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ORIGINAL PAPER

Patterns of Autobiographical Memory in Adults with Autism Spectrum Disorder

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Abstract Two studies are presented that explored the effects of experimental manipulations on the quality and accessibility of autobiographical memories in adults with autism spectrum disorder (ASD), relative to a typical comparison group matched for age, gender and IQ. Both studies found that the adults with ASD generated fewer specific memories than the comparison group, and took significantly longer to do so. Despite this, experimental manipulations affected two indices of autobiographical memory (specificity and retrieval latency) similarly in both groups. These results suggest that adults with ASD experience a quantitative reduction in the speed and specificity of autobiographical memory retrieval, but that when they do retrieve these memories, they do so in a way that is qualitatively similar to that of typical adults.

Keywords Autism · Autobiographical memory · Sensory · Imageability · Frequency

Although not included within the diagnostic criteria for autism spectrum disorder (ASD), memory difficulties have been commonly reported in this group (see Boucher and Bowler 2008, for reviews). In particular, atypicalities in autobiographical memory (recollections of personally experienced events and self-related information) have been noted since the earliest clinical accounts of the disorder. Kanner (1943), for example, documented how children with ASD failed to voluntarily recall events that happened during their day, with the parents of these children reporting how sharing experiences *"seemed foreign"* to them. In addition, Asperger (1944/1991) noted that when these children did recall events (usually in minute detail), they tended to forget information and provide details that were confusing.

Consistent with these early clinical observations, a growing body of research has reported autobiographical memory difficulties in individuals with ASD. Using the autobiographical memory cueing task (cf. Williams and Broadbent 1986), Goddard et al. (2007) found adults with ASD to generate fewer specific autobiographical memories (memories of single events, lasting no longer than a day, e.g., *'my first day at school'*) than typical adults (matched for age, gender and IQ) and to take significantly longer to do so. The autobiographical memory difficulties observed in ASD are robust and have been replicated using a variety of experimental paradigms and across a wide range of ages (e.g., Crane and Goddard 2008; Crane et al. 2009b, 2010, forthcoming; Lind and Bowler 2010; Millward et al. 2000; Tanweer et al. 2010). Despite this, there has been relatively little research exploring the mechanisms underlying autobiographical memory retrieval in this group.

Bowler et al. (2000) suggest that autobiographical memory difficulties in ASD are due to problems in effectively encoding material for long-term retention. Using a remember-know word recognition task (see Gardiner and Richardson-Klavehn 2000, for a review), they found that whilst overall recognition performance in adults with ASD

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was equivalent to that of typical adults (matched for age and IQ), the type of conscious awareness at encoding differed. Specifically, recognition in the typical adults was characterised by autonoetic awareness or 'remembering' (recalling contextual details associated with the original presentation of the word), whilst recognition in the ASD group was more dependent on noetic awareness or 'knowing' (the awareness of knowledge in the absence of contextual information regarding knowledge acquisition). As autonoetic awareness is central to autobiographical memory (Tulving 1985), these findings suggest that difficulties in this domain may underlie the autobiographical memory difficulties commonly reported in ASD.

By combining an autobiographical memory task with a standard remember-know paradigm, this assertion was subsequently confirmed by Tanweer et al. (2010), who found that the recall of personally experienced events was accompanied by a greater reliance on noetic, as opposed to autonoetic, awareness in adults with ASD. This suggests that the subjective experience of autobiographical remembering in adults with ASD may be qualitatively different to that of typical adults. However, Bowler et al. (2007) found that, despite a quantitative reduction in the *amount* of autonoetic awareness observed in adults with ASD, the *experience* of autonoetic remembering in this group was qualitatively similar to that of typical adults. In a series of studies exploring the effects of experimental manipulations known to differentially affect remember and/or know responses, Bowler et al. (2007) found that similar patterns and profiles of recognition performance were observed in both groups. This suggests that when adults with ASD are able to access knowledge of past episodes, they do so in a similar way to typical adults. However, the effects of experimental manipulations on the retrieval of autobiographical events have not been explored in adults with ASD.

The studies presented in this paper aimed to assess the effects of experimental manipulations on autobiographical memory retrieval in adults with ASD, compared to a typical comparison group matched for age, gender and IQ. This was achieved using variants of the autobiographical memory cueing task (cf. Williams and Broadbent 1986), in which participants were presented with a series of 'cues' and were instructed to retrieve a memory of a single episode (lasting no longer than a day) in response to each cue, at speed. Using a series of these tasks that have previously been shown to differentially affect the speed and specificity of retrieved autobiographical memories, the research presented in this paper aimed to (1) replicate previous reports of specific autobiographical memory difficulties in adults with ASD, and (2) further ascertain the nature of the retrieval process (i.e., whether key experimental manipulations affect autobiographical memory retrieval similarly in adults with ASD, relative to typical adults).

Study One: Manipulating the Imageability and Frequency of the Autobiographical Memory Cue

The aim of Study One was to explore the effects of manipulating the imageability and frequency of cue words on autobiographical memory retrieval in adults with and without ASD. The importance of imagery on autobiographical memory has been widely noted, as almost all personal memories are accompanied by visual imagery (Brewer 1986). Further support for this relationship stems from studies of congenitally blind adults (Goddard and Pring 2001) and patients with damage to the visual areas of the brain (O'Connor et al. 1992; Ogden 1993), who have been shown to display autobiographical memory impairments.

The role of imagery on autobiographical memory retrieval has also been explored by Williams et al. (1999). They assessed the speed and specificity of autobiographical memories retrieved using cue words that were high or low in terms of (a) imageability, and (b) frequency. Consistent with predictions, Williams et al. found that cue words high in imageability (but not frequency) facilitated the number of memories retrieved by participants, as well as the time taken to retrieve specific memories. A follow-up study manipulating the sensory modality of the memory cue revealed that only words high in visual (relative to olfactory, tactile, auditory, motor and abstract) imagery facilitated specific memory retrieval (Williams et al. 1999). Overall, this research suggests that imagery is crucial in autobiographical memory retrieval. Visual imagery, in particular, is thought to promote greater connections between general themes and specific events, leading to an increased likelihood of a specific memory being retrieved (Williams et al. 1999).

The research presented in Study One aimed to replicate Williams et al.'s (1999) studies on cue imageability and frequency in a group of adults with ASD and a typical comparison group. In line with a substantial body of previous research, it was predicted that the ASD group would generate fewer specific autobiographical memories than the typical adults and also take longer to do so. Regarding retrieval as a function of memory cue, it was hypothesised that cues high in imageability (but not frequency) would facilitate the speed and specificity of autobiographical memory retrieval in the comparison group (cf. Williams et al. 1999). Further, it was predicted that cues high in visual imagery (relative to other imagery modalities) would lead to the retrieval of a higher number of specific memories, which would also be retrieved faster (cf. Williams et al. 1999). Given the findings of Bowler et al. (2007), demonstrating that experimental manipulations affected remember and know responses similarly in adults with and without ASD, it was predicted that the effects of manipulating the

imagery and frequency of autobiographical memory cues would be observed in both the adults with ASD and the typical comparison group.

Method

Participants

Eighteen adults with ASD (12 males, 6 females; age range = 19–65) and 18 typical comparison participants (12 males, 6 females; age range = 19–65) took part in Study One. The ASD group was recruited from the National Autistic Society (UK), as well as local social groups and websites for adults with ASD. Prior to inclusion in the study, each experimental participant had received a formal diagnosis of ASD from a Psychologist or Psychiatrist experienced in the field of ASD. The majority of diagnoses were made following referrals through the National Health Service (NHS), although some participants self-referred for a private diagnosis at specialist clinics. Sixteen participants were diagnosed with Asperger syndrome and the remaining two had been diagnosed with high functioning autism. To confirm their diagnoses, a review of clinical records, using a checklist based on DSM-IV (American Psychiatric Association 2000) and ICD-10 (World Health Organisation 1990) criteria, was undertaken. This confirmed that all participants met the criteria for an ASD, excluding the requirement of unimpaired language development (for the adults with AS), as this information was often unavailable. Despite this, none of the participants displayed any obvious abnormalities in structural or semantic aspects of their language. In line with their diagnosis, the adults with ASD (mean = 34.39, SD = 5.26) scored significantly higher than the comparison group (mean = 13.67, SD = 2.76) on the Autism Spectrum Quotient (AQ) (Baron-Cohen et al. 2001) [$t(34) = 14.79$, $p < .001$ ($r = .93$)]. In addition, all but one of the participants with ASD (94.44%) scored above the suggested cut-off of 26 (Woodbury-Smith et al. 2005) on this measure, while none of the comparison group did. The participants with ASD were group matched with the comparison group on the basis of IQ (verbal, performance and full scale) on the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler 1999), and were individually matched for age and gender (see Table 1 for participant demographics).

Materials

Autobiographical Memory Cueing Task In the autobiographical memory cueing task (cf. Williams and Broadbent 1986), participants are presented with a series of cues and are asked to generate a specific autobiographical memory (a memory of a single event, lasting no longer than a day) in response to each cue, at speed. In this version of the task, participants were presented with a total of 32 cue words that varied in imageability (low or high) and frequency (low or high). As such, eight words were presented in each of the following four conditions: high imageability/high frequency (e.g., *letter*, *grass*, *sea*), high imageability/low frequency (e.g., *nun*, *bouquet*, *cradle*), low imageability/high frequency (e.g., *duty*, *opportunity*, *interest*), and low imageability/low frequency (e.g., *boredom*, *explanation*, *permission*). The cue words were developed by Williams et al. (1999) and were derived from an established corpus of nouns (Paivio et al. 1968) that were analysed for word frequency using Francis and Kucera's (1982) frequency ratings. See Williams et al. (1999) for a full list of cue words and information concerning the statistical properties of the words.

A separate condition followed, in which participants were presented with a total of 15 cue words that varied in their imagery modality. Five words were presented in each of the following three conditions: odour (e.g., *cheese*, *chlorine*, *coffee*), tactile (e.g., *ice*, *sponge*, *needle*), and auditory (e.g., *choir*, *laugh*, *snore*). Although a wider range of modalities was assessed by Williams et al. (1999), only three modalities were included in this study, to reduce the total testing time. A full list of cues and details concerning the development and statistical properties of the words are presented in Williams et al. (1999).

In both conditions, the cues were presented to participants individually. The order of presentation was invariant for each participant, although the imageability/frequency or modality of the cues was alternated in a fixed order (e.g., odour, tactile, auditory, etc.). These were displayed on A5

Table 1 Demographic data for the ASD and comparison groups (Study One)

	ASD		Comparison		Group differences		
Measures	Mean	SD	Mean	SD	*t*	*p*	*r*
Age	37.17	13.59	37.00	14.04	.04	.97	>.01
Verbal IQ	115.11	9.07	116.39	7.48	−.46	.65	.08
Performance IQ	110.00	17.40	114.72	8.01	−1.05	.30	.18
Full scale IQ	114.00	13.26	117.39	8.22	−.92	.36	.15

sized cards (with words presented in black ink, against a white background, in size 48 font), as well as being verbalised by the experimenter. Participants were instructed to recall a specific autobiographical memory, as quickly as possible, in response to each cue (within a 30 s time limit). First responses to cues were analysed for memory specificity. If participants failed to retrieve a specific memory in response to the cue, they were prompted to retrieve a specific event (*'Can you think of a particular time? One specific instance?'*). Prompting continued until the participant retrieved a specific memory or until the time limit (30 s) elapsed. Memories were either coded as specific (meeting the criteria of a single event lasting no longer than a day) or not. Inter-rater reliability for this coding system (across all manipulations) was assessed for all retrieved memories, with one rater blind to group membership, as well as the experimental hypotheses concerning cue type (imageability/frequency). Cohen's k revealed this to be excellent ($k = .90$). Cumulative latencies to specific memory retrieval were also recorded. The clock was started when the experimenter presented the cue word and stopped when the participant began to speak. If the response was not a specific memory, the participant was prompted by the experimenter and the clock continued. If a participant failed to generate a specific memory within the time limit, a maximum latency of 30 s was recorded.

Practice cues were administered and all participants were required to generate at least two specific autobiographical memories on these practice trials before the experimental session began. Participants were also asked to repeat the instructions of the task to the experimenter at the end of the session, to confirm that they remembered the instructions throughout the experiment (cf. Dalgleish et al. 2007). All participants were able to do this.

Procedure

Participants were tested individually, in a quiet room, either at Goldsmiths, University of London, or in their own homes. Participants completed the WASI first, followed by the AQ and then the cueing tasks. The imageability/frequency condition preceded the sensory modality condition for all participants.

Results

Condition: Imageability and Frequency

Memory Specificity To analyse the number of specific memories retrieved to cue words, a 2 (group: ASD or comparison) × 2 (imageability: high or low) × 2 (frequency: high or low) mixed-design analysis of variance (ANOVA) was conducted (see Table 2 and Fig. 1). This revealed a marginal group difference, with the ASD group generating fewer specific memories than the comparison group, although this fell short of statistical significance [$F(1, 34) = 2.98$, $p = .09$ ($\eta_p^2 = .08$)]. Cue words high in imageability led to the retrieval of a higher number of specific memories than cue words low in imageability [$F(1, 34) = 45.61$, $p < .001$ ($\eta_p^2 = .57$)]. However, there was no significant effect of cue frequency on memory retrieval [$F(1, 34) = 1.27$, $p = .27$ ($\eta_p^2 = .04$)], nor were there any significant interaction effects ($ps > .23$).

Latencies to Memory Retrieval A 2 (group: ASD or comparison) × 2 (imageability: high or low) × 2 (frequency: high or low) mixed-design ANOVA revealed that the ASD group took significantly longer than the comparison group to retrieve specific memories, overall [$F(1, 34) = 13.61$, $p = .001$ ($\eta_p^2 = .29$)]. In line with the results of the specificity analysis, cue words high in imageability led to participants retrieving specific memories significantly faster than cue words low in imageability [$F(1, 34) = 74.15$, $p < .001$ ($\eta_p^2 = .69$)]. There was no significant effect of word frequency on memory retrieval [$F(1, 34) = 3.79$, $p = .06$ ($\eta_p^2 = .10$)], nor were there any significant interaction effects ($ps > .10$).

Table 2 Mean number of specific autobiographical memories retrieved and mean latencies to specific memory retrieval as a function of cue imageability (*HI* high imagery, *LI* low imagery) and frequency (*HF* high frequency, *LF* low frequency) in the ASD and comparison groups (Study One)

		ASD		Comparison	
		Mean	SD	Mean	SD
Mean number of specific memories retrieved (max = 8)	HI/HF	5.39	1.42	6.78	1.44
	HI/LF	5.56	1.69	7.06	1.11
	LI/HF	4.33	2.11	3.56	1.92
	LI/LF	4.61	2.09	4.50	1.62
Mean latency to memory retrieval (max = 30 s)	HI/HF	11.37	7.74	6.19	2.18
	HI/LF	13.60	7.30	7.12	2.09
	LI/HF	18.58	9.92	12.69	4.58
	LI/LF	22.58	11.46	12.18	4.92

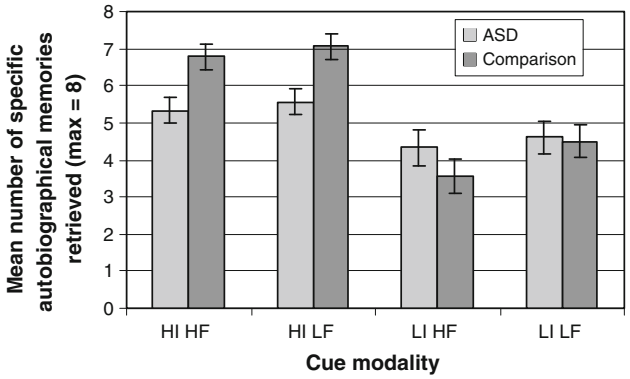

Fig. 1 Mean number of specific autobiographical memories retrieved as a function of cue imageability (*HI* high imagery, *LI* low imagery) and frequency (*HF* high frequency, *LF* low frequency) in the ASD and comparison groups (Study One)

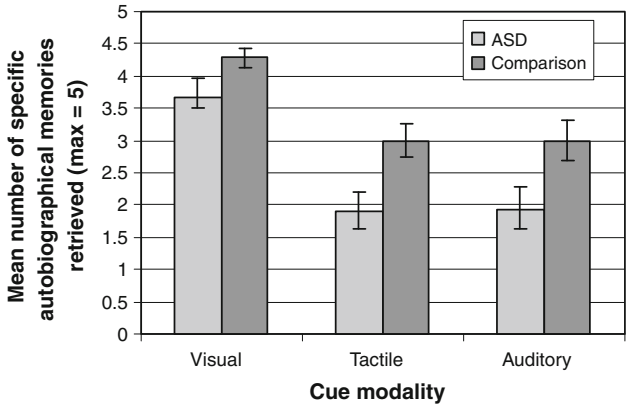

Fig. 2 Mean number of specific autobiographical memories retrieved as a function of cue imagery modality (visual, tactile or auditory) in the ASD and comparison groups (Study One)

Condition: Visual, Tactile and Auditory

Memory Specificity Analysis of the number of specific memories retrieved as a function of sensory modality was conducted using a 2 (group: ASD or comparison) × 3 (imagery modality: visual, tactile or auditory) mixed-design ANOVA (see Table 3 and Fig. 2). This revealed that the ASD group generated fewer specific memories than the comparison group, overall [$F(1, 34) = 8.87$, $p = .005$ ($\eta_p^2 = .21$)]. In addition, the modality of the memory cue had a significant effect on memory retrieval [$F(2, 68) = 31.37$, $p < .001$ (η_p^2 .48)], as participants generated a higher number of specific memories to cues that were high in visual imagery relative to cues that were high in tactile [$t(35) = 7.06$, $p < .001$ ($r = .77$)] or auditory imagery [$t(35) = 6.82$, $p < .001$ ($r = .76$)]. There was no significant difference between the number of specific memories generated to cues high in tactile and auditory imagery [$t(35) = -.12$, $p = .90$ ($r = .02$)]. A non-significant interaction suggested this effect was consistent across groups [$F(2, 68) = .47$, $p = .47$ ($\eta_p^2 = .02$)].

Latencies to Memory Retrieval Analysis of the mean latencies to specific memory retrieval revealed that the ASD group took significantly longer to retrieve specific memories than the comparison group, overall [$F(1, 34) = 14.96$, $p < .001$ ($\eta_p^2 = .31$)]. In addition, and corresponding to the results of the specificity analysis, participants were faster at retrieving specific memories to cue words that were high in visual imagery, relative to cue words high in tactile [$t(35) = -2.53$, $p = .02$ ($r = .39$)] or auditory [$t(35) = -2.47$, $p = .02$ ($r = .39$)] imagery [$F(2, 68) = 4.05$, $p = .02$ ($\eta_p^2 = .16$)]. There was no significant difference in latencies to memory retrieval for words high in tactile or auditory imagery [$t(35) = .48$, $p = .63$ ($r = .08$)]. A non-significant interaction effect suggested this pattern was consistent across both groups [$F(2, 68) = .09$, $p = .91$ ($\eta_p^2 = .003$)].

Discussion

Consistent with the findings of Williams et al. (1999), Study One demonstrated that cue words high in imageability (but not frequency) facilitated the retrieval of specific autobiographical memories; not only were a higher number of specific memories retrieved, they were also accessed faster. Cue words high in visual imagery also facilitated the speed and specificity of memory retrieval (relative to cue words high in tactile or auditory imagery). These effects were observed in both the adults with ASD

Table 3 Mean number of specific autobiographical memories retrieved and mean latencies to specific memory retrieval as a function of cue imagery modality (visual, tactile or auditory) in the ASD and comparison groups (Study One)

		ASD		Comparison	
		Mean	SD	Mean	SD
Mean number of specific memories retrieved (max = 5)	Visual	3.67	1.24	4.28	.67
	Tactile	1.89	1.32	3.00	1.08
	Auditory	1.94	1.39	3.00	1.37
Mean latency to memory retrieval (max = 30 s)	Visual	15.50	10.62	6.01	3.44
	Tactile	19.26	11.24	9.68	4.55
	Auditory	18.04	12.60	9.54	3.56

and the typical comparison group. Taken together, it appears that adults with ASD retrieve fewer specific memories than typical adults and take significantly longer to do so, but the underlying patterns of memory retrieval in the two groups appear to be similar.

A noteworthy finding from the current study regards how visual imagery facilitated autobiographical memory retrieval in both groups. This is surprising given that poor visual memory has been associated with difficulties retrieving specific autobiographical memories in ASD (Goddard et al. 2007). As autobiographical memories are primarily stored in a visual mode (Brewer 1986), deficits in encoding, storing and retrieving memories visually may contribute to the autobiographical memory difficulties observed in ASD. However, it should be noted that the effect sizes for the differences between the specificity and latency scores to high imageability/low frequency and low imageability/high frequency cues were large in the comparison group, but barely moderate in the ASD group; independent of cue frequency, when cues were high in imageability, comparison participants clearly performed better than participants with ASD. This study is underpowered to detect such interaction effects, but it may not necessarily be the case that adults with ASD fail to store their memories visually; they may just use the visual modality less effectively than typical adults. Successful memory retrieval is associated with the ability to recall events from a first-person field perspective, which necessitates autonoetic awareness (Crawley and French 2005). As autonoetic awareness is reduced in ASD (Bowler et al. 2000, 2007), it is possible that this group retrieve their memories from a third-person observer perspective, which does not reinstate the context of the memory as effectively (relying on noetic, rather than autonoetic, awareness). Consistent with this suggestion, Lind and Bowler (2010) found that adults with ASD were less likely than typical adults to report retrieving their memories from a first-person field perspective, and were more likely to adopt a third-person observer perspective. Further research could extend this work by manipulating the perspective that autobiographical memories are retrieved from in ASD (encouraging a first-person viewpoint) to ascertain whether this could improve memory recall. This could shed further light on the nature of the interaction between autobiographical memory and visual memory in this ASD, and highlights a potential difference between the patterns of memory in the ASD and comparison groups that warrants further exploration.

It is also important to note that the current study used words as cues to past experiences, whereas in everyday life memories are cued via a range of sensory stimuli. To enhance the ecological validity of this investigation and to assess the robustness of the results obtained in Study One, Study Two employed an alternative experimental manipulation known to affect autobiographical memory retrieval. Specifically, a range of sensory stimuli (including odours, sounds and words) was used to cue personal experiences in adults with and without ASD. This was to determine the effects of different sensory modality cues on the accessibility of specific autobiographical memories in ASD.

Study Two: Manipulating the Sensory Modality of Autobiographical Memory Cues

Odours have often been regarded as especially potent cues to past experiences, enabling the recall of extremely vivid and emotional memories, often from the very distant past (Proust 1957). Goddard et al. (2005) evaluated the efficacy of odours (relative to images or words) as autobiographical memory retrieval cues and found that memories cued using odour stimuli tended to be older and more emotional, but also more general in nature (referring to repeated events, e.g., *'when I was at school'*). Odour-cued memories also took significantly longer to be retrieved. Likewise, Herz (2004) presented three memory cues (popcorn, campfire, and fresh-cut grass) in either odour, image or auditory form and found that only odour cues generated more emotional and evocative memories. This supports previous research suggesting that there may be a special relationship between autobiographical memory and olfaction.

The aim of Study Two was to replicate and extend these studies to a sample of adults with and without ASD, to determine whether similar patterns of memory (as a function of cue type) were observed in both groups. In this study, odour and auditory stimuli were compared against image and word stimuli as cues to specific autobiographical memory retrieval. In line with the results of Study One, it was predicted that adults with ASD would generate fewer specific memories than comparison participants (matched for age, gender and IQ), and would take significantly longer to do so. It was further predicted that odour cues would generate qualitatively different memories to those retrieved through other sensory modalities (specifically, that a higher number of general memories would be retrieved to odour cues and that they would be slower to be retrieved). Given the results of Study One, it was predicted that patterns of memory retrieval as a function of cue modality would be similar in both the ASD and comparison groups.

Method

Participants

In total, 36 adults participated in this study: 18 adults with ASD (10 males, 8 females; range = 18–65) and 18 typical

comparison participants (10 males, 8 females; range = 19–64). These participants were recruited through similar sources to Study One and met similar diagnostic criteria (four participants with ASD took part in both Study One and Two). The adults with ASD (mean = 35.28, SD = 5.78) scored significantly higher than the comparison group (mean = 12.53, SD = 3.50) on the AQ (Baron-Cohen et al. 2001) [$t(34) = 13.32, p < .01$ ($r = .92$)]. In addition, all but one of the participants with ASD (94.44%) scored above the suggested cut-off of 26 on this measure (Woodbury-Smith et al. 2005), while none of the comparison group did. The comparison group was group-matched with the ASD group for IQ (verbal, performance and full scale) on the WASI (Wechsler 1999), and individually-matched for age and gender (see Table 4 for participant demographics).

Materials

Autobiographical Memory Cueing Task As in Study One, participants were presented with a series of memory cues to which they were required to generate a specific autobiographical memory, at speed. Two versions of the task were administered—an odour, image and word cue condition, and an auditory, image and word cue condition. In the odour, image and word condition, participants were presented with 21 cues; seven in odour form, seven in image form and seven in word form (see "Appendix"). Three stimulus sets were devised so that the modality of the cue alternated between participants (e.g., one participant received the cue *cigarette* as an odour, another as an image and another as a word), although the order of the cues was invariant for each participant. The cue items were taken from previous studies on odour-cued autobiographical memory (Chu and Downes 2000; Goddard et al. 2005), and a range of stimuli was included, selected on the basis that they would be familiar to most people. Odour stimuli were presented in covered glass jars (to ensure that participants could not use visual aids to memory). The word and image cues were presented on A5 sized cards, with the images presented as photographs (in colour), and the words in black ink, against a white background, in size 48 font.

The procedure of the auditory, image and word condition was identical to that of the odour, image and word condition, but with different cues (see "Appendix"). Although, ideally, the same cues would be used in the odour and auditory conditions (to enable a direct comparison between the two stimulus modalities), it was not possible to find a range of identifiable stimuli that could be presented in both olfactory and auditory form. Due to the lack of previous research assessing auditory cues to autobiographical memories, the stimuli used in the current study were novel, but were designed to be familiar to a range of people. Auditory stimuli were presented to participants via a CD player, with each clip lasting 3 s. Each stimulus clip was repeated continuously until the participant chose to pause the clip (via a push button), or until the participant reported a specific memory. However, participants were encouraged to report memories irrespective of whether or not the sound clip had finished. In both conditions, cues were presented individually, in a fixed order, with the modality of the cue alternating (e.g., odour, image, word, etc.)

At the end of the testing session, participants were presented with each of the auditory and odour cues and were asked to identify them. Participants were able to recognise all of the cues, although identification was often idiosyncratic (e.g., the sound clip *car* was often reported as *motorbike*). In both conditions, practice cues were administered prior to the presentation of the experimental cues, and all participants were required to generate at least two specific autobiographical memories on these practice trials before the experimental session began. Participants were also asked to repeat the instructions of the task to the experimenter at the end of the session, to confirm that participants remembered the instructions throughout the study (cf. Dalgleish et al. 2007), which all participants were able to do.

As in Study One, memories were coded as specific or not. However, given that Goddard et al. (2005) found odour cues to result in a higher proportion of general (categoric) memories only, error responses were further coded into one of three categories: memory failures (in which no memory was retrieved), general categoric memories (memories of

Table 4 Demographic data for the ASD and comparison groups (Study Two)

	ASD		Comparison		Group differences		
Measures	Mean	SD	Mean	SD	*t*	*p*	*r*
Age	41.78	15.27	39.50	13.27	.48	.63	.08
Verbal IQ	116.22	11.09	111.78	11.19	1.20	.24	.20
Performance IQ	115.83	11.77	114.83	11.02	.26	.79	.04
Full scale IQ	118.17	10.74	114.89	11.75	.87	.39	.15

repeated instances, e.g., *'going to school'*), or general extended memories (memories of single events lasting longer than a day, e.g., *'my first week at school'*). Inter-rater reliability for this coding system was assessed for all retrieved memories, with one-rater blind to group membership, as well as the experimental hypotheses concerning cue modality. Cohen's k revealed this to be excellent (odour, image and word condition, $k = .81$; auditory, image and word condition, $k = .90$). Mean latencies to memory retrieval (max = 30 s) were also calculated, in line with the procedures used in Study One.

Procedure

Participants were tested individually, in a quiet room, either at Goldsmiths, University of London, or in their own homes. Participants completed the WASI first, followed by the AQ and a questionnaire unrelated to the current study (see Crane et al. 2009a). The autobiographical memory cueing task followed, with the odour, image and word condition preceding the auditory, image and word condition.

Results

Condition: Odour, Image and Word

Memory Specificity In the odour, image and word condition, initial responses to cue words were first analysed for specificity using a 2 (group: ASD or comparison) × 3 (cue modality: odour, image or word) mixed-design ANOVA (see Table 5 and Fig. 3). This revealed that the ASD group generated fewer specific memories than the comparison group, across all cue modalities [$F(1, 34) = 15.03$, $p < .01$ ($\eta_p^2 = .31$)]. There was also a significant main effect of cue modality, as fewer specific memories were retrieved to odour cues relative to image and word cues [$F(2, 68) = 43.67$, $p < .01$ ($\eta_p^2 = .56$)]. These main effects were qualified by a small, but significant, interaction effect [$F(2, 68) = 3.75$, $p < .05$ ($\eta_p^2 = .10$)]. This was due to the ASD group retrieving fewer specific memories than the comparison group in response to the odour [$t(34) = -3.65$, $p < .001$ ($r = .17$)] and word [$t(34) = -3.75$, $p < .001$ ($r = .18$)] cues, whilst this effect was not as pronounced for the image cues [$t(34) = -2.73$, $p = .01$ ($r = .15$)].

When participants failed to retrieve a specific memory in response to a cue, the response could either be a general memory (categoric or extended), or the participant could fail to respond. The adults with ASD (mean = 1.46, SD = 1.17) retrieved a significantly higher number of categoric memories than the comparison group (mean = .52, SD = .66) overall [$F(1, 34) = 8.94$, $p < .01$ ($\eta_p^2 = .21$)]. In addition, there was also a significant main effect of cue modality [$F(2, 68) = 4.52$, $p < .05$ ($\eta_p^2 = .12$)], as odour cues (mean = 1.33, SD = 1.49) resulted in the retrieval of a higher number of categoric memories than both image (mean = .89, SD = 1.14) [$t(35) = 2.26$, $p = .01$ ($r = .36$)], or word (mean = .75, SD = 1.10) cues [$t(35) = 2.61$, $p < .005$ ($r = .40$)], whilst there was no significant difference between the numbers of categoric memories retrieved to image and word cues [$t(35) = .78$, $p = .44$ ($r = .13$)]. A non-significant interaction [$F(2, 68) = .26$, $p = .77$ ($\eta_p^2 < .01$)] suggested that this effect was consistent across groups.

As the total number of extended memories and memory failures retrieved by participants was very small, these were not analysed as a function of cue modality. Independent samples t-tests revealed there to be no significant difference between the overall number of extended memories retrieved by the ASD (mean = .07, SD = .14) or

Table 5 Mean number of specific autobiographical memories retrieved and mean latencies to specific memory retrieval by the ASD and comparison groups in the odour, image and word condition and the auditory, image and word condition (Study Two)

		ASD		Comparison	
		Mean	SD	Mean	SD
Mean number of specific memories retrieved (max = 7)	Odour	2.94	2.04	5.17	1.58
	Image	5.06	1.39	6.22	1.16
	Word	5.33	1.14	6.56	.78
Mean latency to memory retrieval (max = 30 s)	Odour	22.04	5.52	18.27	6.50
	Image	12.86	4.98	8.54	4.35
	Word	11.05	3.99	7.30	2.80
Mean number of specific memories retrieved (max = 7)	Auditory	4.72	2.35	6.00	1.71
	Image	4.89	1.91	6.61	.78
	Word	5.67	1.33	6.61	.70
Mean latency to memory retrieval (max = 30 s)	Auditory	17.14	6.90	12.48	5.63
	Image	13.16	6.03	7.42	3.10
	Word	11.24	4.57	8.12	3.75

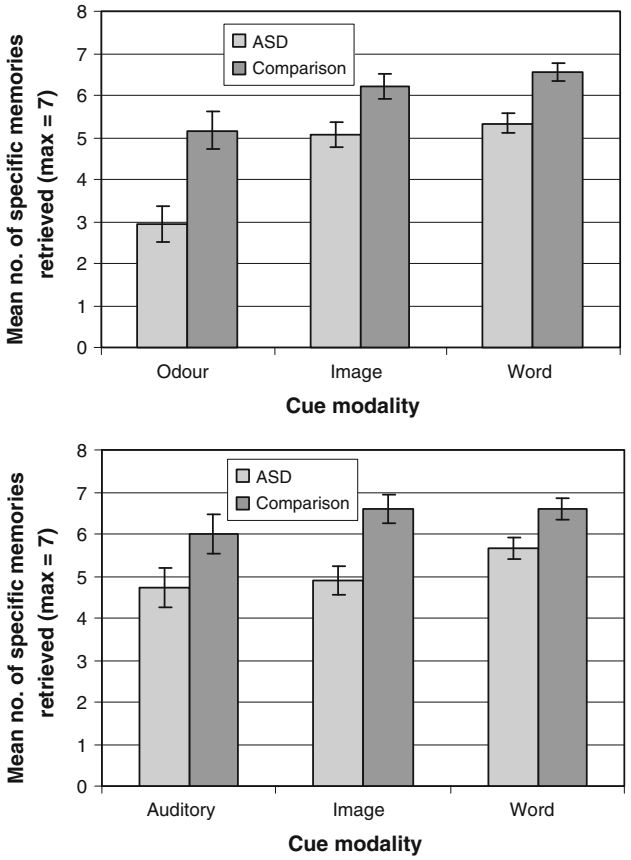

Fig. 3 Mean number of specific autobiographical memories retrieved by the ASD and comparison groups in the odour, image and word condition and the auditory, image and word condition (Study Two)

comparison (mean = .04, SD = .11) groups, and the ASD group (mean = 1.02, SD = .81) also failed to retrieve a specific memory significantly more often than the comparison group (mean = .46, SD = .73) [$t(34) = 2.15$, $p = .04$ ($r = .34$)].

Latencies to Memory Retrieval As well as examining the type of memories retrieved to cues, mean latencies to memory retrieval were analysed. For the odour, image and word condition, the ASD group took significantly longer to retrieve memories than the comparison group overall [$F(1, 34) = 9.00$, $p < .01$ ($\eta_p^2 = .21$)]. There was also a significant main effect of cue modality [$F(2, 68) = 108.57$, $p < .01$ ($\eta_p^2 = .76$)], as participants took longer to retrieve memories to odour cues than image [$t(35) = 10.33$, $p < .001$ ($r = .87$)] or word [$t(35) = 13.61$, $p < .001$ ($r = .92$)] cues. However, this effect was not as pronounced between image and word cues [$t(35) = 2.36$, $p = .02$ ($r = .37$)]. A non-significant interaction effect [$F(2, 68) = .08$, $p = .92$ ($\eta_p^2 < .01$)] suggested that this effect was consistent across groups.

Condition: Auditory, Image and Word

Memory Specificity Regarding specificity ratings for the auditory, image and word condition (see Table 5 and Fig. 3), a 2 (group: ASD or comparison) × 3 (cue modality: auditory, image or word) mixed-design ANOVA revealed the ASD group to generate significantly fewer specific memories than the comparison group, overall [$F(1, 34) = 11.45$, $p < .01$ ($\eta_p^2 = .25$)]. However, no significant main effect of cue modality was observed [$F(1.37, 46.59) = 3.22$, $p = .07$ ($\eta_p^2 = .09$)], nor was there a significant interaction effect [$F(1.37, 46.59) = .81$, $p = .41$ ($\eta_p^2 = .02$)].

The comparison group (mean = .52, SD = .66) generated fewer categoric memories than the ASD group (mean = 1.46, SD = 1.17) overall [$F(1, 34) = 8.34$, $p < .01$ ($\eta_p^2 = .20$)] but there was no difference between responses as a function of cue modality [$F(2, 68) = 2.48$, $p = .12$ ($\eta_p^2 = .07$)], nor was there a significant interaction effect [$F(2, 68) = .20$, $p = .66$ ($\eta_p^2 < .01$)]. There were no differences between groups regarding the number of extended memories retrieved [$t(34) = .88$, $p = .39$ ($r = .15$)], but the ASD group (mean = .78, SD = .80) failed to retrieve memories significantly more often than the comparison group (mean = .28, SD = .56) [$t(34) = 2.17$, $p = .04$ ($r = .35$)].

Latencies to Memory Retrieval The adults with ASD took significantly longer to retrieve specific memories than the comparison group [$F(1, 34) = 10.16$, $p < .01$ ($\eta_p^2 = .23$)]. There was also a significant main effect of cue modality [$F(1.48, 50.47) = 21.53$, $p < .01$ ($\eta_p^2 = .39$)], as participants took significantly longer to retrieve memories to auditory cues than image [$t(35) = 4.24$, $p < .001$ ($r = .58$)] or word [$t(35) = 5.78$, $p < .001$ ($r = .70$)] cues, but there was no significant difference between memories cued using images and words [$t(35) = 1.00$, $p = .32$ ($r = .17$)]. There was also no significant interaction effect [$F(1.48, 50.47) = 1.19$, $p = .31$ ($\eta_p^2 = .03$)], which suggested that the main effect of cue modality was consistent across both groups.

Discussion

To summarise, Study Two investigated the speed and specificity of autobiographical memory retrieval in adults with and without ASD when cueing memories using different sensory stimuli. In line with previous research, autobiographical memory difficulties in adults with ASD were noted; not only did this group generate fewer specific memories than the comparison adults, they took significantly longer to do so. The ASD and comparison groups did, however, display similar patterns of memory as a

function of cue modality, with odour cues leading to the retrieval of a higher number of general (categoric) memories, which took longer to access, than memories cued using images or words. This suggests that, despite quantitative deficits in the speed and specificity of autobiographical memory retrieval in adults with ASD, the patterns of memories in this group appear to be qualitatively similar to that of typical adults.

The results of Study Two are also consistent with previous research on sensory-cued autobiographical memories, which have found odours to generate qualitatively different memories to those cued through other sensory modalities. Although the data are not fully presented in this paper (for purposes of clarity, not all comparisons are reported here. See Crane 2010, for full details), this study also found odours to result in the retrieval of memories from the more distant past, and sounds to elicit memories rated as more emotional, in both groups. However, these findings do contrast with those of Goddard et al. (2005), who found odour-cued memories to be rated as more emotional than word- or image-cued memories, whereas the present study found auditory-cued memories to be rated as more emotional (than word- or image-cued memories) by both the ASD and comparison groups. This contrasting result may be due to differences in the stimulus lists used, with the auditory stimuli in the current study (e.g., *fireworks*, *thunder*) being more emotive than the odour stimuli (e.g., *wine*, *onion*). Importantly, this result was observed in both the adults with and without ASD, suggesting that this explanation is not simply a function of the memory atypicalities noted in ASD.

General Discussion

The two studies presented in this paper found that adults with ASD experience difficulties in retrieving specific autobiographical memories; generating fewer memories than typical adults and taking significantly longer to do so. Despite this, experimental manipulations were shown to affect autobiographical memory similarly in both groups. Study One revealed that cue words high in imageability (but not frequency) facilitated the specificity of autobiographical memory retrieval in both adults with and without ASD. This effect appeared to be largely driven by cue words high in visual (opposed to auditory or tactile) imagery facilitating memory retrieval. Following up these results, Study Two demonstrated that both adults with and without ASD retrieved fewer specific memories in response to odour cues (relative to image or word cues) and took longer to do so, but no differences in specificity were observed between memories cued using auditory, image or word cues. Comparable results (across both studies) were observed when analysing latencies to memory retrieval, illustrating the robustness of the results (with the same patterns of memory being observed on two indices of autobiographical memory—specificity and latency).

The findings from these studies are consistent with a growing body of research demonstrating that adults with ASD experience difficulties in accessing memories of specific autobiographical events (Crane and Goddard 2008; Crane et al. 2009b, 2010, forthcoming; Goddard et al. 2007; Lind and Bowler 2010; Tanweer et al. 2010). These studies also extend our knowledge by demonstrating that (despite experiencing a quantitative reduction in the speed and specificity of memory retrieval) adults with ASD display similar underlying patterns of recall to typical adults (as evidenced by the similar effects of experimental manipulations on autobiographical memory retrieval). This finding is in line with the work of Bowler et al. (2007), who reported that, despite adults with ASD relying on autonoetic awareness to a lesser extent than typical adults, experimental manipulations affected remember and know responses similarly in both groups.

These results and conclusions do, however, appear to contrast with recent research exploring the mechanisms associated with autobiographical memory retrieval in adults with ASD. Crane et al. (forthcoming), for example, reported that levels of rumination (an excessive focus on negative emotions) and depressed mood were negatively related to specific autobiographical memory retrieval in typical adults, whereas no significant relationship between these variables was observed in adults with ASD. Additionally, Crane et al. (2009b) found that adults with ASD (in contrast to typical adults) failed to use information concerning their personal goals to structure and organise their personal memories; a pattern that was related to their difficulties in accessing memories of specific autobiographical events. One suggestion as to how these ostensibly contradictory results can be reconciled is that when memory retrieval is successful (i.e., when an event has been encoded and subsequently accessed), adults with ASD utilise the same underlying mechanisms as typical adults, whilst the converse is true when retrieval is unsuccessful (i.e., when an event has been encoded but cannot be accessed, or when an event was not encoded in a way that enabled long-term memory storage). It is also possible that adults with ASD preferentially draw on different strategies from typical adults overall, although they do occasionally use the same strategies (as found by Bowler et al. 2007, in their studies of episodic memory in ASD). Further exploration of the memory strategies used by adults with ASD, perhaps on a cue-by-cue basis, is warranted to shed further light on this issue.

It is also important to note that other studies have failed to find similar patterns of autobiographical memory in adults with ASD and typical adults as a function of cue

type. Goddard et al. (2007), for example, found that emotionally valenced cue words facilitated memory retrieval in typical adults, whereas a corresponding relationship was not observed in adults with ASD. Likewise, Crane et al. (2009b, 2010) found evidence for a self-referential memory bias in typical adults (with cues relating to the self facilitating the speed and specificity of memory retrieval, relative to cues that were not connected to the self); a pattern that was notably absent in adults with ASD. It is therefore possible that similar mechanisms to memory retrieval are adopted by the groups when recalling memories to everyday, neutral cues (as in the current study), but that more significant cues (e.g., those relating to emotions or the self) are processed differently in ASD.

An important question not addressed in the current research is *why* adults with ASD experience difficulties in accessing specific autobiographical memories. The finding that experimental manipulations (e.g., varying the imageability/modality of the memory cue) affected autobiographical memory similarly in groups with and without ASD suggests that adults with ASD may attempt to use the same strategies to memory retrieval as typical adults, but that the memories of this group are organised less effectively (and therefore they retrieve fewer specific memories and take longer to do so). Consistent with this suggestion, Crane et al. (2010) reported that adults with ASD do not frame their personal memories within a wider context of higher-level cognitions, as typical adults do. Whilst their sample of typical adults was able to report individual events and link them to other related events or themes (e.g., *'Reflecting on this experience, I learned to value my friends and family to a greater extent'*), adults with ASD appeared to store their memories as isolated events. This suggests that it is the way in which these memories are organised (i.e., not within a broader framework of past experiences) that is a key issue in ASD.

The idea that adults with ASD do not organise their memories as effectively as typical adults is not a new one. However, these difficulties may operate at a lower level than previously discussed. Bowler and colleagues (Bowler and Gaigg 2008; Bowler et al. 2011) have suggested that the memory problems faced by adults with ASD are due to difficulties in drawing together disparate elements of an event to form a coherent representation. This is particularly relevant to the study of autobiographical memory—adults with ASD may not only experience difficulties in binding together related autobiographical memories to form a higher-order category of memories linked by a theme or emotion (as noted by Crane et al. 2010), but they may also find it difficult to integrate the various elements of a specific autobiographical event (i.e., the who, what, where and when) to form an individual memory in the first place.

To summarise, this research found that adults with ASD (relative to typical adults) experienced a quantitative reduction in the speed and specificity of autobiographical memory retrieval, but similar patterns of memory as a function of cue type were observed in both groups. The specific memory difficulties experienced by adults with ASD are of considerable significance developmentally; this group may struggle to think of specific memories to share in social conversations (which need to be accessed and relayed quickly, before the conversation moves onto another topic), and may hinder the formation of social relationships (as the sharing of experiences is crucial in the development of social bonds, cf. Fivush et al. 1996). These difficulties may reinforce the negative and awkward social interactions experienced by this group and may make the individuals less likely to seek such interactions in the future. Further difficulties could be encountered when solving social problems, as specific memories are used to provide a database of exemplars to problems (Williams 1996). Difficulties in recalling and using memories in this way may lead to existing problems being unresolved and may contribute to emotional difficulties (e.g., depression, anxiety) that are commonly noted in this group (e.g., Hill et al. 2004).

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Appendix

See Table 6 below.

Table 6 Memory cues in the odour, image and word and the auditory, image and word conditions (Study Two)

Odour, image and word condition			Auditory, image and word condition		
Word	Odour	Image	Word	Sound clip	Image
Cigarette	Cigarette ash	Cigarette	Police	Police siren	Police car
Perfume	Perfume	Perfume bottle	Dog	Dog barking	Dog
Mint	Polo mints	Polo mints	Money	Coin dropping	Coins
Paint	Paint	Paint tin	Clock	Clock ticking	Clock

Table 6 continued

Odour, image and word condition			Auditory, image and word condition		
Word	Odour	Image	Word	Sound clip	Image
Cheese	Cheese powder	Cheese	Telephone	Telephone ring	Telephone
Talcum powder	Talcum powder	Johnson's talcum powder	Thunder	Thunder	Lightning
Curry	Curry powder	Curry meal	Cat	Cat purring	Cat
Alcohol	Whiskey	Whiskey bottle	Scissors	Scissors cutting	Scissors
Bleach	Bleach	Bottle of bleach	Car	Car engine	Car
Chocolate	Chocolate	Chocolate bar	Bell	Bell	Bell
Soap	Soap	Bar of soap	Aeroplane	Aeroplane take-off	Aeroplane
Vinegar	Vinegar	Vinegar bottle	Bird	Bird singing	Bird
Coconut	Desiccated coconut	Coconut	Drill	Drill	Drill
Sun tan lotion	Sun tan lotion	Sun tan lotion bottle	Vacuum cleaner	Vacuum cleaner	Vacuum cleaner
Onion	Onion	Onion	Broom	Broom sweeping	Broom
Orange	Orange-scented oil	Orange	Bee	Bee	Bee
Tomato	Tomato ketchup	Tomato	Piano	Piano chords	Piano
Lemon	Lemon juice	Lemon	Whistle	Whistle	Whistle
Wine	Red wine	Glass of wine	Train	Train horn	Train
Tea	Tea	Tea bag and cup	Fireworks	Fireworks	Fireworks
Coffee	Coffee	Cup of coffee	Drums	Drums	Drums

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