Recollection in adolescents with Autism Spectrum Disorder

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Abstract

Introduction: Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder primarily affecting social interaction and communication. Recently, there has been interest in whether people with ASD also show memory deficits as a result of abnormal brain development. However, at least in adolescents with ASD, the recollection component of episodic memory has rarely been explored. This paper is an evaluation of recollection in three different experiments in adolescents with ASD, using both objective (source discrimination) and subjective methods (Remember–Know judgments).

Methods: Three experiments were designed to measure different aspects of contextual information: sensory/perceptual information (Experiment 1), temporal information (Experiment 2) and spatial information (Experiment 3). To measure objective and subjective recollection, for all three experiments, all participants were presented with information to learn in a specific context. At the recognition stage, they were asked whether they remembered the information or just knew the information was there (R/K response, subjective method). To assess the quality of these subjective judgments, participants justified their Remember responses using the contextual information. After the recognition task, to assess source memory (objective measure), all items presented at encoding were represented and participants have to recall the source for all these items.

Results: All three experiments showed that adolescents with ASD could correctly recall source information. However, in the first experiment adolescents with ASD gave significantly fewer Remember responses than controls.

Conclusions: These findings point to a specific and subtle recollection impairment in adolescents with ASD, at least when subjective methods are used. We discuss how these might relate to differences in the self and to the brain abnormalities in ASD.

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1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder primarily affecting social interaction and communication. Recently, there has been interest in whether people with ASD also show memory deficits as a result of abnormal brain development. Studies investigating memory in ASD have compared two main systems: the episodic memory system and the semantic memory system (Tulving, 1985). Episodic and semantic memory differ in the subjective state or conscious awareness associated with retrieval (Tulving, 1985; Wheeler et al., 1997; for a neuroscience perspective see Habib et al., 2003). Episodic retrieval is associated with autonoetic awareness and includes the source of the memory, an awareness of its origin, and a conscious evaluation of itself. Episodic retrieval is thus characterized by a recollective experience and a feeling of the self in the past (Tulving, 1985). Semantic retrieval is associated with noetic awareness and reflects conceptual knowledge. Studies in ASD have revealed impairments in episodic memory (Boucher and Bowler, 2008) but intact performance on semantic memory tasks (Bowler et al., 2007; Lind and Bowler, 2009; Salmond et al., 2005). To explain this dissociation, it has been suggested that episodic memory deficits in ASD could be due to a lack of recollection (Boucher et al., 2008; Lind and Bowler, 2008). However, at least in children and adolescents with ASD, recollection has rarely been explored. The novelty of this paper is therefore an evaluation of recollection in three different experiments in adolescents with ASD, using both objective (source discrimination) and subjective methods (Remember–Know judgments). Furthermore, research with high functioning adults with ASD has suggested that the mixed findings reported on episodic memory tasks could be due to compensatory mechanisms developed by some individuals (see Boucher and Bowler, 2008). Thus, in the current study, episodic memory and in particular recollection were assessed on adolescents with ASD.

Neuropathological findings in ASD support the prediction that recollection might be impaired. Indeed, in ASD, atypicalities in brain regions known to be involved in memory functioning have been found (see Palmen et al., 2004, for review). For example, abnormalities of the hippocampus are very well documented (see Nicolson et al., 2006) and it is now well-established that the medial-temporal lobes and in particular the hippocampus are critical for recollective experience (see Eichenbaum et al., 2007; Yonelinas, 2002). For instance, patient studies have revealed that damage to the hippocampus is linked to a lack of recollection (e.g., Bowles et al., 2007; Schacter et al., 1996, 1997; Verfaellie and Treadwell, 1993). On the other hand, parahippocampal areas, known to be involved in familiarity processes and also in encoding of the contextual information (Eichenbaum et al., 2007) seem to be less affected in ASD (Bauman and Kemper, 1985). The role played by the hippocampus in episodic recollection has also been confirmed in an emergent literature exploring the developmental differences in brain regions associated with recollection. For example, Ghetti et al. (2010) using Functional Magnetic Resonance Imaging (fMRI) data collected in Typically Developing (TD) children and adults showed that the hippocampus was selectively activated for subsequent recollection only in adults and adolescents (from 14 years old). This was not the case for younger children, suggesting that developmental changes in the hippocampus were related to the developmental changes observed in recollection. In view of the brain abnormalities observed in ASD, and in particular the abnormalities found in the hippocampus, and the role played by this neural region in recollection, it is thus reasonable to assume that people with ASD may experience difficulties in recollection tasks (see Gaigg and Bowler, 2008, for a similar argument).

Recollection can be indexed either by objective information such as the source of the item, or subjective reports about the quality of retrieval as for example with the Remember–Know paradigm introduced by Tulving (1985). We will now in turn review the studies in ASD that have used objective and subjective measures to assess recollection in ASD. Source memory is assessed by asking participants to retrieve contextual information linked to the target, such as sensory/perceptual information, spatial and temporal information, semantic detail and affect (Johnson et al., 1993). Few studies have explored memory for sensory/perceptual, temporal or spatial contextual information associated with a specific event in people with ASD. In fact, studies exploring whether people with ASD can recall contextual information have only explored one contextual dimension (temporal source) and have revealed contradictory findings (Bennetto et al., 1996; Gras-Vincendon et al., 2007). Most studies of children with ASD have examined reality monitoring skills by asking participants to discriminate between self versus other as the source of information. TD children from age six perform well in reality monitoring tasks (Foley et al., 1993). The results of studies with children and adolescents with ASD reveal contradictory findings with some finding no impairment (Farrant et al., 1998; Hill and Russell, 2002; Russell and Hill, 2001; Williams and Happe, 2009a, 2009b) while others show clear monitoring difficulties (Hala et al., 2005; Lind and Bowler, 2009; Millward et al., 2000; Russell and Jarrold, 1999). Children with ASD also have an impairments on internal source monitoring tasks (Johnson et al., 1993) when, for example, asked to discriminate between heard versus seen words (Bowler et al., 2004) or thought versus said words (Hala et al., 2005). Thus, to date no studies have investigated systematically whether or not people with ASD can retrieve sensory/perceptual, temporal or spatial contextual information. In an exploratory way, three experiments will measure different aspects of contextual information: sensory/perceptual information (Experiment 1), temporal information (Experiment 2) and spatial information (Experiment 3), with the aim of examining whether any aspects of source retrieval are impaired in adolescents with ASD.

As opposed to the objective measure of recollection of contextual detail recorded by source judgments, when recollection is assessed by subjective states participants are asked to report whether or not information is familiar or remembered. With the Remember–Know paradigm originally proposed by Tulving (1985), participants are asked to learn a list of words and then during a recognition task are required to classify their responses, either as Remember responses or
Know responses. A Remember (R) response is provided when participants remember contextual information about the learning episode (recollection), while Know (K) responses are provided when participants know that the recognized information has been learned, but that they do not remember any information about the learning episode. Studies looking at developmental patterns in recollection have explored Remember and Know judgments in children and have shown that from age eight they can give Remember responses and that there is a developmental trend in the subjective experience of recollection (Billingsley et al., 2002; Friedman et al., 2010; Ofen et al., 2007; Piolino et al., 2007). For example, Billingsley et al. (2002) showed an increase in the proportion of Remember responses with age (from 8 to 19 years), with the youngest group giving fewer correct Remember responses (5% for the youngest group vs 28% for the oldest group). There is no literature on subjective reports of recollection in children or adolescents with ASD. However, studies using the Remember–Know paradigm (Tulving, 1985) in adults with Asperger’s Syndrome have all consistently shown a reduced number of Remember judgments (Bowler et al., 2000a, 2000b, 2007; Tanweer et al., 2009). Thus, this paper will be the first to explore Remember responses in adolescents with ASD and based on previous findings in adults, we predict that adolescents with ASD will make fewer Remember responses in comparison to TD adolescents.

A remaining question is to establish whether the Remember responses given by the individuals with ASD also differ qualitatively to those of TD controls. According to Bowler et al. (2007), Remember judgments in adults with Asperger’s Syndrome differ quantitatively but not qualitatively. In other words, individuals with ASD have similar recollective experiences but present fewer of them. To ascertain this, in a set of three experiments Bowler et al. (2007) showed that manipulations known to affect Remember responses (such as divided attention) had similar effects on the recollection performance of both the people with Asperger’s Syndrome and the control participants. The originality of the current paper is not only to measure Remember responses in adolescents with ASD but also to explore the quality of the given Remember responses. To assess quality, in each experiment we asked our participants to justify their Remember responses by recalling source information. Because subjective judgments cannot be objectively verified, many researchers have combined judgments of source with subjective experience in attempts to tap both objective and subjective measures of recollection (Conway and D’Cruze, 1995; Hicks et al., 2002; Meiser and Bröder, 2002; Meiser and Sattler, 2007; Perfect et al., 1996; Starns and Hicks, 2005). Overall, studies have shown that Remember responses are associated with source recall, such as the modalities of words presented either visually or acoustically ( Humphreys et al., 2003) or the spatial location of items (Meiser and Bröder, 2002; Perfect et al., 1996).

To sum up, this paper investigates an underexplored domain in adolescents with ASD: recollection. The novelty of the three studies presented in this paper lies in assessing recollection using objective and subjective methods conjointly. To do so, for all three experiments, all participants were presented with information to learn in a specific context. At the recognition stage, they were asked whether they remember the information or just know the information was there (R/K response, subjective method). To assess the quality of these subjective judgments, participants were also asked to justify their Remember responses using the contextual information. After the recognition task, to assess source memory (objective measure), all items presented at encoding were represented and participants asked to recall the source for all these items. Finally, for the first time in the literature source memory for three different types of contextual information (sensory/perceptual, temporal and spatial information) was assessed in the same group of participants with the purpose of giving a better picture of source memory in ASD.

2. Experiment 1 — perceptual/sensory contextual information

The aim of the first experiment was to investigate source memory for perceptual/sensory information. It was designed to examine the ability to discriminate between memories from two different sources of perceptual/sensory contextual information (color of pictures and gender of speaker; Brewer et al., 2010) and to assess the impact of encoding manipulations (incidental vs intentional learning) on source memory. Studies have shown that source memory is better under intentional encoding (Bowler et al., 2010; Meiser and Sattler, 2007) and that memory performance in individuals with ASD can be improved by deeper levels of encoding (Bowler et al., 1997; Mottron et al., 2001; but see Toichi and Kamio, 2002). Therefore we predicted that for both TD adolescents and adolescents with ASD, the recognition of source information would be better in the intentional encoding condition.

In addition to objective judgment of source, recollection in this experiment was also assessed by asking participants at the recognition stage to give subjective Remember–Know judgments. Because of previous findings in adults with Asperger syndrome (AS) (Bowler et al., 2000a, 2000b), we also expected to find reduced number of Remember judgments in adolescents with ASD, thus suggesting lower overall episodic recollection in this population. Finally, we assessed the quality of Remember responses by asking participants to justify their answers by giving contextual/source information when giving a Remember response. In assessing the relation between source memory and Remember judgments, some studies have demonstrated that factors that facilitate Remember judgments also increase source memory accuracy (Conway and D’Cruze, 1995; Donaldson et al., 1996; Meiser and Sattler, 2007). In this experiment, we were thus expecting that the source justifications given to Remember responses would be better in the intentional learning condition. However, in accordance with results showing that individuals with ASD do not use contextual information to support their learning (Bowler et al., 1997, 2000a, 2000b, 2010), we also predicted that adolescents with ASD would fail to justify their Remember responses using source information.

2.1. Method

2.1.1. Participants

Nineteen adolescents with ASD (16 males, 3 females) and nineteen TD adolescents (14 males, 5 females) participated in
the study. Table 1 shows their characteristics. There were no group differences on age (t(36) = 1.16, ns), full IQ (t(34) = .96, ns) and performance IQ (t(36) = .20, ns) (WASI; Wechsler, 1999).

There was a group difference approaching significance in verbal IQ (VIQ) with the ASD group achieving lower scores than the TD group (t(36) = 1.90, p = 0.07). However, the groups did not differ on receptive language, as measured by the Peabody Picture Vocabulary Test (PPVT; Dunn and Dunn, 2006).

A male and a female speaker prerecorded the verbal labels. The items were randomized so that half of the color pictures and half of the line drawings were spoken by a different gender.

2.1.2. Study. Participants were informed that they were going to study pictures for a later memory test. They were told to pay attention to whether the picture was presented in color or as a line drawing. No mention was made regarding speaker’s gender (cf. Brewer et al., 2010). Thus, the encoding of color was intentional whilst the encoding of gender was incidental. Forty pictures along with their verbal labels were presented using Microsoft PowerPoint on a laptop computer and each appeared on screen for 5 sec in a random order, with the spoken label being played at the onset of the picture on the screen.

2.1.2.2. Recognition. The recognition task occurred immediately after the presentation of the last picture in the study phase. Participants were given a paper answer sheet with a randomized list of the 40 target labels and 40 distracter labels in written form. The participants were always given the option to ask the experimenter for clarification. In the recognition memory task a one-step Remember–Know–New (RKN) procedure was used (cf. Perfect et al., 1996). For each item, participants were asked whether they Remembered (R), Knew (K) or simply had Not Seen (NS) the item in the sequence. They did this by writing one of the options on the answer sheet (R/K/NS). The instructions for the R–K–NS judgments were similar to those used in previous research of this paradigm (Gardiner and Java, 1993) but were simplified to ensure that all participants could understand them (Friedman et al., 2010; Piolino et al., 2007; Billingsley et al., 2002). The participants were also required to justify their R judgments (Friedman et al., 2010; Billingsley et al., 2002). They were asked to provide some specific thoughts, images or memories that they had about the word. A description of what constituted an R, K, and NS response was available to the participants on a sheet of paper throughout the experiment. Furthermore, for all R responses (Hits only), after giving the justifications participants were asked to justify their R responses further by giving source information. They were first asked whether the labels were presented in a male or a female voice and then whether it was presented in a color or a line drawing. They were also given the choice to give a ‘don’t know’ answer. Unlike in previous studies (Conway and Dewhurst, 1995; Perfect et al., 1996) the source justification was done only on R responses in order not to confuse the participants with the meaning of the Remember judgments.

2.1.2.3. Source discrimination. Finally, all participants were randomly represented with the 40 pictures from the study phase, all in black line drawings with their written labels. No new items were included. During this test, participants were first asked to indicate whether a male or a female voice spoke each word and then asked whether the picture had been presented as a color picture or a line drawing (see Brewer et al., 2010). ‘Don’t know’ responses were also permitted.
2.2. Results and discussion

2.2.1. Recognition performance

First, we examined the proportion of Hits in both groups (see Table 2). A one-way ANOVA did not reveal a significant group effect \(F(1, 37) = .59, \text{ ns}\). For both TD \([t(18) = 6.92, p < .001]\) and ASD groups \([t(18) = 8.42, p < .001]\) recognition performance was above chance. A one-way ANOVA was also carried out on the proportion of false alarms (FA) which also did not reveal a significant effect of group \([F(1, 37) = .05, \text{ ns}\]. These analyses confirm previous findings showing that memory in people with ASD is usually comparable to controls (Boucher and Warrington, 1976; Bowler et al., 1997).

2.2.1.1. Subjective measure of recollection. As predicted, for the proportion of R responses (given to Hits only), an ANOVA revealed that the TD adolescents gave significantly more R responses than the adolescents with ASD [Table 2, \(F(1, 37) = 4.76, p < .05\)]. This result is consistent with previous findings in adults with ASD (Bowler et al., 2000a, 2000b, 2007; Tanweer et al., 2009). To explore the quality of Remember responses, we looked at the proportion of Remember responses accompanied by correct source recall. For these analyses, only the children who gave Remember responses were included: 12 adolescents with ASD (age: \(m = 14.3, SD = 2.70\); full IQ: \(m = 114.75, SD = 13.40\)) and 17 TD adolescents (age: \(m = 12.94, SD = 2.76\); full IQ: \(m = 119.52, SD = 13.12\)). The groups were still matched on age \([F(1, 28) = 1.73, \text{ ns}\) and full IQ \([F(1, 28) = .92, \text{ ns}\). On the proportion of Remember responses (Hits only) accompanied by correct source recall, a \(2\times 2\) ANOVA did not reveal a significant main effect of group \([F(1, 27) = 1.74, \text{ ns}\]. However, there was a significant main effect of source type \([F(1, 27) = 22.08, p < .001]\). For both adolescents with ASD and TD controls, more Remember responses were associated with correct source recall for the color source (\(m = 75, SD = .31\) for ASD; \(m = 71, SD = .32\) for TD) than for the voice source (\(m = .42, SD = .40\) for ASD; \(m = .24, SD = .25\) for TD). No significant interaction was found \([F(1, 27) = .55, \text{ ns}\). Therefore, more correct source information was recalled for Remembered items in the intentional learning (or color) condition.

2.2.1.2. Objective measure of recollection. We measured the proportion of correct source identifications in the source discrimination task. A \(2\times 2\) ANOVA showed no main effect of group \([F(1, 37) = .05, \text{ ns}\), but revealed a significant main effect of source type \([F(1, 36) = 55.62, p < .001]\). Both groups had better source discrimination for color than for voice. No significant interaction was found \([F(1, 36) = .46, \text{ ns}\). One-sample t-tests revealed that the performance for source memory for voice was above chance (\(50\%) for ASD \([t(17) = 2.59, p < .02, m = .58, SD = .13\) but not TD participants \([t(18) = .75, m = .52, SD = .13\). For the color source memory, performance was above chance for ASD \([t(18) = 9.67, p < .001, m = .75, SD = .11\) and TD groups \([t(18) = 11.22, p < .001, m = .76, SD = .10\). Finally, as the participants were given the opportunity to give a ‘don’t know’ response, we also looked at these answers. A \(2\times 2\) ANOVA showed no main effect of group \([F(1, 37) = .09, \text{ ns}\), a main significant effect of source type \([F(1, 37) = 47.46, p < .001]\), but no interaction \([F(1, 37) = 1.01, \text{ ns}\). Both groups gave more don’t know responses for the voice source (\(m = 15.32, SD = 10.32\) for ASD; \(m = 15.89, SD = 8.87\) for TD) than the color source (\(m = 7.74, SD = 6.43\) for ASD; \(m = 5.57, SD = 6.57\) for TD). These findings show that adolescents with ASD can recall perceptual/sensory contextual information when the encoding of the source is intentional. Performance in the incidental condition (source for voice) was slightly above chance in the individuals with ASD but in the TD controls, however, group means did not differ significantly. The encoding manipulation also had a similar effect in adolescents with ASD and TD controls, in that intentional encoding improves source memory performance (Brewer et al., 2010; Meiser and Sattler, 2007).

Experiment 1 therefore finds that participants with ASD have unimpaired recognition memory compared to controls, but that they subjectively report fewer instances of remembering at test than controls. Remember judgments are however, equally based on correct recall of source in both controls and people with ASD, and there were also no group differences in source memory, but both groups had superior source memory for the intentionally encoded factor, color.

### Table 2 – Mean (and Standard Deviations) for recognition performance in ASD and TD groups in the three experiments. Table shows Hits and FA as a proportion of the study list and the Remember judgments (R) as a proportion of hits.

<table>
<thead>
<tr>
<th></th>
<th>ASD (n = 19)</th>
<th>TD (n = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hits</td>
<td>FA</td>
</tr>
<tr>
<td>Exp. 1</td>
<td>.73 (.12)</td>
<td>.09 (.09)</td>
</tr>
<tr>
<td>Exp. 2</td>
<td>.69 (.21)</td>
<td>.13 (.13)</td>
</tr>
<tr>
<td>Exp. 3</td>
<td>.61 (.20)</td>
<td>.18 (.19)</td>
</tr>
</tbody>
</table>

3. Experiment 2 — temporal source memory

The aim of this second experiment was to explore temporal source memory. In ASD, only a few studies have assessed temporal source memory. For example, in a first study, Bennett et al. (1996) used temporal intrusions as a measure of source memory. Participants (adolescents with ASD and TD controls) were given the California Verbal Learning test (CVLT, Delis et al., 1987) and the number of intrusions of items from previous lists was measured. It was found that the responses of individuals with ASD included more intrusions than controls and individuals with ASD had difficulties judging temporal order when asked to indicate which items had been presented most recently. Using a similar recency task with picture stimuli, Gras-Vincendon et al. (2007) explored this further and found no deficits in adults with ASD. However, Bigham et al. (2010), demonstrated recency judgment impairments in low functioning children/adolescents with ASD. The novelty of the current experiment was to combine objective measures of recollection by asking participants when the words had been presented and subjective measures by asking them to give Remember/Know judgments on the recollection task.

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To do so, we used a paradigm similar to the one used by Perfect et al. (1996, Experiment 1). In their experiment, participants were presented with a list of words and then were asked to make an RKN judgment. After the RKN judgments participants were asked to put the words presented in order of their occurrence in the original list. Results revealed that participants were able to make temporal discriminations for those items that were accompanied by recollective experience (R judgments).

### 3.1. Materials and procedure

For this second experiment, sixty words within the frequency range of 1–472 were selected from the MRC linguistic database (Coltheart, 1981). All words were between three and nine letters long. Thirty of these words were used as targets and thirty as distractors. The targets and distractors were matched on age of acquisition $[t(58) = .30, ns]$, frequency $[t(58) = 1.05, ns]$ and concreteness $[t(58) = .59, ns]$.

#### 3.1.1. Study

Participants were informed that they were going to study a list of words and were asked to try and remember the words. The exact nature of the test (source memory) was not specified. Participants were visually presented with the 30 words, one at a time, at a rate of 5 sec per word, using PowerPoint Presentation.

#### 3.1.2. Recognition

Immediately after the study phase, participants were presented with the 30 targets plus the 30 distracters on a sheet of paper. As in the first experiment participants were asked to make an R–K–NS judgment on every item. The instructions used were exactly the same as in Experiment 1 and every effort was made to make sure that the participants understood the different judgments. Furthermore, for all R responses (Hits only), participants were also asked to justify their responses by giving source information, i.e., whether the words were presented at the beginning, in the middle, or at the end of the list. As in the first experiment this was done only on R responses so as not to confuse the participants with the meaning of the Remember judgments.

#### 3.1.3. Source discrimination

After the participants had responded to all items in the recognition task, they were represented with the 30 targets [all individually written on a card in the same style (Font and Size)] and three boxes labeled ‘Beginning’, ‘Middle’, ‘End’. Participants were asked to put each card in one of the boxes at their own speed. Don’t know responses were also permitted.

### 3.2. Results and discussion

#### 3.2.1. Recognition performance

First, we examined the proportion of Hits in both groups (see Table 2). A one-way ANOVA did not reveal a significant group effect $[F(1, 37) = .008, ns]$ on this measure. Furthermore, a one-sample t-test revealed that the recognition performance of both the ASD $[t(18) = .83, p < .001]$ and TD group $[t(18) = 5.41, p < .001]$ was above chance. A one-way ANOVA carried out on the proportion of FA also showed no significant main effect of group $[F(1, 37) = .18, ns]$. These results are consistent with the first experiment and confirm that recognition performance of individuals with ASD is equivalent to that of controls.

#### 3.2.1.1. Subjective measure of recollection. Contrary to our prediction, and the results of Experiment 1, for the proportion of R responses (Table 2), the ANOVA did not reveal a significant main effect of group $[F(1, 37) = .27, ns]$. Adolescents with ASD did not show a lack of recollection as measured by subjective reports. In this experiment only eight adolescents with ASD (age: $m = 13.45, SD = 2.39$; full IQ: $m = 116.13, SD = 13.97$) and 13 TD participants (age: $m = 13.39, SD = 3.06$; full IQ: $m = 118.38, SD = 14.79$) gave any Remember responses. Due to the small number of participants in each group we did not carry out any statistical analysis on the proportion of Remember responses accompanied by correct source identification.

#### 3.2.1.2. Objective measure of recollection. To explore temporal source memory, we looked at the proportion of correct source identifications, i.e., whether or not adolescents with ASD and TD controls could remember if the words had been presented at the beginning of the list, in the middle, or at the end. A one-way ANOVA on the proportion of sources correctly identified did not reveal any significant effect of group $[F(1, 37) = .02, ns]$. One-sample t-tests demonstrated that both the ASD group $[t(18) = 3.76, p < .001, m = .52, SD = .21]$ and the TD group $[t(18) = 4.16, p < .001, m = .51, SD = 1.18]$ performed above chance level (i.e., above .33). Finally, we looked at the don’t know responses and did not show any significant group effect on this measure $[F(1, 37) = .01, ns]$. In other words, both groups had similar levels of don’t know responses ($m = 6.53, SD = .64$ for ASD; $m = 6.58, SD = .87$ for TD). These results thus suggest that adolescents with ASD like TD controls were able to retrieve temporal information relating to where the items had been presented in the list.

Experiment 2 therefore confirms that adolescents with ASD have unimpaired recognition memory. However, contrary to our prediction, and the results of Experiment 1, they did not report fewer instances of remembering than controls. Similarly, no group differences were observed in source memory and both individuals with ASD and TD controls were able to recall where the information had been presented in the list.

### 4. Experiment 3 — spatial source memory

To the best of our knowledge, no study has yet explored spatial source memory in adolescents with ASD. The aim of this last experiment was to investigate this using a similar paradigm to the one developed by Perfect et al. (1996, Experiment 3). In their paradigm, participants are presented with words in a grid of four quadrants at study and at recognition, and when making R and K judgments are asked to provide information regarding the spatial location of items in the grid. Perfect et al. (1996) demonstrated that participants were able to support their R responses using spatial information. In the present study this approach was used to...
examine whether on such a task adolescents with ASD would experience fewer recollective experiences than TD controls and whether they would have difficulties recalling where the information had been presented (source discrimination).

4.1. Materials and procedure

The materials consisted of 56 words, 28 target words and 28 distracters. The words were within the frequency range of 1–492 and were selected from the MRC linguistic database (Coltheart, 1981). Word length was between 3 and 11 letters. The targets and distracters were matched on age of acquisition \([t(54) = .27, \text{ns}],\) frequency \([t(54) = .73, \text{ns} \text{and concrete-}\) ness \([t(54) = .16, \text{ns}].\)

4.1.1. Study

Four words were presented at a time, one word printed in each of four quadrants of a box (see Fig. 1) at a rate of 8 sec per box, with a 2 sec gap between boxes. Participants were asked to learn the words for a later memory test. The exact nature of the memory test (source memory) was not specified.

4.1.2. Recognition

For the recognition task, responses were collected in the same manner as in Experiments 1 and 2. Furthermore, for the Remember responses, all participants were also asked to indicate in which quadrant of the box each word had been presented by giving a number from 1 to 4. To do this, the participants were presented with an empty box just indicating the numbers.

4.1.3. Source discrimination

For this task, participants were given the 28 targets all presented individually on cards and were asked to place each word card on one of the quadrant of the box. Don’t know responses were also permitted.

4.2. Results and discussion

4.2.1. Recognition performance

First, we examined the proportion of Hits in both groups (see Table 2). A one-way ANOVA revealed a group difference that was approaching significance suggesting that adolescents with ASD tended to recognize fewer items than the TD controls \([F(1, 37) = 3.37, p = .08].\) However, a one-sample t-test showed that both adolescents with ASD \([t(19) = 2.50, p < .05]\) and TD controls \([t(19) = 7.84, p < .001]\) performed above chance on the recognition test. When FA were analyzed, no significant main effect of group was found \([F(1, 37) = .87, \text{ns}].\)

4.2.1.1. Subjective measure of recollection. As in the temporal source experiment (Experiment 2), for the proportion of R responses (Hits only, see Table 2), a one-way ANOVA did not reveal a significant effect of group \([F(1, 37) = .01, \text{ns}].\) However, only a small number of participants actually gave Remember responses: 7 adolescents with ASD (age: \(m = 13.97, SD = 2.29;\) full IQ: \(m = 112, SD = 15.29\) and 11 TD controls (age: \(m = 12.65, SD = 2.40;\) full IQ: \(m = 124.73, SD = 8.71\)). We therefore decided due to small samples not to carry out analyses on the source justification (whether or not participants justified their R responses using source information).

4.2.1.2. Objective measure of recollection. To examine source memory, we looked at the proportion of spatial sources correctly identified (i.e., the proportion of words put in the correct quadrant). A one-way ANOVA did not reveal any significant group effect \([F(1, 37) = .22, \text{ns}].\) One-sample t-tests revealed that for both adolescents with ASD \([t(16) = 4.95, p < .001, m = .69, SD = .35]\) and TD controls \([t(18) = 5.82, p < .001, m = .51, SD = .19]\) performance was above chance (above .25). Finally, we looked at the don’t know responses and again did not show any significant group differences \([F(1, 37) = 1.15, \text{ns}, m = 14.89, SD = 10.49 \text{for ASD}; m = 11.74, SD = 7.48 \text{for TD}].\)

To sum up, Experiment 3 showed that adolescents with ASD gave a similar amount of Remember responses as TD controls and as for sensory/perceptual information in Experiment 1 and temporal source in Experiment 2, adolescents with ASD were able to correctly retrieve spatial source information at an equivalent level of performance as TD controls.

5. General discussion

The aim of these experiments was to explore recollection in adolescents with ASD using both objective measures (source discrimination) and subjective measures (Remember–Know judgments). Recollection was measured in three experiments assessing perceptual/sensory source information (Experiment 1), temporal information (Experiment 2) and spatial information (Experiment 3). All three experiments showed that adolescents with ASD could, like TD controls, correctly recall source information. This suggests that recollection, as measured by the retrieval of contextual information, is preserved in adolescents with ASD. However, recollection as measured by the subjective states associated with retrieval was shown to be impaired, at least in Experiment 1 in which the participants with ASD gave significantly fewer Remember responses than TD controls. These findings point to a specific and subtle recollection impairment in adolescents with ASD.

When asked to recall how (color of the pictures, gender of the speaker in Experiment 1), when (Experiment 2) or where (Experiment 3) to be remembered information was presented, adolescents with ASD could accurately recall all three types of source at an equivalent level to the TD controls. Furthermore, in the first experiment, the encoding manipulation (incidental vs intentional) had a similar effect in both groups. Consistent with previous findings (Brewer et al., 2010), intentional encoding of the source improved its recall. However, a limitation of this study is that in the paradigm used (Brewer et al., 2010) the same dimension (gender) was always encoded intentionally, whereas the other dimension (color) was always
encoded incidentally. Thus, results should be interpreted with caution and future experiments explore counterbalanced variants of this paradigm.

These findings of preserved memory for perceptual/temporal/spatial source information in individuals with ASD are somewhat surprising when we consider the brain abnormalities found in ASD. Indeed, whilst many studies have reported abnormalities in the hippocampus of individuals with ASD, at the same time it has become clear that the hippocampus plays a crucial role in the retrieval of source information (Davachi et al., 2003) and in the retrieval of both spatial and temporal information (Ekstrom et al., 2011). In autism, Gaigg and Bowler (2008) have suggested that impaired episodic memory and in particular diminished relational encoding may be due to abnormal functioning of the hippocampus, thus leading to diminished recollection. In other words, due to malfunctioning of the hippocampus, it would be expected that people with ASD would have difficulties binding items to contextual information. However, recent studies show that temporal and spatial aspects of memory, despite both being related to the action of the hippocampus are also supported by additional brain regions. In particular, the orbito-frontal cortex could contribute to encoding and retrieval of temporal information (Duarte et al., 2010; Ekstrom et al., 2011). Furthermore, the parahippocampal regions could be involved in spatial processing (Ekstrom et al., 2011) but also in a more general way in the encoding of contextual information (Eichenbaum et al., 2007). It is thus possible that adolescents with ASD rely on these additional brain regions to successfully encode and retrieve contextual information.

Our results demonstrate that adolescents with ASD can retrieve contextual information and these findings differ from those obtained using self versus other reality monitoring tasks in which impairments in ASD are sometimes reported (Hala et al., 2005; Lind and Bowler, 2009; Millward et al., 2000). Of particular interest is the study by Russell and Jarrold (1999) which showed that children with ASD were impaired at discriminating whether they or another person had placed a card on a grid. In fact, when the self-condition was disregarded, the children with ASD could like the TD children recognize items. Further studies should thus compare the impact of different judgment procedures in ASD.

It may be the case that source memory deficits in ASD are more subtle than has yet been explored. For example, source deficits may depend on the type of source information (contextual, social self) or also the encoding and retrieval conditions used. Bowler et al. (2010) demonstrated that, when presented with list of categorized words, adults with ASD showed less categorical clustering, suggesting difficulties in using the provided semantic context to support their learning. Importantly though, when retrieval conditions were altered (categories represented at retrieval) Bowler et al. (2008) showed that individuals with ASD were able to use the semantic context (Task Support Hypothesis, Bowler et al., 1997). Interestingly, in Experiment 1, we showed that adolescents with ASD like TD controls could use sensory/perceptual information to justify their Remember responses, suggesting an adequate use of contextual information to support recollective experience. This finding could be related to the fact that at retrieval, when asked to make recognition/Remember/source justification judgments, the participants were presented with the words again, in a similar way as in the encoding stage. Several studies have shown that matching the study and test context influences recognition performance (Macken, 2002, for example). Thus, we suggest here that our results are in agreement with the Task Support Hypothesis (Bowler et al., 1997) and suggest that adolescents with ASD are able to use contextual information to support their retrieval when the task allows it.

The most striking findings in this paper are that adolescents with ASD were able to retrieve contextual information in three source memory experiments, suggesting preserved recollection, at least as measured objectively by the source memory performance. However, in the first experiment, despite being able to correctly identify the gender of the speaker and the color of the pictures and use this information to justify their Remember responses, adolescents with ASD showed impaired recollection as they gave overall fewer Remember responses. These findings suggest a dissociation between objective and subjective measures of recollection in individuals with ASD.

It is however important to note that differences between groups on Remember responses were found only in the first experiment. We suggest here that this could be due to an overall low level of Remember responses across both groups in all three experiments and that as a result these findings need to be interpreted with caution. Several points are worth noting in reference to this concern. Low levels of Remember responses are a common finding in research on adolescents and children’s subjective experience of memory (Billingsley et al., 2002; Friedman et al., 2010; Ofen et al., 2007; Piolino et al., 2007). Furthermore, the low levels of Remember responses observed in our experiments could be due to the one-step RKN judgment procedure used in all three experiments. Indeed, according to Hicks and Marsh (1999), the one-step procedure is a more difficult task than the two-step procedure where an old—new recognition judgment is followed by a separate Remember—Know judgment for only recognized items. Further studies should thus compare the impact of different judgments procedures in ASD.

We suggest that a difference between groups was found in the first experiment because the levels of Remember responses in this experiment were slightly higher in the TD controls in comparison to the other two experiments. One of the main differences between Experiment 1 and Experiments 2 and 3 is that in Experiment 1 pictorial stimuli were used. It has long been known that memory for pictures is better than memory for words (Paivio, 1971). This so called ‘picture superiority effect’ is explained by the fact that pictures are represented in a more rich sensory—perceptual code than words. Previous results showed that people with ASD demonstrate a lower picture superiority effect on a free recall memory task compared to controls (Whitehouse et al., 2006). Of particular interest to our study, Dewhurst and Conway (1994) found a picture superiority effect in Remember...
responses (also see Rajaram, 1993). To explore the possibility that the picture superiority effect influenced responses in the current experiments, within-group t-tests were carried out to compare the proportion of R responses (Hits only) between the different tasks. For the TD controls, the analysis revealed that the proportion of R responses was higher in Experiment 1 (picture stimuli) than in Experiment 2 [temporal source memory, t(18) = 2.02, p < .05] and Experiment 3 [spatial source memory, t(18) = 3.31, p < .01]. However, for the adolescents with ASD, the proportion of R responses was not found to differ across experiments. Thus, rich contextual information presented at study, as it is the case for pictures, might have helped the TD controls to use elaborative processes to integrate item and context into a meaningful ensemble in Experiment 1, thus resulting in an increase in Remember responses. However, it appears that adolescents with ASD were not able to use pictures in this manner. This could suggest that recollective experiences in participants with ASD might not be sensitive to the fact that for pictures, information can be encoded in two modalities, visual and verbal.

The brain abnormalities found in autism could explain why individuals with autism do not efficiently use both visual and verbal modalities to encode information. Recent neuroimaging studies have shown that the brain regions associated with accurate recognition and also recollection were related to the type of stimuli presented. Accurate recognition of words activates left frontal and left temporal areas of the brain whilst accurate recognition of pictures activates posterior parts of the right hemisphere (Guerin and Miller, 2009; Simons et al., 2001). This hemispheric material specificity for recollection has also been observed in patients (Moscovitch and McAndrews, 2002) and neuroimaging studies (Galli and Otten, 2011). However, the retrieval of pictures has also been shown to produce bilateral activations in the prefrontal cortex and it has been suggested that this could be related to the fact that pictures can be encoded in more than one modality (Kelley et al., 1998). Interestingly, structural magnetic resonance imaging studies have consistently reported decreased volume in the corpus callosum in ASD, thus suggesting decreased interhemispheric connectivity in this population (Hardan et al., 2009; Stanfield et al., 2008). This decreased interhemispheric connectivity might prevent individuals with autism encoding pictures in an elaborative way to support rich contextual recollective experiences. However, there are two caveats to the lack of picture superiority effect interpretation. The first regards the VIQ by Group interaction approaching significance and the second concerns the lack of picture superiority effect on the recognition performance in the TD group.

The results of Experiment 1 showed a dissociation between objective measures (source memory) and subjective measures of recollection (Remember responses) in adolescents with ASD. This dissociation is in some ways similar to the one found by Bowler et al. (2000a). Using the Deese–Roediger–McDermott paradigm (DRM, Deese, 1959; Roediger and McDermott, 1995), Bowler et al. (2000a) showed that adults with Asperger’s Syndrome did not differ from controls in terms of false recognition of critical lures, suggesting adequate use of recollective processes to minimize memory errors in this population. However, this result was contrasted by overall low levels of Remember responses in the Asperger’s Syndrome group, thus suggesting a form of recollective deficit. Interestingly, as noted by the authors, the recollection impairment as shown by fewer R responses in the Asperger’s Syndrome group had no impact on their level of false-recall in the DRM paradigm.

So why would recollection be impaired in ASD when assessed by subjective states? We suggest here that this might be related to the fact that Remember judgments rely not only on sensory–perceptual contextual information but also on thoughts–feelings and information related to the self (Tulving, 1985; Conway, 2005). Indeed, unlike with any other procedures, the Remember–Know method asks participants for conscious self-evaluation of memory ‘feelings’. However, individuals with ASD have difficulties in re-experiencing the self in the past (see Lind, 2010, for a review). Findings from different paradigms support this hypothesis. For example, studies investigating autobiographical memory in autism reveal that children and adults with ASD have difficulties in recalling events and facts from their personal life (Bruck et al., 2007; Goddard et al., 2007; Crane and Goddard, 2008). However, as Conway (2005) stated, the integrity of autobiographical knowledge and the self is essential for normal functioning, as autobiographical memory is the knowledge base for the self (see also Addis and Tippett, 2004). Furthermore, many studies have now shown a reduced self-reference effect (SRE) in autism (Hare et al., 2007; Lombardo et al., 2007; Millward et al., 2000; Wojcik et al., 2011). In other words, unlike controls individuals with ASD are not better at retrieving information from memory when this information was encoded with reference to the self. Finally, some studies also show that individuals with ASD define their sense of self in a qualitatively different way. For example, using an interview method, Lee and Hobson (1998) showed that adults with ASD had difficulties viewing themselves as part of a wider social group. Similarly, Tanweer et al. (2009) using the Twenty Statements Task (TST, Kuhn and McPartland, 1954) demonstrated that adults with Asperger’s Syndrome gave more statements about themselves as isolated individuals. Of particular interest to the current study, Tanweer et al. (2009) found that the differences in the style of identity construction in Asperger’s were accompanied by a lack of recollection (fewer Remember responses) on an autobiographical memory task. Tanweer et al. (2009) therefore suggested that memory in autism was characterized by a lack of specificity or recall of rich specific details. We propose here that memory in autism, and in particular recollective experience, might be characterized by a lack of rich details related to the self. This interpretation would also fit with the resting state connectivity studies showing abnormalities of the default-mode network (DMN) in autism (Buckner et al., 2008; Kennedy et al., 2006). Indeed, several studies have now shown that the DMN plays a putative role in self-referential representations. For example, Buckner et al. (2008) suggest that autobiographical memory relies on this default network which involves several regions including: the ventral medial prefrontal cortex, the posterior cingulated/retrosplenial cortex, inferior parietal lobule, lateral temporal cortex, dorsal medial prefrontal cortex and hippocampal formation (Buckner et al., 2008). Interestingly, this default network also participates in theory of mind tasks, suggesting a strong involvement of this brain network in self-relevant material (see Buckner et al., 2008). Moreover, when
engaged in theory of mind tasks, several studies showed that a network of brain regions was consistently underactive in individuals with ASD. This network, called the social brain, involves brain regions very similar to the ones involved in the default network (Buckner et al., 2008). In particular, within this network abnormalities were found in the MPFC (Kennedy and Courchesne, 2008), a region also known to be involved in recollection (see Yonelinas, 2002).

To conclude, the results of these three experiments support the idea that as suggested by Powell and Jordan (1993), individuals with ASD experience events at an objective and perceptual level, but may be less in a subjective manner. However, the conclusions of this paper, especially with regards recollection as measured by subjective states, are tempered by the low levels of Remember responses and for this reason should be seen as preliminary, rather than definitive. What is clear is that different tasks appear to reveal different patterns of deficit and preservation in ASD, needing a more nuanced view of the relationship between contextual information of different modalities and recollection. This is an issue that might be of value in other neuropsychological groups with putative recollection deficits.

**References**


