relationships, although it reduced the degree to which the groups were equated on baseline measures. For this aspect of the study, which is presented in Section 2, the ASD group consisted of 73 children/adolescents with autistic disorder ($n = 65$) or Asperger's disorder ($n = 8$). The comparison group consisted of 55 children/adolescents with general intellectual disability of unknown origin ($n = 27$) and typically developing children ($n = 28$). All of these participants passed the control questions for the false-belief task, ensuring that any failure on the test question was due to a specific difficulty with representing false-beliefs as opposed to extraneous task demands. The characteristics of each group are presented in Table 2.

[place Table 2 about here]

Materials

For the memory task, a master set of 42 pictures was selected from the Expressive One Word Vocabulary Scale (Brownell, 2000). On the basis of the participants' level of receptive vocabulary, it was expected that they would be able to label these pictures with ease (and, indeed, no child had any difficulty with naming the pictures). This master set was used to create three fully counterbalanced versions of the test. In each version, 28 pictures were used as stimuli and 14 pictures were used as distractor items at test. Each individual picture was used as a stimulus in two out of three versions and as a distractor in the third version.

Within each version of the test, the pictures were presented in a fixed order. For each picture, self/other status (i.e., whether the participant or experimenter would be naming the picture) was designated at random, subject to the constraints (a) that in a given version, no more than three turns of “self” or “other” would occur in a row and (b) that overall, there were equal numbers of “self” and “other” pictures. Given that each picture was used in two out of three versions, individual pictures were assigned “self” status in one of those versions and “other” status in the other of those versions.

The stimulus materials consisted of three sets of laminated, grey-scale picture cards, measuring approximately 11 × 8 cm. The cards assigned to the experimenter were indicated by presence of a small, black “x” on the back.

For the unexpected-contents false-belief task, the usual Smarties tube and pencils were substituted with a “Pringles” (well-known type of potato crisp/chip) tube and a tennis ball.

Procedure

Participants completed the memory task first and then the false-belief task.

Memory task.

Participants were randomly assigned one of the three versions of the task. The experimenter sat opposite the participant and placed the picture cards, face-down in between them, whilst giving the participant the following instructions: “*Now we’re going to play a picture naming game. I’d like you to try to remember the names, because I’m going to see how many you can remember later on. Sometimes, I’m going to pick up a picture and name it and sometimes, you’re going to pick up a*

picture and name it. I'll tell you whose turn it is each time." The experimenter and child then began picking up and naming the pictures. For each picture, the experimenter provided a verbal cue to indicate whose turn it was. If the participant did not pick up the picture after the initial cue, the experimenter gave the prompt, *"Can you pick up the picture and name it?"* If the participant did not respond with a label, the experimenter gave the prompt, *"What's that?"* If the child gave a name for the picture that did not correspond to the "expected" name (e.g., "bunny" instead of "rabbit"), this was noted and used as a substitute for the "expected" name at test.

After a filled delay of two minutes, the participants were told, *"OK, now I'm going to read out some names of things and I want you to tell me whether or not we saw those things in the pictures we looked at earlier. We saw some of the things earlier but others we didn't see."* The experimenter then read aloud the recognition test list, which included the labels for all of the 42 pictures in the master set, in a fixed order, each time saying, *"Did we see a picture of a [recognition item]?"* (assessing recognition memory). When the participant identified an item as old, responding with "yes", they were asked, *"Who picked up the picture of the [recognition item] and named it?"* (assessing source memory). Participants' responses were noted on a test record form at the time of testing.

False-belief task.

The experimenter removed the Pringles tube from a plastic bag, showing it to the child, and asking them, *"What's in here?"* They were then shown the true contents and told, *"No, it's a ball."* The ball was then replaced and the box was closed again. The child was then asked the following questions: (a) *"What's in here?"* (first reality control question); (b) *"Your teacher hasn't seen this box. When s/he comes in later,*

I'll show her/him this box just like this and ask her/him what's in here. What will s/he say?" (test question); (c) *"Is that what's really in the box?"* (second reality control question).

Scoring

Performance on yes-no recognition tests is typically summarised by measures of "discrimination" and "response bias". Discrimination measures provide an estimate of memory accuracy – the ability to discriminate between old (studied) and new (distractor) test items. Response bias measures quantify the tendency to respond either predominantly liberally ("yes" responses) or conservatively ("no" responses). Importantly, both types of measure take into account both correct and incorrect responses.

Measures of discrimination and response bias are calculated using the more basic measures, "hit-rate" and "false-alarm-rate". Hit-rate is the percentage of old items correctly identified as old. False-alarm-rate is the percentage of new items incorrectly identified as old.

The current data were suited to the non-parametric indices of item discrimination and response bias, A' and B''_D (see Donaldson, 1992). A' and B''_D scores were calculated as shown in equations (1) and (2) below (where H = hit-rate, and FA = false-alarm-rate):

$$(1) A' = 1/2 + [(H - FA)(1 + H - FA)]/[4H(1 - FA)]$$

$$(2) B''_D = [(1 - H)(1 - FA) - HFA]/[(1 - H)(1 - FA) + HFA]$$

Higher values of A' indicate better item discrimination and the maximum score is 1.00. Values of B''_D which are greater than zero indicate a conservative bias (a greater tendency to identify test items as new) and values which are less than zero indicate a liberal bias (a greater tendency to identify test items as old).

Because self-other differences in recognition memory were to be explored, separate hit-rates were calculated for items that had been picked up by the child (self) and those that had been picked up by the experimenter (other) at study. These “self” and “other” hit rates were subsequently used in the calculation of A' item discrimination and B''_D response bias estimates, such that separate “self” A' and B''_D scores, and “other” A' and B''_D scores were derived. Given that false-alarm-rates are necessarily derived from performance on distractor items, which by definition are not associated with either self or other, a single common false-alarm-rate was used for calculation of both “self” and “other” A' and B''_D scores².

Source memory scores were calculated using the method recommended by Bayen, Murnane, and Erdfelder (1996), which ensures that scores are largely independent of recognition memory. Thus, source memory score was the proportion of correctly recognised items for which the source was correctly identified. Separate “self” and “other” source memory scores were calculated as follows: “self” source memory = number of correct source attributions for self/number of hits for self; “other” source memory = number of correct source attributions for other/number of hits for other.

Results

“Results” section is divided into two subsections (i.e. Section 1 and Section 2).

Section 1: Group differences in recognition and source memory

Table 3 displays mean “self” and “other” recognition (A' and B''_D) and source memory scores for the ASD and comparison groups.

[place Table 3 about here]

Separate one-sample t -tests for each group revealed that both groups obtained “self” and “other” A' (all t s > 16.61 , all p s $< .001$, all r s $> .92$) and “self” and “other” source memory (all t s > 6.50 , all p s $< .001$, all r s $> .67$) scores that were significantly above chance (.50).

In order to assess group and self-other differences in (a) A' item discrimination scores, (b) B''_D response bias scores, and (c) source memory scores, three 2 (Group: ASD/comparison) \times 2 (Self-Other: self/other) mixed ANOVAs were conducted, with Group as the between-participants variable and Self-Other as the within-participants variable. The results of these analyses are reported in Table 4.

[place Table 4 about here]

Recognition memory measures.

The analysis of A' scores revealed that the groups did not significantly differ in their ability to discriminate between old and new test items – they showed very similar

levels of recognition memory. Also, irrespective of group, participants showed significantly better item discrimination for “self” items than for “other” items.

The analysis of B''_D scores indicated that the groups each showed similar levels of (conservative) response bias but, regardless of group membership, there was a significantly stronger bias for “other” items than for “self” items. B''_D scores of zero indicate no response bias. Thus, a one-sample t -test was conducted to establish whether participants obtained “self” B''_D and/or “other” B''_D scores that were significantly above zero. These indicated that the scores were significantly above zero (“self”: $t(102) = 2.59, p = .01, r = .25$; “other”: $t(102) = 9.03, p < .001, r = .67$), confirming the presence of a genuine response bias

Source memory measures.

The analysis of source memory scores indicated that individuals with ASD performed significantly less well on the source memory task than comparison individuals. Additionally, individuals from both groups showed significantly better source memory for “self” items than “other” items.

Section 2: The relationship between ToM and source memory

A total of 37/73 (50.7%) participants with ASD passed the false-belief task, compared to 37/55 (67.3%) comparison participants. The association between group and false-belief task performance was significant, $\chi^2(1) = 3.54, p = .04, \phi = .17$. The “self” and “other” source memory scores for false-belief task passers and failers within the ASD and comparison groups are displayed in Table 5.

[place Table 5 about here]

Both groups obtained “self” and “other” source memory scores which were significantly above chance (all $t_s > 5.47$, all $p_s < .001$, all $r_s > .62$).

Separate point biserial correlations were calculated for each of the groups, in order to assess the possible relationship between false-belief task performance and “self” and “other” source memory. These correlations are reported in Table 6.

[place Table 6 about here]

They revealed that “self” source memory was not significantly related to false-belief task performance within either group. However, “other” source memory was significantly related to false-belief task performance within both the ASD and comparison groups.

Additional analyses were conducted in order to ensure that the relationship between “other” source memory and false-belief task performance was not confounded by the effects of chronological age (CA), verbal mental age (VMA), or verbal IQ (VIQ). “Other” source memory was not significantly correlated with CA or VIQ within either group (all $r_s < .14$, all $p_s > .23$). “Other” source memory was significantly correlated with VMA within the ASD group, $r = .32$, $p < .01$, but not within the comparison group, $r = .20$, $p = .15$. Moreover, VMA was also significantly correlated with false-belief task performance within each of the groups, (ASD: $r_{pb} = .43$, $p < .01$; comparison: $r_{pb} = .35$, $p < .01$).

Thus, to ensure that the apparent relationship between “other” source memory and false-belief task performance within each group was not merely an artefact of the effect of VMA, partial correlations were conducted, controlling for the effect of

VMA. These are also reported in Table 6. It was found that after controlling for the effect of VMA, “other” source memory and false-belief task performance were not significantly correlated within the ASD group but they were still significantly correlated within the comparison group.

In order to compare the bivariate and partial correlations between “other” source memory and false-belief task performance within the ASD group to the correlations within the comparison group, Fisher’s Z transformations were conducted. These indicated no significant group differences in either the bivariate, $Z_{r1-r2} = 0.74$, $p = .45$, or partial, $Z_{r1-r2} = 1.12$, $p = .26$, correlations.

Discussion

In line with predictions, the results demonstrated undiminished recognition memory but significantly diminished source memory amongst children with ASD. Participants with and without ASD were similarly able to discriminate between old and new test items, demonstrating comparable levels of item recognition accuracy. These results mirror previous research, which has also demonstrated unimpaired recognition memory amongst high-functioning individuals with ASD (e.g., Minshew, Goldstein, Muenz, & Payton, 1992). Both groups also showed a similar magnitude of conservative response bias, which indicates a tendency to favour “no” responses. This suggests that both groups were using similar decision criteria when considering whether or not they had seen an item at study.

These results should, however, be interpreted with some degree of caution, given that the mean A' scores for both groups were fairly high, particularly the “self” A' scores. This may suggest that the task lacked the sensitivity necessary to detect

latent group differences. However, it is reassuring that only 12% of the sample performed at ceiling, and when these participants were excluded and the data were re-analysed, the results did not substantively change. One final point to make here is the fact that the groups performed so similarly on the recognition memory measures demonstrates that the groups were well matched on the areas of intellectual ability that were essential to the experimental task and further supports the use of the BPVS as a matching tool in the current study.

Although both groups of participants performed reasonably well on the source memory element of the task, participants with ASD demonstrated significantly poorer self-other source memory than comparison participants. However, the effect size ($r = .19$) was small (but, notably, of a similar magnitude to that yielded by the group difference in ToM task performance: $\phi = .17$), indicating that the impairment was relatively subtle. Therefore, it is perhaps unsurprising that previous studies of self-other source memory in ASD have yielded inconsistent results. The current findings might be considered to provide a more authoritative picture of the self-other source memory abilities of individuals with ASD, and are consistent with the proposal that semantic memory functions comparatively well in ASD, whereas episodic memory is significantly impaired.

One interpretation of the current pattern of results (i.e., intact recognition but impaired source memory in the ASD group) is that on the recognition component of the task, participants with ASD were able to compensate for their impaired episodic memory by utilising their intact semantic memory. Such a compensatory process would not, however, facilitate performance on the source memory component of the task, which required the recollection of contextual information (i.e., who it was that

picked up and named the given picture card), and hence the ASD group were impaired on this element.

Also consistent with predictions, participants, both with and without ASD, showed an enactment effect – that is, significantly superior recognition and source memory for “self” items than for “other” items. That is, they showed better memory for self-performed, as opposed to experimenter-performed actions. It was interesting to find that each group also showed a significantly stronger conservative response bias for “other” items than for “self” items. This suggests that participants experienced a greater degree of uncertainty when deciding whether “other” items, rather than “self” items, were old or new. Together, these results suggest that memory traces for “self” items were more strongly encoded, possibly because of the additional motoric component, and were more readily retrieved as a consequence.

The finding of a typical enactment effect, alongside overall lower levels of source memory performance in the ASD group, is consistent with the idea that action-monitoring is intact whereas episodic memory is impaired in this population. Thus, the results seem to indicate a diminution of episodic memory *per se* rather than a specific problem of *personal* episodic memory or memory for experiences directly involving the *self* (which would result in a reduced enactment effect), as previously suggested by Powell and Jordan (1993) and Hare et al. (2007).

The final prediction was that ToM and source memory task performance would be significantly related within each of the groups. The results indicated that in the comparison group, false-belief task performance was not significantly correlated with “self” source memory but it was significantly correlated with “other” source memory, even after statistically controlling for the effect of VMA. In the ASD group, false-belief task performance was not found to be significantly correlated with either

“self” or “other” source memory, once the effects of VMA were statistically controlled. However, it was found that the size of the correlation between “other” source memory and false-belief task performance did not significantly differ between the ASD and comparison groups, implying that the groups were not showing qualitatively distinct patterns of association with respect to these variables.

These findings are somewhat challenging to interpret. Superficially, they seem to suggest that ToM impairments in ASD do not account for episodic memory difficulties. This raises the question of why individuals with ASD do manifest episodic memory difficulties. A number of researchers have claimed that diminished auto-noetic consciousness in ASD may contribute to episodic memory impairments (e.g., Bowler, Gardiner, & Grice, 2000; Lind & Bowler, 2008; Toichi, 2008). Certainly, attenuated auto-noetic awareness would impact upon the ability to mentally re-experience past episodes – an ability which is necessary to make reliable self-other source judgements. However, the results of the current study suggest that if the source memory difficulties observed amongst participants with ASD were the consequence of a diminished capacity for auto-noetic awareness, this was unlikely to be a downstream effect of impaired ToM. Perhaps, instead, impaired auto-noetic consciousness in ASD is connected with other related difficulties, such as a generally reduced capacity for introspection (Hurlburt, Happé, & Frith, 1994) and diminished self-awareness (e.g., Hobson, 1990).

An alternative explanation for the source memory difficulties, observed amongst participant with ASD in the current study, is that individuals with ASD have difficulties with binding together the various elements of episodes within memory (Gaigg, Gardiner, & Bowler, 2008). Such relational memory difficulties could easily contribute to source monitoring difficulties. In the current task, for example, in order

to make a correct source judgement, it was necessary to bind together at least two elements of the study episode – i.e. *what* the item was and *who* picked up and named the item.

Another possible explanation for the non-significant relationships between the source memory measures and false-belief task performance in the ASD group is that false-belief task performance amongst children with ASD may not invariably index a representational ToM. Some children with ASD may be able to use compensatory, non-ToM strategies to “hack out” solutions to typical false-belief tasks (e.g., Happé, 1995). For example, they may be able to utilise their syntactic knowledge (i.e., complement syntax; e.g., Lind & Bowler, in press; Tager-Flusberg & Joseph, 2005) or general memory skills (e.g., Williams & Happé, in press) to facilitate task performance. Thus, on the basis of the current results, we cannot entirely rule out the possibility that impaired ToM contributes to source memory difficulties in ASD. Future research may attempt to address this issue by utilising non-verbal ToM tasks, such as Baron-Cohen, Leslie, and Frith’s (1986) picture sequencing task.

The finding that false-belief understanding was related specifically to “other” source memory (in the comparison group) seems to suggest that developments in ToM are involved in the development of memory for actions that one has observed another person perform to a greater extent than memory for one’s own actions. One possible explanation for this is that source memory for the experimenter’s cards relied on episodic recollection to a greater extent than source memory for one’s own cards. “Self” source memory may be partially accomplished through action monitoring: encoding a conscious motor image may facilitate memory for one’s own actions. But, remembering the actions of others may be more heavily dependent on the ability to become auto-noetically aware of one’s own memories. Furthermore, children with a

well developed ToM might be more likely to attend to, and therefore encode, information about what others are doing and hence have more elaborate memories for others' actions.

In summary, in line with predictions, children with ASD showed significantly diminished self-other source memory, but undiminished recognition memory and a typical enactment effect, relative to age and verbal ability matched comparison children. However, contrary to predictions and despite the fact that, as a group, participants with ASD showed a similar degree of impairment in both source memory and ToM, these abilities were not significantly associated. These results do not, therefore, support the hypothesis that impaired ToM accounts for the episodic memory difficulties experienced by individuals with ASD.

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Footnotes

(1) A number of participants (23 with ASD, 6 comparison) gave perseverative responses to the item or source components of the memory test (i.e., provided the same response to more than 90% of questions). The mean (*SD*) verbal mental age (VMA), chronological age (CA), and verbal IQ (VIQ) of the participants with ASD who gave perseverative responses was 5.91 (1.45), 10.27 (3.38), and 66.96 (18.19), respectively. The mean (*SD*) VMA, CA and verbal IQ of the comparison participants who gave perseverative responses was 4.48 (1.45), 7.03 (5.53), and 83.83 (33.13), respectively. Because the performance of these individuals would not have been a fair reflection of their item or source memory ability (but rather their executive difficulties), these individuals were excluded from the sample.

(2) Following the suggestion of Dr Chris Jarrold, who reviewed this paper, we also tried an alternative method of determining false-alarm-rates. Specifically, half of the distractors were arbitrarily assigned to be “self-distractors” and half to be “other-distractors”, and then separate false-alarm-rates were calculated. The data were re-analysed using these “self” and “other” false alarm rates, but the pattern of results did not differ from those presented in the main body of the paper.

Table 1

Participant characteristics for Section 1

	ASD (<i>n</i> = 53, 8 female)	Comparison (<i>n</i> = 50, 15 female)	<i>t</i>	<i>df</i>	<i>p</i>	Effect size (<i>r</i>)
CA: years	9.26 (2.06)	9.09 (4.28)	0.24	69.70	.81	.03
VMA: years	6.66 (1.93)	6.51 (1.93)	0.40	101	.69	.04
VIQ	80.54 (12.61)	83.74 (22.73)	0.88	75.57	.39	.10

*CA: chronological age; VMA: verbal mental age; VIQ: verbal IQ

Table 2

Participant characteristics for Section 2

	ASD (<i>n</i> = 73, 13 female)	Comparison (<i>n</i> = 55, 18 female)	<i>t</i>	<i>df</i>	<i>p</i>	Effect size (<i>r</i>)
CA: years	10.06 (3.11)	8.56 (4.53)	2.21	90.57	.04	.15
VMA: years	6.56 (2.00)	6.14 (2.04)	1.15	126	.25	.10
VIQ	75.66 (16.88)	84.98 (24.01)	2.58	92.04	.02	.26

*CA: chronological age; VMA: verbal mental age; VIQ: verbal IQ

Table 3

Mean (*SD*) “self” and “other” recognition (A' , B''_D) and source memory scores for the ASD and comparison groups

	ASD		Comparison	
	Self	Other	Self	Other
A' (discrimination)	.91 (.13)	.85 (.15)	.92 (.11)	.85 (.12)
B''_D (bias)	.17 (.75)	.53 (.61)	.21 (.70)	.58 (.61)
Source memory	.86 (.16)	.74 (.27)	.90 (.13)	.83 (.20)

Table 4

ANOVA statistics for item discrimination, response bias and source memory measures

Effect	Dependent variable		
	A' item discrimination	B''_D response bias	Source memory
Group	$F(1,101) = 0.09, p = .77, r = .03$	$F(1,101) = 0.14, p = .71, r = .01$	$F(1,101) = 3.81, p < .05, r = .19$
Self-other	$F(1,101) = 56.31, p < .001, r = .60$	$F(1,101) = 51.44, p < .001, r = .58$	$F(1,101) = 17.00, p < .001, r = .38$
Group × Self-other	$F(1,101) = 0.12, p = .73, r = .03$	$F(1,101) = 0.01, p = .91, r = .01$	$F(1,101) = 0.86, p = .36, r = .09$

Table 5

Mean (SD) “self” and “other” source memory scores according to group and false-belief task performance

Group	False-belief	<i>n</i>	Source memory	
			Self	Other
ASD	Pass	37	.82 (.18)	.78 (.27)
	Fail	36	.78 (.25)	.61 (.32)
Comparison	Pass	37	.89 (.12)	.84 (.18)
	Fail	18	.86 (.19)	.63 (.30)

Table 6

Point biserial correlations between “self” and “other” source memory and false-belief task performance

	False-belief	
	Bivariate	Partial (controlling for VMA)
ASD		
“Self” Source memory	.09	-
“Other” source memory	.28*	.17
Comparison		
“Self” source memory	.10	-
“Other” source memory	.40**	.36**

** $p < .01$, * $p < .05$