Object-location memory in adults with Autism Spectrum Disorder

Melanie Ring

Autism Research Group

City University London

Sebastian B. Gaigg

Autism Research Group

City University London

Dermot M. Bowler

Autism Research Group

City University London

Author note

Melanie Ring, Autism Research Group, Department of Psychology, City University London and Autismuszentrum Chemnitz e.V., Chemnitz, Germany; Sebastian B. Gaigg, Autism Research Group, Department of Psychology, City University London; Dermot M. Bowler, Autism Research Group, Department of Psychology, City University London

A previous version of the results reported in this manuscript was presented at the International Meeting for Autism Research (May, 2013) in Donostia/ San Sebastian, Spain.

Correspondence concerning this article should be addressed to Melanie Ring, Autism Research Group, Department of Psychology, City University London, Northampton Square, London, EC1V 0HB, United Kingdom. Email: Melanie.ring.1@city.ac.uk or +44(0)20 7040 8380.

Lay Abstract

This study tested memory for the locations of objects in rooms presented to participants as pictures on a computer-screen. A group of adults with an Autism Spectrum Disorder (ASD) was compared to a group of typically developing (TD) adults. The aim was to investigate to what extent the two groups actively retrieved knowledge about the object-locations (explicit memory) or subconsciously remembered them (implicit memory). For this participants were presented with the same rooms and objects that they had studied and were either asked to indicate the previously studied location for the object or assign it a new location out of a choice of three. Scores for explicit and implicit memory were calculated and it was found that ASD individuals had more difficulty actively retrieving the object's location compared to the TD group. They did as well in subconsciously remembering the location. In addition participants performed equally well on simple recognition tests for the objects and locations they had studied, suggesting that the present result can be explained by a difficulty of forming a relation between object and location rather than by difficulties in remembering objects or locations per se in ASD. The findings also show that when memory retrieval is supported at test, ASD individuals show less difficulty in memory.

Scientific Abstract

This study tested implicit and explicit spatial relational memory in Autism Spectrum Disorder (ASD). Participants were asked to study pictures of rooms and pictures of daily objects for which locations were highlighted in the rooms. Participants were later tested for their memory of the object locations either by being asked to place objects back into their original locations or into new locations. Proportions of times when participants choose the previously studied locations for the objects irrespective of the instruction were used to derive indices of explicit and implicit memory (process-dissociation procedure, Jacoby, 1991, 1998). In addition, participants performed object and location recognition and source memory tasks where they were asked about which locations belonged to the objects and which objects to the locations. The data revealed difficulty for ASD individuals in actively retrieving object locations (explicit memory) but not in subconsciously remembering them (implicit memory). These difficulties cannot be explained by difficulties in memory for objects or locations *per se* (i.e., the difficulty pertains to object-location relations). Together these observations lend further support to the idea that ASD is characterised by relatively circumscribed difficulties in relational rather than item-specific memory processes and show that these difficulties extend to the domain of spatial information. They also lend further support to the idea that memory difficulties in ASD can be reduced when support is provided at test.

Keywords: explicit relational memory, implicit relational memory, Autism Spectrum Disorder, recognition memory, source memory, task support hypothesis, process-dissociation procedure

Autism Spectrum Disorder (ASD) is associated with a heterogeneous cognitive profile with a consistent pattern of strengths and weaknesses in the domain of memory (see Boucher & Bowler, 2008; Boucher et al., 2012 for reviews). ASD individuals experience difficulties with free recall where information needs to be remembered without retrieval support. This is especially marked when categorical information is available in the studied material that typically facilitates memory (Bowler et al., 1997; Gaigg et al., 2008; Tager-Flusberg, 1991). By contrast, when test procedures provide support for retrieving studied information, memory tends to be spared in ASD. Supported procedures include immediate cued recall (e.g. Mottron et al., 2001) and recognition memory tasks (e.g. Boucher et al., 2005; Bowler et al., 2000a; Bowler, et al., 2000b; Kuusikko-Gauffin, et al., 2011). The pattern of performance on supported and unsupported memory tests led Bowler and colleagues (1997) to propose the 'task support hypothesis' suggesting that ASD participants perform as well as TD individuals when procedures are used that scaffold retrieval. Since then various studies have confirmed this idea (Bowler et al., 2004; Gaigg et al., 2008; Ring et al., under review).

A further characteristic of memory function in ASD is a relatively pervasive difficulty in remembering the temporal order of events (Poirier et al., 2011; Gaigg et al., 2014) and in remembering the autobiographical past and imagining the autobiographical future (e.g. Crane et al., 2009; Lind & Bowler, 2010). This suggests difficulties particularly with episodic memory, which requires the binding of the spatial-temporal context that defines specific events. Interestingly, when participants with ASD are tested on where, when or how they studied certain stimuli (source memory tasks), findings are inconsistent. Some studies suggest impaired source memory in ASD (e.g. Bowler et al., 2004; Lind & Bowler, 2009), whereas others do not (e.g. Bowler et al., 2004; Souchay et al., 2013). Importantly, here as well, difficulties tend to become more apparent when using less supported task procedures e.g. a four alternative recall task (Bowler, et al., 2004) and when source information is incidental to the task compared to when it has been studied intentionally as part of the task (Souchay et al., 2013).

A third distinction in memory in ASD is that between explicit memory, defined as knowledge that can be actively retrieved, and implicit memory which is knowledge of which an individual is unaware but which nevertheless can be shown to influence behaviour. To date, four studies have systematically compared explicit and implicit memory and overall these suggest intact implicit but difficulties with explicit memory for single items in ASD. Again, difficulties arise especially when less support is provided at test (Bowler et al., 1997; Gardiner et al., 2003; Renner et al., 2000). There are a few caveats related to these earlier studies, however. First, the procedures employed to measure implicit and explicit memory are not comparable in their processing requirements. Implicit memory was measured with more incidental tests like priming whereas explicit memory was generally measured with more intentional tests like recognition or free recall. Explicit tests are more effortful because participants have to engage in some form of search process to retrieve the specific information they were asked to study. In addition in order to be able to consciously retrieve an item it needs to have been processed in a more elaborative way in the first place. Whereas in implicit tests participants are instructed simply to state the first thing that comes to mind. Since individuals with ASD have been shown to experience difficulties in engaging effective retrieval strategies such as category clustering (e.g. Gaigg et al., 2008) one could argue that it is due to the procedural differences at test that ASD individuals show intact implicit but compromised explicit memory. Second, when implicit and explicit memory are compared in within-subjects designs, implicit memory is typically measured through priming first, introducing order confounds that could contribute to the pattern of findings. The current study employs an experimental procedure that avoids these issues in an attempt to provide a less ambiguous comparison of explicit and implicit memory in ASD.

A further aim of the current study was to examine explicit and implicit memory for material that goes beyond the single words or pictures of previous studies, therefore emulating the complexities of daily life. As noted above, memory in ASD tends to be characterised by difficulties particularly in the domain of episodic memory. To form an episodic representation of an experience it is necessary to bind information such as time and place to what happened. Several explanations have been put forward for the observed difficulties in this domain in ASD. Bowler and colleagues (2011) argue that ASD individuals show intact item-specific memory but have difficulties with relational memory. Item-specific memory refers to memory for individual elements of an experience (e.g. the items of furniture in a room), whereas relational memory refers to the spatial, temporal or conceptual relations between these items (e.g. the relative position of furniture in a room; see Hunt & Einstein, 1981). Several studies show that relational memory is selectively compromised in ASD whereas item-specific memory is preserved (Bowler et al., 2009; Gaigg et al., 2008; Gaigg et al., in press), however, all of the relevant studies were concerned with explicit memory and it remains unclear whether implicit memory for relational information may be preserved in ASD.

To address the methodological issues relating to previous studies concerning explicit and implicit memory in ASD, and to establish whether relational memory difficulties are evident in both explicit and implicit memory in this disorder, we implemented an object-location memory task. According to Postma and colleagues (2008b) object-location memory comprises at least three different processes: the processing of the object, its location, and the binding between object and location. To test this whole framework, we included object, location and object-location binding recognition tasks. For the latter we used a paradigm based on the *process dissociation procedure* (Jacoby, 1991; Jacoby, 1998), which requires participants to recall the locations of objects by placing them into the locations where they had previously studied them (‘include’ trials) or to place them in new locations (‘exclude’ trials; Figure 1). This procedure allows the calculation of estimates of explicit and implicit memory. This task has been used to examine different clinical populations, that helped inform our predictions. Specifically, studies of Alzheimer’s Disease (Kessels et al., 2005a; Randolph et al., 1995), amnesia (Hampstead et al., 2011), Korsakoff patients (Postma et al., 2008a) and TD older adults (Kessels et al., 2005b) found a similar distinction between impaired explicit and intact implicit object-location memory. While the neural underpinnings for functional decline in these (patient) populations might be different, they have in common that either hippocampal (Alzheimer’s Disease, amnesia) or hippocampal and frontal functions (Korsakoff disease, TD older adults) are affected, suggesting the involvement of the fronto-hippocampal circuit particularly in explicit relational memory. Abnormalities in this network that appear to parallel those seen in typically aging populations have recently also been shown to be associated with the relational memory difficulties in ASD (Gaigg et al., in press). Implicit memory measured through contextual cuing is intact in TD older adults (Howard et al., 2004), suggesting it is not affected by a decline of fronto-hippocampal circuit function. It seems to involve broader areas in the temporal lobes within and outside the MTL (Chun & Jiang, 2003). Similarly, item memory is not affected in TD older adults (Cabeza et al., 2000) suggesting reliance on brain regions outside the fronto-hippocampal circuit. Therefore we predicted a similar distinction between impaired explicit but intact implicit memory for object-location relations in ASD. We also expected to find similar performance of ASD and TD groups in object and location recognition because item memory is usually intact in ASD (Bowler et al., 2011).

Method

Participants

Twenty-six TD and 25 ASD individuals were tested. Three TD individuals were excluded from the final sample. The testing session of 1 individual was disrupted by loud noise due to building works, 1 individual reported getting confused by the task instructions and the performance of 1 individual was at chance. The performance of all other individuals was above chance. The final sample included 23 TD individuals (17 men, 6 women, M_{age} = 40.87 years, age range: 20-61) and 25 ASD individuals (20 men, 5 women, M_{age} = 42.13 years, age range: 25-69). There was no difference between groups in gender, $X^2 = 0.25$, $p = .62$. Groups were closely matched on chronological age, Verbal (VIQ), Performance (PIQ) and Full-scale IQ (FIQ) as measured by the third edition of the Wechsler Adult Intelligence Scale (WAIS-III^{UK}; The Psychological Corporation, 2000; see Table 1). VIQ, PIQ and FIQ were above 70 in both groups. ASD participants were randomly selected from a panel of over 50 individuals with whom the Autism Research Group of City University London is in regular contact. They had all been diagnosed within the UK National Health Service by experienced clinicians according to the DSM-IV-TR criteria (American Psychiatric Association, 2000). In addition 22 ASD individuals were assessed using the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1989; see Table 1) by individuals trained to research reliability standards on this instrument. TD individuals were recruited through advertisements and were only included in the study if they had no personal or family history of a psychological or neurodevelopmental disorder and did not report taking any psychotropic medication. All participants were native English speakers. Informed consent was obtained from all individuals prior to the study and they were reimbursed for their time and travel expenses with standard university fees. This study was approved by City

University London's ethics committee and the procedures outlined below adhere to the ethical guidelines set out by the British Psychological Society.

[Insert Table 1 here]

Materials

The object locations to be used in the experiment were chosen by means of a pilot study involving twenty-two individuals (16 women, 6 men) recruited mainly from City University London's student population. Their age ranged from 19 to 40 years (M_{age} = 24.37). Participants were presented with pictures of 7 rooms (e.g. kitchen, bathroom etc.) and 9 to 12 context appropriate pictures of objects for each room (e.g. a toothbrush in the bathroom) on a computer screen. Pictures of the rooms filled approximately 80% of the screen and objects were presented underneath one at a time. Participants were asked to click on up to 15 different locations that they considered appropriate for each of the objects (e.g. a toothbrush could be chosen to be put next to the sink, in the cabinet above the sink, next to the bath etc. in the bathroom). After this data was gathered, all locations that were selected were superimposed on the room pictures and a 96-cell grid overlay was used to rank-order all possible object locations in terms of the frequency with which participants endorsed them as plausible. Three locations were then selected for each object for the experiment proper – a goal location in which the object was to be presented during the learning trials and two distracter locations that would serve for the test trials. The goal location was always the location in the middle of the rank order distribution of the pilot study. One distracter location was chosen to be ranked as more likely than the goal location (but not the most likely) while the other was always ranked as less likely (but not the least likely). Objects with an insufficient number of plausible locations were excluded. Locations for the remaining objects were chosen to ensure that two goal locations for two different objects were never in the same place. Finally, small adjustments were made in order to render all locations appropriate (e.g. a watering can was put on top of a table instead of half way on top and half way underneath it). Based on this process we selected one room with 5 objects for practice trials, while six rooms with 8 objects each served for the experimental trials. An overview of all rooms with their objects is provided in Table 1 in the supplementary online material.

Procedure

Object-location task

Following a series of 5 practice trials to familiarise participants with the study-test procedure, they were then presented with 24 learning trials of the test proper including six rooms with 4 objects each. In each trial participants were shown a picture of a room occupying approximately 80% of the screen. The goal location was highlighted in the room and underneath the picture of an object was shown. Participants were asked to click on the object, after which a red frame appeared around it. Next they needed to click on the location, after which the object was presented in this location for 3 seconds before the next object appeared (see Figure 1). The presentation of rooms was completely randomised in order to avoid any order effects. Participants were asked to name the objects and to describe their locations briefly. This was to ensure that participants were fully paying attention and that all participants verbalised the materials to a similar extent.

In the test phase participants were presented with the familiar room pictures and with the 24 originally studied objects intermixed with 24 new objects (4 per room) to control for chance performance. The include instruction required participants to recall the old location where they had studied the object and select that location out of a choice of 3 highlighted locations. Under the exclude instruction participants were first required to recall the old location they had studied for the object and then to choose a new location for the object by clicking on one of the other 2 highlighted locations where the object had never been placed before. Importantly, these instructions place very similar demands on the participants in terms of effort in retrieval. Objects were counterbalanced across the test conditions, i.e. across participants each object was tested under include and exclude conditions an equal number of times. The order of presentation of the test conditions was however random. The two sets of 24 items were counterbalanced across participants, so that half of the participants studied items from set 1 and saw items from set 2 as new items and vice versa for the other half of the participants. For the test phase participants were instructed to name the object and the location and to read out loud the instruction, which either said old location (include) or new location (exclude). This served to ensure that they were fully paying attention. Figure 1 provides examples of study and test displays. Eye-movements were measured during study and test trials but the results are presented elsewhere (Ring et al., in preparation) and will not be discussed further in this paper.

[Insert Figure 1 here]

Object and Location recognition and source memory

After the object-location memory task participants completed an object and a location recognition task. In the object recognition task 96 pictures of objects were presented which participants had either seen twice before (in the study and the test phases), only once (in the test phase) or not at all. Participants were asked to name each object and then to indicate if they had seen it before using a Yes-No procedure. If they had seen it before, they were asked to indicate whether they could also remember its location (source memory). Participants were asked to name the exact location verbally. This information was audio-recorded for further analysis.

In the location recognition task participants were presented with 96 individually highlighted locations in the pictures of the rooms they had seen earlier (16 locations per room). Only the goal and distracter locations for the 24 objects that participants had studied initially were tested. Twelve of the 16 locations were old locations that participants had seen highlighted earlier (4 goal locations, 8 distracter locations- 2 per object) and 4 locations per room (1 for each of the 4 objects) were new. Participants were asked to indicate if they had seen exactly this location highlighted before using a Yes-No procedure. If they chose 'Yes', they were then asked to name the object that had been presented with that location (source memory). This information was audio-recorded for further analysis.

Results

Results were analysed using independent samples t-tests and repeated measures ANOVAs. In the case of significant differences post hoc tests were calculated. In case the Sphericity assumption was violated Greenhouse Geisser correction (GGC) was used. In addition Chi-Squared tests were used for nominal data and bivariate correlations were calculated. The significance level was chosen at .05 for all tests.

Object-location task

The proportions of target relocations were calculated for the two conditions. These are the proportions of times participants chose the goal/old location for the include condition where they were asked to click on the old location (in this case a correct answer) and for the exclude condition where they were asked to click on a new location (clicking on the old location would in this case be an incorrect answer). The same proportions were calculated for new objects that participants had never encountered before (new objects are from set A for one half of the participants and from set B for the other half of the participants). The latter proportions serve as an estimate of potential biases to place objects in the goal location without any prior study phase. Preliminary analyses confirmed that there were no such biases in either participant group (i.e. the goal location was chosen equally often for new objects, irrespective of instructions). In addition these estimates did not differ significantly from .33 which is the expected percentage of chance target relocations as the participant could choose between three different locations for each object (chance include: $M = 0.30$, $SD = 0.12$, $t(47) = -1.52$, $p = .14$; chance exclude: $M = 0.31$, $SD = 0.17$, $t(47) = 0.93$, $p = .36$). Thus, all remaining analyses focused exclusively on target relocations for the studied objects. A 2 (Instruction [include, exclude]) x 2 (Group [ASD, TD]) repeated measures ANOVA for proportions of target relocations for include and exclude conditions showed a significant main effect of Instruction, $F(1,46) = 739.43$, $p < .001$, $\eta_p^2 = .94$, with a higher number of target relocations in the include ($M = 0.84$, $SD = 0.16$) compared to the exclude ($M = 0.05$, $SD = 0.08$) condition. There was a marginal main effect of Group, $F(1,46) = 3.61$, $p = .06$, $\eta_p^2 = .07$, with more target relocations in the TD ($M = 0.47$, $SD = 0.10$) compared to the ASD ($M = 0.43$, $SD = 0.14$) group and a significant Group x Instruction interaction, $F(1,46) = 4.50$, $p < .05$, $\eta_p^2 = .09$, with a higher target relocation rate in the TD ($M = 0.89$, $SD = 0.12$) compared to the ASD ($M = 0.79$, $SD = 0.19$) group in the include condition ($p < .05$) but similar relocation rates for the 2 groups for exclude ($M_{TD} = 0.04$, $SD_{TD} = 0.07$; $M_{ASD} = 0.06$, $SD_{ASD} = 0.08$; $p = .36$).

The proportions of target relocations for include and exclude conditions were used to calculate estimates of implicit and explicit memory using the formulas by Jacoby (1991; 1998). The estimate of explicit memory (conscious- C) is determined by the difference between include (I) and exclude (E) proportions of target relocations (C = I - E). Implicit memory (unconscious- U) corresponds to the quotient of exclude target relocations and the difference between 1 and the estimate of explicit memory (U = E/ (1 – C); Jacoby, 1991). The data are set out in Figure 2. An implicit memory score was only available for 17 TD and 21 ASD individuals. The remaining individuals performed perfectly in include and exclude conditions precluding calculation of an implicit memory score. To investigate this further we counted the number of perfectly performing participants in each group in both conditions. These data were analysed using Chi-Squared tests. There were no significant differences in the number of individuals making mistakes in include (X^2 = .26, p = .61) or exclude conditions (X^2 = .43, p = .51) in both groups (no mistakes/mistakes- TD: 8/15; ASD: 7/18 and TD: 15/8; ASD: 14/11). It is worth noting that participants from both groups included in the implicit vs explicit analysis were well matched on gender (X^2 = .11, p = .74) age, VIQ, PIQ and FIQ (all t_{max} = 1.18, p_{max} = .25, Cohen's d_{max} = 0.39). Because the two scores for implicit and explicit memory were calculated from the same values (data from inclusion and exclusion trials) the data were analysed separately using independent samples t-tests. There was a significant difference between groups for the explicit memory score, t(43.20) = 2.15, p < .05, Cohen's d = 0.62, with a higher score for the TD compared to the ASD group but no difference between groups for the implicit memory score, t(36) = 0.08, p = .94, Cohen's d = 0.02, (see Figure 2).

[Insert Figure 2 here]

Object and Location recognition and source memory

Corrected recognition rates (Hits minus False alarms) for objects were calculated separately for the target objects that participants had to put into relevant locations during study as well as test and for the new objects that participants placed into locations only during the test phase. The data are outlined in Table 2 and were analysed using a 2 (Repetition [1 interaction vs. 2 interactions]) x 2 (Group [ASD, TD]) repeated measures ANOVA. There was a significant main effect of Repetition, $F(1,46) = 15.90$, $p < .001$, $\eta_p^2 = .26$, with higher corrected recognition rates for objects interacted with twice ($M = 0.98$, $SD = 0.04$) rather than once ($M = 0.91$, $SD = 0.14$). There was no main effect of Group, $F(1,46) = 2.49$, $p = .12$, $\eta_p^2 = .05$, and no Repetition x Group interaction, $F(1,46) = 1.55$, $p = .22$, $\eta_p^2 = .03$. Audio recordings of participant's source responses for the object task (i.e. comments on where in the room pictures the objects were presented) were transcribed, scored and then analysed using an independent samples t-test. Scoring was relatively unambiguous because all locations used in the study had been pre-selected and had relatively clear labels (e.g. on the sink). If it was unclear which location the participant was referring to exactly or if there was more than one possible location that fitted the participants' description they were given credit in the benefit of the doubt (e.g. "Some scales, yes I do remember and I remember putting them in the middle of the floor in the bathroom."). In addition participants were given the choice which location they remembered- there were 3 locations to choose from for each object (1 goal and 2 distracter locations). Credit was granted for either of them. Because of a recording problem, these data were available for 23 TD and 24 ASD individuals. No significant difference between groups was found, $t(38.98) = 0.24$, $p = .81$, Cohen's $d = 0.07$, indicating that both groups of participants remembered a similar number of locations for objects that they recognised from the previous task (Table 2).

For the location recognition test corrected recognition rates for locations were split up by the number of interactions with the locations (i.e. the number of times a participant clicked on the locations). The data, outlined in Table 2, were available from 23 TD and 24 ASD individuals and were analysed using a 3 (Repetition [no interaction, 1 interaction, 2 interactions] x 2 (Group [ASD, TD]) repeated measures ANOVA. Results showed a significant main effect of Repetition, $F(1.69,76.11) = 186.16$, $p < .001$, $\eta_p^2 = .81$, GGC, with increasing corrected recognition rates as a function of increasing number of interactions (0 interactions [$M = 0.19$, $SD = 0.11$] < 1 interaction [$M = 0.50$, $SD = 0.20$] < 2 interactions [$M = 0.64$, $SD = 0.18$], all $p < .001$). There was no main effect of Group, $F(1,45) = 0.25$, $p = .62$, $\eta_p^2 = .01$, nor a significant Repetition x Group interaction, $F(1.69,76.11) = 0.26$, $p = .73$, $\eta_p^2 = .01$, GGC. Audio recordings of participant's source responses for the locations (i.e. comments on the objects that were previously studied in the recognised locations) were transcribed and analysed using an independent samples t-test. The data were available for 23 TD and 24 ASD individuals. No significant difference between groups was found, $t(45) = -0.30$, $p = .76$, Cohen's $d = 0.09$, indicating that both groups of participants remembered a similar number of objects for locations recognised from the previous task (Table 2). Similar results for object and location recognition were found when the 17 TD and 21 ASD individuals who remained for the object-location task were included.

Finally, to rule out that the large age range within both groups may have obscured possible group differences because of age-related variability in the data all analyses were repeated including age as a covariate. The only difference from the findings just presented was in the results for object recognition. When controlling for age by means of an ANCOVA results showed no significant main effect of Repetition, $F(1,45) = 1.97$, $p = .17$, $\eta_p^2 = .04$, no significant main effect of Group, $F(1,45) = 2.35$, $p = .13$, $\eta_p^2 = .05$, and no Repetition x Group interaction, $F(1,45) = 1.44$, p = .24, $\eta_p^2 = .03$. However, there was a significant Repetition x Age interaction, $F(1,45) = 7.95$, $p < .01$, $\eta_p^2 = .15$. There was no significant difference between groups in the object source score when controlling for age, $F(1,44) = 0.04$, $p = .84$, $\eta_p^2 = .00$. This indicates that the older individuals in our sample were less good at learning objects over repeated presentations but there was no suggestion that such age effects operated differently in the two groups.

[Insert Table 2 here]

Correlations between tasks

The data are presented in Table 3. Significant positive correlations were found between explicit relational memory and corrected object and location recognition and source scores. In addition corrected object recognition was also positively correlated with corrected location recognition and object source scores and corrected location recognition positively correlated with object and location source rates. There were no significant correlations between implicit memory and any of the other measures.

[Insert Table 3 here]

Discussion

The current study is the first to examine explicit versus implicit relational memory in adults with ASD with the aim of testing the prediction that such individuals experience specific difficulties with relational but not item-specific memory using an existing externally valid object-location memory paradigm. The task involved participants' studying locations for objects in rooms followed by a test of their memory for the object's location and their recognition of the object and the location separately. We also included a source memory test examining recall of locations for remembered objects and objects for remembered locations. Our first prediction was that ASD participants would show difficulties with explicit memory but intact implicit memory for object-location relations indicating retrieval difficulties for relational material. This prediction was supported. We found that ASD compared to TD individuals showed lower explicit memory for the object locations in the presence of intact implicit memory. More specifically, ASD individuals, when asked to place an object into its old location when presented with a choice of three locations struggled to do so. This finding provides further support for a distinction between explicit and implicit memory performance in ASD (Bowler et al., 1997; Gardiner et al., 2003; Renner et al., 2000) and extends previous findings on single items to relational material.

Our second prediction that ASD individuals would show intact memory for locations and objects when tested in a recognition task was also supported. Together these findings provide further support for the suggestion that relational memory difficulties are relatively circumscribed in ASD and do not affect item-specific memory (Bowler et al., 2011). Our finding of intact source memory for objects and locations sheds more light on inconsistencies in the previous literature. It is in line with Bowler and colleagues (2004) and Souchay and colleagues (2013) suggesting that when material is studied intentionally and a supported test procedure is used, source memory is preserved in ASD.

The correlations between performances on the different tasks permit some conjectures about which underlying brain structures might be working differently in ASD. Implicit memory performance did not correlate with performance on any of the other tasks, which may well reflect the fact that it has been found to involve different brain regions compared to those associated with the other tasks (Chun & Jiang, 2003). The correlations between object-location and location and object recognition tasks could be explained by the fact that they seem to involve the parietal cortex (Postma et al., 2008b). Object and location tasks both depend on parietal and prefrontal brain regions which might explain the positive correlations between them. The correlations between source tasks and recognition tasks are supported by the dependence of both on prefrontal regions, whereas the positive relation between source memory and explicit object-location memory may reflect hippocampal function (Cansino et al., 2002; Postma et al., 2008b). Both prefrontal cortex and the hippocampus or a complex interaction between the two have been suggested to underlie memory difficulties in ASD (Bowler, 2007; Bowler et al., 2011; Minshew & Goldstein, 1998). The present findings provide most support for the relational memory account (Bowler et al., 2011) - a conclusion that is supported by the parallel we find here with findings from studies involving patients with hippocampal damage (Caldwell & Masson, 2001; Kessels et al., 2008; Kessels, et al., 2005a; Postma et al., 2008a) and TD older adults (Kessels, et al., 2005b). However, participants in these last studies had difficulty in finding a new location for an old item as well as in choosing the old location for that item, whereas ASD individuals in the present study only struggled with the latter. It is worth noting that in the current study a ceiling effect may have masked the between-group difference in exclude trials. However, it is also possible that memory difficulties in ASD are less pronounced than those in the patient populations (as suggested by Boucher et al., 2012; Bowler et al., 2010). Support for this idea comes from the result that ASD participants showed no difficulties in a source memory test using the same materials when support was provided. Since source memory depends on frontal lobe functions (Craik et al., 1990), frontal lobe processes seem to be less disrupted in ASD than they are in TD older adults, and impaired functions in ASD that depend on frontal lobe processes may rather be the result of a less efficient communication between the hippocampus and frontal lobes. However, it is important to note that (memory) atypicalities in ASD result from an atypical developmental trajectory where connections between brain regions may get formed differently, whereas dysfunction in TD older adults and patients with hippocampal damage occurs after a period of typical development.

The conclusions of the present study rely heavily on the process-dissociation-procedure, which has attracted some criticism. For instance, Buchner and colleagues (1995) argued that it is problematic to use the process-dissociation-procedure in within-subject comparisons for several reasons. First, participants performing perfectly in both include and exclude conditions would lead to an underestimation of the explicit memory component and since there were slightly more people in the TD group who made no mistakes, this is all the more true for TD individuals. Since we still found a difference in the explicit score between the 2 groups when the measure might have been slightly underestimated leads us to conclude that the effect reported here is rather robust and might possibly be even larger. An underestimation might be avoided by dropping perfectly performing participants from the analysis, which is what we did in the current study. Another point is that it could be quite difficult to perform both sets of test instructions after one another in one test phase because they are quite complex (Graf & Komatsu, 1994). We counterbalanced the order of the presentation of the two types of instructions to avoid any order effects and to ensure participants followed the instructions we asked participants to read these out loud for every trial. Another concern raised is that the standard error for every single participant would be quite high as only a few values are used to calculate explicit and implicit memory scores for participants (Buchner et al., 1995) making the detection of an effect harder. However, we still found an effect, whose large effect size suggests that it is substantial. Two other criticisms of the process-dissociation procedure are the assumption that implicit and explicit memory are working independently from one another (Curran & Hintzman, 1995) and that the original procedure (Jacoby, 1991) does not take correct guesses into account (Buchner et al., 1995). To avoid both criticisms a multinomial model was devised taking guesses into account in the calculation of explicit and implicit memory scores (Buchner et al., 1995; Caldwell & Masson, 2001). We re-ran our analysis using this model and the results showed again a clear difference in explicit relational memory ($t(37.91) = 2.19$, $p > .05$, Cohen's $d = 0.63$) between groups but not implicit relational memory ($t(36) = 0.74$, $p = .47$, Cohen's $d = 0.24$).

Finally, it is worth noting that our sample size might be regarded as small. However, we are confident in our results since they yield large effect sizes when we replicate previous findings. Power calculations with G*Power (Faul, et al., 2007) show that to repeat our finding of lower explicit relational memory in ASD with a similar effect size to that reported here and 85% power, we would need a sample size of 38 in each group. By contrast, the effect size for a potential difference between groups in the implicit relational memory score is very small. We can therefore be confident in our result that there is no difference between groups in implicit relational memory and can accept the null-hypothesis.

In conclusion the current study offers a test of the object-location memory framework in ASD using an externally valid paradigm. Results suggest difficulty with object-location memory rather than recognition memory for objects or locations per se being apparent only in explicit relational but not implicit relational memory which points to intact encoding but a problem with the explicit retrieval of the encoded information from memory. This finding has important implications for the design of future brain imaging studies as well as for the design of training and support programmes for ASD individuals, where implicit procedures should receive greater emphasis. Strategies shown to help to improve memory in older TD individuals, such as errorless learning (Kessels & de Haan, 2003), might also help in ASD.

Acknowledgements

We would like to thank Dr. Roy Kessels and Professor Albert Postma for providing some of the pictures that were used in this research. We also want to thank Professor James Hampton, City University London for helpful advice regarding the selection of object-locations in the first pilot study. We would also like to thank all the participants who have taken part this research. This study has been supported by a PhD studentship from City University London to the first author.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders- DSM-IV-TR (4th ed., text revision).* Washington, DC: Author.

Boucher, J., & Bowler, D. M. (Eds.). (2008). *Memory in autism: Theory and evidence.* Cambridge: Cambridge University Press.

Boucher, J., Cowell, P., Howard, M., Broks, P., Farrant, A., Roberts, N., & Mayes, A. (2005). A combined clinical, neuropsychological, and neuroanatomical study of adults with high functioning autism. *Cognitive Neuropsychiatry*, *10*(3), 165-213. doi: 10.1080/13546800444000038

Boucher, J., Mayes, A. & Bigham, S. (2012). Memory in autistic spectrum disorder. *Psychological Bulletin, 138*(3), 458-496. doi: 10.1037/a0026869

Bowler, D. M. (2007). *Autism spectrum disorder. Psychological theory and research.* Chichester: Wiley.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2009). Free recall learning of hierarchically organised lists by adults with Asperger's Syndrome: Additional evidence for diminished relational processing. *Journal of Autism and Developmental Disorders, 39,* 589-595.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2010). Multiple list learning in adults with autism spectrum disorder: Parallels with frontal lobe damage or further evidence of diminished relational processing? *Journal of Autism and Developmental Disorders, 40*(2), 179-187. doi: 10.1007/s10803-009-0845-x

Bowler, D. M., Gaigg, S. B., & Lind, S. (2011). Memory in autism: Binding, self and brain. In I. Roth & P. Rezaie (Eds.), *Researching the autism spectrum: Contemporary perspectives* (p. 316-346). Cambridge: Cambridge University Press.

Bowler, D. M., Gardiner, J. M. & Berthollier, N. (2004). Source memory in adolescents and adults with Asperger's syndrome. *Journal of Autism and Developmental Disorders, 34*(5), 533-542. doi: 10.1007/s10803-004-2548-7

Bowler, D. M., Gardiner, J. M., & Grice, S. J. (2000a). Episodic memory and remembering in adults with Asperger syndrome. *Journal of Autism and Developmental Disorders, 30*(4), 295-304. doi: 10.1023/A:1005575216176

Bowler, D. M., Gardiner, J. M., Grice, S. J., & Saavalainen, P. (2000b). Memory illusions: False recall and recognition in adults with Asperger's syndrome. *Journal of Abnormal Psychology*, *109*(4), 663-672. doi: 10.1037//0021-843X. 109.4.663

Bowler, D. M., Matthews, N. J., & Gardiner, J. M. (1997). Asperger`s syndrome and memory: Similarity to autism but not amnesia. *Neuropsychologia*, *35*(1), 65-70. doi: 10.1016/S0028-3932(96)00054-1

Buchner, A., Erdfelder, E., & Vaterrodt-Plunnecke, B. (1995). Toward unbiased measurement of conscious and unconscious memory processes within the process dissociation framework. *Journal of Experimental Psychology: General, 124*(2), 137-160. doi: 10.1037/0096-3445.124.2.137

Cabeza, R., Anderson, N. D., Houle, S., Mangels, J. A., & Nyberg, L. (2000). Age-related differences in neural activity during item and temporal-order memory retrieval: A positron emission tomography study. *Journal of Cognitive Neuroscience, 12*(1), 197-206. doi: 10.1162/089892900561832.

Caldwell, J. I., & Masson, E. J. (2001). Conscious and unconscious influences of memory for object location. *Memory & Cognition, 29*(2), 285-295. doi: 10.3758/BF03194922

Cansino, S., Maquet, P., Dolan, R. J., & Rugg, M. D. (2002). Brain activity underlying encoding and retrieval of source memory. *Cerebral Cortex*, *12*(10), 1048-1056. doi: 10.1093/cercor/12.10.1048

Chun, M. M., & Jiang, Y. (2003). Implicit, long-term spatial contextual memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(2), 224-234. doi: 10.1037/0278-7393.29.2.224

Craik, F.I., Morris, L.W., Morris, R.G. & Loewen, E.R. (1990) Relations between source amnesia and frontal lobe functioning in older adults. *Psychology and Ageing, 5*(1): 148-151. doi: 10.1037/0882-7974.5.1.148

Crane, L., Goddard, L., & Pring, L. (2009). Specific and general autobiographical knowledge in adults with autism spectrum disorders: The role of personal goals. *Memory, 17*(5), 557-576. doi: 10.1080/09658210902960211

Curran, T., & Hintzman, D. L. (1995). Violations of the independence assumption in process dissociation. *Journal of Experimental Psychology, 21*(3), 531-547. doi: 10.1037/0278-7393.21.3.531.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191. doi:10.3758/BF03193146.

Gaigg, S. B., Bowler, D. M., & Gardiner, J. M. (2014). Episodic but not semantic order memory difficulties in autism spectrum disorder: Evidence from the Historical Figures Task. *Memory, 22*(6), 669-678. doi: 10.1080/09658211.2013.811256.

Gaigg, S. B., Gardiner, J. M., & Bowler, D. M. (2008). Free recall in autism spectrum disorder: The role of relational and item-specific encoding. *Neuropsychologia, 46*(4), 986-992. doi: 10.1016/j.neuropsychologia.2007.11.011

Gaigg, S. B., Bowler, D. M., Ecker, C., Calvo-Merino, B. & Murphy, D.G. (2015). Episodic recollection difficulties in ASD result from atypical relational encoding: Behavioural and Neural Evidence. *Autism Research.*

Hunt, R. R., & Einstein, G. O. (1981). Relational and item-specific information in memory. *Journal of Verbal Learning and Verbal Behavior, 20*(5), 497-514. doi: 10.1016/S0022-5371(81)90138-9

Gardiner, J. M., Bowler, D. M., & Grice, S. J. (2003). Further evidence of preserved priming and impaired recall in adults with Asperger's syndrome. *Journal of Autism and Developmental Disorders, 33*(3), 259-269. doi: 10.1023/A:1024450416355

Graf, P. & Komatsu, S.-I. (1994). Process dissociation procedure: Handle with care! *European Journal of Cognitive Psychology, 6*(2), 113-129. doi: 10.1080/09541449408520139

Hampstead, B. M., Stringer, A. Y., Stilla, R. F., Amaraneni, A., & Sathian, K. (2011). Where did I put that? Patients with amnestic mild cognitive impairments demonstrate widespread reductions in activity during the encoding of ecologically relevant object-location associations. *Neuropsychologia, 49*(9), 2349-2361. doi: http://dx.doi.org/10.1016/j.neuropsychologia.2011.04.008

Howard, J. H., Dennis, N. A., Howard, D. V., Yankovich, H., & Vaidya, C. J. (2004). Implicit spatial contextual learning in healthy aging. *Neuropsychology, 18*(1), 124-134. doi: 10.1037/0894-4105.18.1.124

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30*(5), 513-541. doi: http://dx.doi.org/10.1016/0749-596X(91)90025-F

Jacoby, L. L. (1998). Invariance in automatic influences of memory: Toward a user's guide for the process-dissociation procedure. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24*(1), 3-26. doi: 10.1037/0278-7393.24.1.3

Kessels, R. P. C. & de Haan, E. H. F. (2003). Mnemonic strategies in older people: a comparison of errorless and errorful learning. *Age and Ageing, 32*(5), 529-533. doi: 10.1093/ageing/afg068

Kessels, R. P. C., Feijen, J. & Postma, A. (2005a). Implicit and explicit memory for spatial information in Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders, 20*(2-3), 184-191. doi: 10.1159/000087233

Kessels, R.P.C., te Boekhorst, S., & Postma, A. (2005b). The contribution of implicit and explicit memory to the effects of errorless learning: A comparison between young and older adults. *Journal of the International Neuropsychological Society, 11*(2), 144-151. doi: http://dx.doi.org/10.1017/S1355617705050174

Kuusikko-Gauffin, S., Jansson-Verkasalo, E., Carter, A., Pollock-Wurman, R., Jussila, K., Mattila, M.- L., … Moilanen, I. (2011). Face memory and object recognition in children with high-functioning autism or Asperger syndrome and in their parents. *Research in Autism Spectrum Disorders, 5*(1), 622-628. doi: http://dx.doi.org/10.1016/j.rasd.2010.07.007

Lind, S., & Bowler, D. M, (2009). Recognition Memory, Self-Other Source memory, and theory of mind in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 39*(9), 1231-1239. doi: 10.1007/s10803-009-0735-2

Lind, S., & Bowler, D.M. (2010). Episodic memory and episodic future thinking in adults with autism. *Journal of Abnormal Psychology, 119*(4), 896-905. doi: 10.1037/a0020631

Lord, C., Rutter, M., Goode, S., Heemsbergen, J., Jordan, H., Mawhood, L., & Schopler, E. (1989). Autism diagnostic observation schedule: A standardized observation of communicative and social behaviour. *Journal of Autism and Developmental Disorders, 19*(2), 185-212. doi: 10.1007/BF02211841

Minshew, N. J., & Goldstein, G. (1998). Autism as a disorder of complex information processing. *Mental Retardation and Developmental Disabilities Research Reviews, 4*(2), 129-136. doi:10.1002/(SICI)1098-2779(1998)4:2<129::AID-MRDD10>3.0.CO;2-X

Mottron, L., Morasse, K., & Belleville, S. (2001). A study of memory functioning in individuals with autism. *Journal of Child Psychology and Psychiatry, 42*(2), 253-260. doi: 10.1111/1469-7610.00716

Poirier, M., Martin, J., Gaigg, S. B., & Bowler, D. M. (2011). Short-term memory in autism spectrum disorder. *Journal of Abnormal Psychology, 120*(1), 247-252. doi: 10.1037/a0022298

Postma, A., Antonides, R., Wester, A. J., & Kessels, R. P. C. (2008a). Spared unconscious influences of spatial memory in diencephalic amnesia. *Experimental Brain Research, 190*(2), 125-133. doi: 10.1007/s00221-008-1456-z

Postma, A., Kessels, R. P. C., & van Asselen, M. (2008b). How the brain remembers and forgets where things are: The neurocognition of object-location memory. *Neuroscience and Behavioral Reviews, 32*(8), 1339-1345. doi: http://dx.doi.org/10.1016/j.neubiorev.2008.05.001

Randolph, C., Tierney, M. C., & Chase, T.N. (1995). Implicit memory in Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 17*(3), 343-351. doi: 10.1080/01688639508405128

Renner, P., Klinger, L. G., & Klinger, M. R. (2000). Implicit and explicit memory in autism: Is autism an amnesic disorder? *Journal of Autism and Developmental Disorders, 30*(1), 3-14. doi: 10.1023/A:1005487009889

Ring, M., Bowler, D. M., & Gaigg, S. B. (in preparation). An eye-movement study of explicit and implicit relational memory in adults with Autism Spectrum Disorder.

Ring, M., Gaigg, S. B., Altgassen, M., Barr, P. & Bowler, D. M. (under review). Allocentric versus egocentric spatial memory in Autism Spectrum Disorder.

Souchay, C., Wojcik, D. Z., Williams, H. L., Crathern, S., & Clarke, P. (2013). Recollection in adolescents with autism spectrum disorder. *Cortex, 49*(6), 1598-1609. doi: 10.1016/j.cortex.2012.07.011

Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence for a cognitive deficit. *British Journal of Developmental Psychology, 9,* 417-430.

The Psychological Corporation (2000). *Wechsler Adult Intelligence Scale III UK edition (WAIS-IIIUK; 3rd ed.).* London, UK: Author.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53*, 1-25. doi: 10.1146/annurev.psych.53.100901.135114

Table 1

Participant characteristics for individuals with autism spectrum disorder (ASD) and typically developing (TD) individuals

	ASD (20m, 5f)	**TD (17m, 6f)**			
Measure	***M (SD)***	***M (SD)***	***t*(46)**	***p***	**Cohen's *d***
Age (years)	42.13 (13.20)	40.87 (13.51)	0.33	.75	0.09
VIQ [a]	108 (15.0)	114 (12.3)	1.41	.17	0.41
PIQ[b]	106 (15.6)	109 (11.0)	0.88	.39	0.25
FIQ[c]	108 (15.4)	113 (12.2)	1.23	.22	0.36
ADOS-C[d]	2.68 (1.52)	(0 – 6)			
ADOS-RSI[e]	6.27 (2.49)	(3 – 12)			
ADOS-Total[f]	8.95 (3.12)	(5 – 17)			
ADOS-I[g]	1.24 (0.62)	(0 – 2)			
SB[h]	1.27 (1.08)	(0 – 3)			

Note. [a]Verbal IQ (WAIS-III[UK]). [b]Performance IQ (WAIS-III[UK]) [c]Full-scale IQ (WAIS-III[UK]). [d]ADOS- Communication subscale. [e]ADOS- Reciprocal Social Interaction subscale. [f]ADOS Total score- Communication + Reciprocal Social Interaction. [g]ADOS- Imagination/ Creativity subscale. [h]Stereotyped Behaviours and Restricted Interests. For ADOS scores range of scores in brackets.

Table 2

Descriptive statistics for TD and ASD groups for the object recognition and location recognition tasks.

	ASD	TD
Measure	***M (SD)***	***M (SD)***
Object recognition (23 TD, 25 ASD)		
1 interaction	0.88 (0.18)	0.94 (0.08)
2 interactions	0.97 (0.05)	0.99 (0.02)
Object total source score (23 TD, 24 ASD)	0.81 (0.13)	0.82 (0.08)
Location recognition (23 TD, 24 ASD)		
no interaction	0.21 (0.11)	0.17 (0.11)
1 interaction	0.50 (0.21)	0.50 (0.19)
2 interactions	0.65 (0.18)	0.63 (0.18)
Location total source score (23 TD, 24 ASD)	0.35 (0.08)	0.35 (0.07)

Table 3

Correlations between explicit and implicit relational memory scores for the object-location task and corrected object and corrected location recognition rates and object and location source scores for the recognition tasks.

	Explicit	**Implicit**	**Object**	**Location**	**Object source**	**Location source**
Explicit	1	.04 (.80)	.59**	.52**	.52**	.49**
Implicit		1	-.06 (.74)	.12 (.49)	-.09 (.58)	-.11 (.53)
Object			1	.35*	.49**	.21 (.15)
Location				1	.34*	.68**
Object source					1	.55**
Location source						1

Note. + $p < .1$. * significant at $p < .05$. ** significant at $p \leq .01$. For all other correlations the p value is presented in brackets.

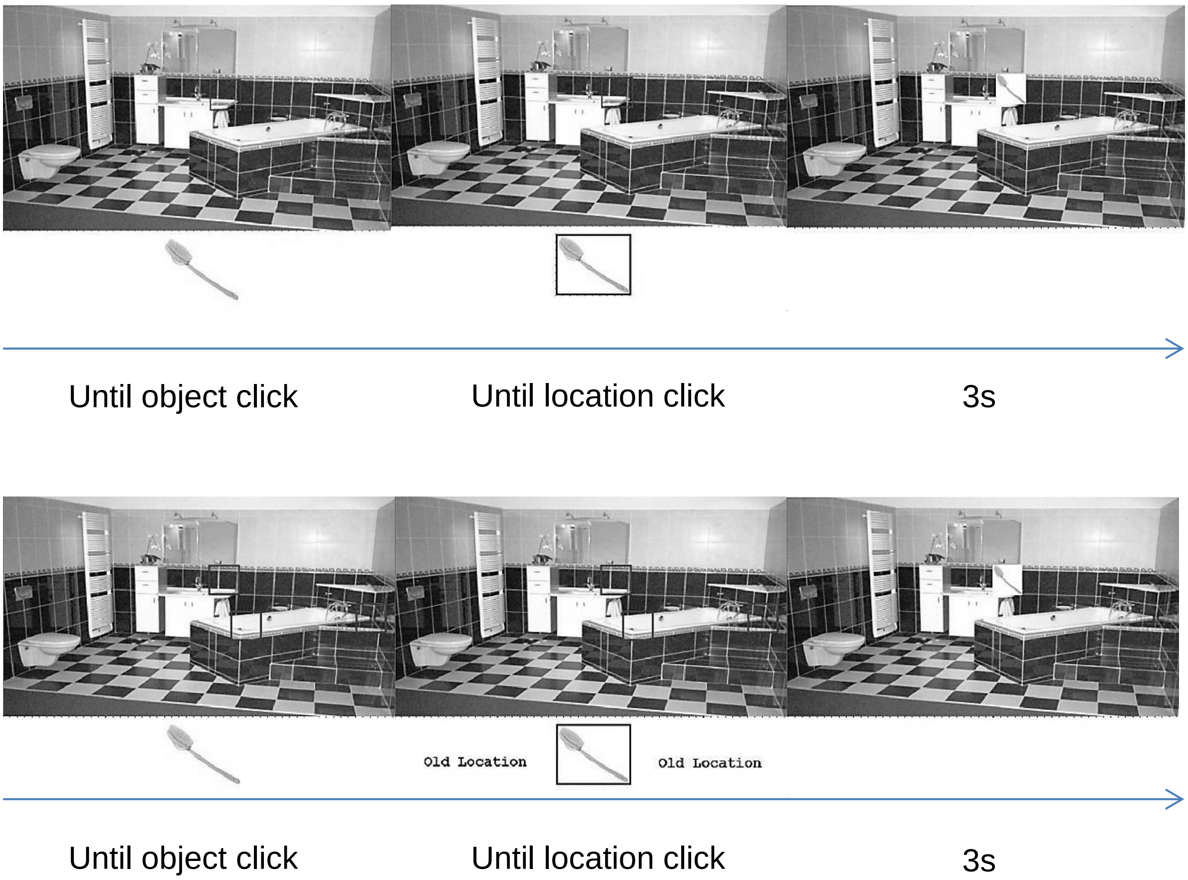

Figure 1. Examples of study phase (top) and test phase (bottom).

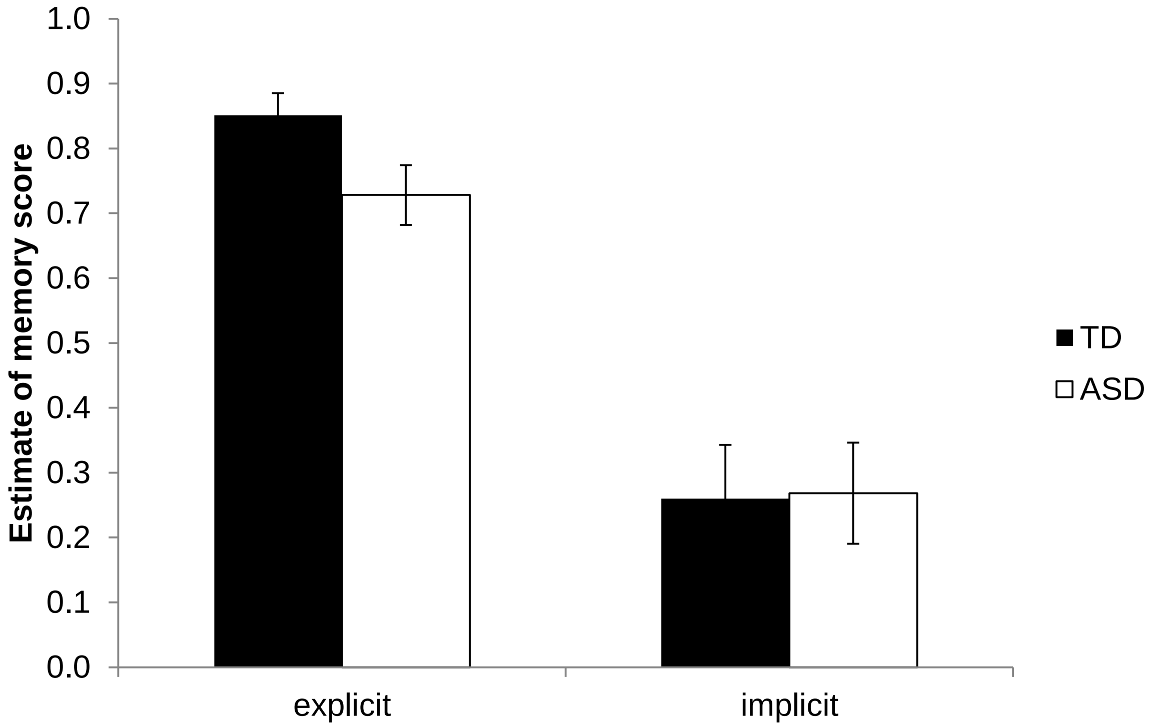

Figure 2. Estimates for explicit and implicit memory calculated from scores for include and exclude conditions according to Jacoby (1991) formulae. Explicit memory is constituted by 23 TD and 25 ASD individuals. Implicit memory was available for 17 TD and 21 ASD individuals.

Supplementary online material

Table S1

List of rooms and objects for practice and test and which sets they were studied in. Set A was used as study set for one half of the participants. They received Set B as new items in the test. Whereas the other half of the participants studied Set B and received Set A as the new items in the test.

Room	Object	Set
practice		
Garden	Mower	studied in Set A
Garden	Milk can	studied in Set A
Garden	Birdhouse	studied in Set A
Garden	Watering can	studied in Set B
Garden	Spade	studied in Set B
test		
Bathroom	Bath brush	studied in Set A
Bathroom	Bathing slippers	studied in Set A
Bathroom	Scales	studied in Set A
Bathroom	Shaver	studied in Set A
Bathroom	Soap	studied in Set B
Bathroom	Toilet paper	studied in Set B
Bathroom	Toothbrush	studied in Set B
Bathroom	Shampoo	studied in Set B

Living room	Videocassette	studied in Set A
Living room	Candle	studied in Set A
Living room	CD collection	studied in Set A
Living room	clock	studied in Set A
Living room	Radio	studied in Set B
Living room	Remote	studied in Set B
Living room	Wine bottle	studied in Set B
Living room	Books	studied in Set B
Kitchen	Washing-up liquid	studied in Set A
Kitchen	Cheese	studied in Set A
Kitchen	Potatoes	studied in Set A
Kitchen	Eggs	studied in Set A
Kitchen	Knife block	studied in Set B
Kitchen	Cloths	studied in Set B
Kitchen	Spatula	studied in Set B
Kitchen	Saltshaker	studied in Set B
Bedroom	Book	studied in Set A
Bedroom	House shoes	studied in Set A
Bedroom	Night cream	studied in Set A
Bedroom	Pillow	studied in Set A
Bedroom	Socks	studied in Set B
Bedroom	Tie	studied in Set B

Bedroom	Underpants	studied in Set B
Bedroom	Teddy	studied in Set B
Office	Agenda	studied in Set A
Office	Stapler	studied in Set A
Office	Letter tray	studied in Set A
Office	Desk tidy	studied in Set A
Office	Briefcase	studied in Set B
Office	Hole puncher	studied in Set B
Office	File	studied in Set B
Office	Biro	studied in Set B
Storeroom	Bag	Studied Set A
Storeroom	Carton	Studied Set A
Storeroom	Cooler	Studied Set A
Storeroom	Dartboard	Studied Set A
Storeroom	Cable spool	studied in Set B
Storeroom	Keys	studied in Set B
Storeroom	Painting	studied in Set B
Storeroom	Polish	studied in Set B