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Title: Episodic memory and episodic future thinking in adults with autism

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Abstract

The ability to remember past experiences (episodic memory) is thought to be related to the ability to imagine possible future experiences (episodic future thinking). Although previous research has established that individuals with autism spectrum disorder (ASD) have diminished episodic memory, episodic future thinking has not previously been investigated within this population. In the present study, high-functioning adults with ASD were compared to closely matched typical adults on a task requiring participants to report a series of events that happened to them in the past and a series of events that might happen to them in the future. For each event described, participants completed two modified “Memory Characteristics Questionnaire” (MCQ) items to assess self-reported phenomenal qualities associated with remembering and imagining, including self-perspective and degree of auto-noetic awareness. Participants also completed letter, category, and ideational fluency tasks. Results indicated that participants with ASD recalled/imagined significantly fewer specific events than comparison participants, demonstrating impaired episodic memory and episodic future thinking. In line with this finding, participants with ASD were less likely than comparison participants to report taking a “field” (first-person) perspective, and more likely to report taking an “observer” (third-person) perspective, during retrieval of past events (but not during simulation of future events), highlighting that they were less likely to mentally re-experience past events from their own point of view. There were no group differences in self-reported levels of auto-noetic awareness or fluency task performance.

Keywords

Autism spectrum disorder; auto-noetic consciousness; episodic future thinking; episodic memory; imagination; prospection

Introduction

It is widely accepted that there are various “types” of memory (Gardiner, 2008). According to the influential “systems” theory, memory is underpinned by multiple separate, but interacting, neuro-cognitive systems, each with unique functions and properties (Schacter & Tulving, 1994). The “semantic” and “episodic” systems are two such hypothetical memory systems. Broadly defined, semantic memory refers to memory for de-contextualised factual information (e.g., knowledge of the boiling point of water), and episodic memory refers to memory for personally experienced events (e.g., remembering boiling a kettle of water to make tea this morning). For a number of years, it has been argued that the ability to remember one’s past experiences is closely related to the ability to imagine one’s possible future experiences (e.g., Suddendorf & Corballis, 1997; Wheeler, Stuss, & Tulving, 1997). This latter ability is generally referred to as “episodic future thinking” (e.g., Atance & O’Neill, 2005) or “prospection” (e.g., Buckner & Carroll, 2007). “Autonoetic consciousness” – a type of *self*-consciousness that involves becoming aware of past, present, or future states of self – is considered to be one of the key hallmarks of both episodic memory and episodic future thinking (Wheeler, Stuss, & Tulving, 1997). Becoming autonoetically aware of a past or possible future state of self is said to give rise to a sense of “mental time travel”, whereby one mentally travels backwards or forwards through time in order to mentally re-experience a past episode or pre-experience a possible future episode (Suddendorf & Corballis, 1997).

There is considerable evidence for the proposed overlap between episodic memory and episodic future thinking. For example, individuals with amnesia, who are unable to remember past personal experiences, and individuals with depression or schizophrenia, who show attenuated memory for past personal experiences, show a corresponding deficit in imagining future personal experiences (D'Argembeau, Raffard, & Van der Linden, 2008; Klein, Loftus, & Kihlstrom, 2002; Tulving, 1985; Williams et al., 1996). Episodic memory and episodic future thinking also appear to emerge at similar points in typical development – at around 4 years of age (e.g., Atance, 2008; Perner, Kloo, & Gornik, 2007) – and are highly correlated amongst typical adults (D'Argembeau, Raffard, & Van der Linden, 2008) and children (Busby & Suddendorf, 2005). Moreover, using a meta-analysis, Spreng, Mar, and Kim (2009) established a set of functional neural correlates common to both episodic memory and episodic future thinking (within medial-prefrontal, medial-temporal, and parietal regions, as well as the lateral prefrontal cortex, lateral temporal cortex, and occipital lobe).

In order to construct a coherent event representation during either episodic memory retrieval or episodic future thinking – a process sometimes referred to as “scene construction” (Hassabis & Maguire, 2007) – it is necessary to “bind” various multimodal features together (e.g., Schacter & Addis, 2007b). Although both episodic memory and episodic future thinking are thought to involve this type of constructive process, the constructive processes involved in imagining future events need to be considerably more flexible than those involved in remembering past events. Therefore, episodic future thinking is likely to be more cognitively demanding than episodic memory. It has been

suggested that the simulation of future events involves the selective, recursive sampling and recombination of event features stored in episodic memory as well as general semantic knowledge (Corballis, 2003; Suddendorf & Busby, 2005). This feature of episodic future thinking allows one to entertain unlimited potential future scenarios, each with unique combinations of features. In this way, the processes involved in episodic future thinking closely resemble those involved in imaginative processes *per se*. Indeed, recent research demonstrates that imagining fictitious or fantastic events (that are not temporally displaced) has similar neural correlates to imagining plausible future events and remembering past events (Hassabis, Kumaran, & Maguire, 2007).

From an evolutionary perspective – and following the more general logic that learning and memory, of whatever type, are only useful insofar as they inform future behaviour – it has been argued that episodic future thinking, rather than episodic memory, is the primary evolutionary function of the episodic memory system (Schacter & Addis, 2007b; Suddendorf & Corballis, 1997, 2007). According to this view, the ability to mentally simulate future events allows individuals to test alternative plans of action without the potential risks associated with actually carrying out those (potentially flawed) plans of action (Currie, 1995). Thus, simulation of future events may considerably improve the chances of forming optimal plans of action to guide adaptive future behaviour. Moreover, through allowing an individual to consider multiple possible courses of action, episodic future thinking is thought to facilitate behavioural flexibility and self-control (Suddendorf & Corballis, 2007). For example, the capacity for foresight

helps enable individuals to forego immediate gratification in order to achieve long-term gains.

These considerations may be relevant to our understanding of autism spectrum disorder (ASD). ASD comprises a range of developmental disorders including autistic disorder, Asperger's disorder, and pervasive developmental disorder not otherwise specified/atypical autism. These disorders are characterized by impairments in social interaction and also impairments in one or both of the domains of communication and behavioural flexibility, as manifested in a restricted and repetitive repertoire of behaviours and interests (American Psychiatric Association, 2000; World Health Organisation, 1993). In addition to these behavioural impairments, individuals with ASD also tend to exhibit uneven cognitive profiles, including peaks and troughs in their memory abilities (Ben Shalom, 2003; Boucher & Mayes, in press; Bowler, Gaigg, & Lind, in press). For example, whilst individuals with ASD (at least those without additional intellectual disability) demonstrate intact semantic memory, they show significant impairments in episodic memory. They show diminished memory for personally experienced events (e.g., Bruck, London, Landa, & Goodman, 2007; Crane & Goddard, 2008), source memory (e.g., Lind & Bowler, 2009a; Russell & Jarrold, 1999), and free recall (e.g., Boucher & Warrington, 1976), each of which is considered to index episodic memory (e.g., Wheeler, Stuss, & Tulving, 1997). Bowler, Gardiner, and Gaigg (2007) have also directly shown that individuals with ASD are less likely to experience auto-noetic awareness, the hallmark of episodic memory, during recognition memory tasks (suggesting a greater reliance on semantic memory).

Individuals with ASD also characteristically show significantly diminished imaginative skills (Harris & Leevers, 2000; Wing & Gould, 1979). For example, the fact that children with ASD show impoverished spontaneous pretend play (Jarrold, 2003) may be taken as evidence of diminished imagination. Thus, given that people with ASD have impaired episodic memory and imagination, and given that amongst typical individuals episodic memory, imagination, and episodic future thinking are thought to rely on overlapping processes, it seems reasonable to predict that episodic future thinking will also be impaired in ASD.

One plausible explanation for observed deficits in episodic memory and imagination (and predicted deficits in episodic future thinking) in ASD is that each of these difficulties stem from executive difficulties with strategically *accessing* stored information (Boucher, 2007). Difficulties with retrieving information stored within episodic or semantic memory may affect the ability of individuals with ASD to reconstruct past events or simulate possible future/fictitious events. Such difficulties may also potentially account for generativity deficits in ASD. The term “generativity” is used to refer to the capacity to spontaneously generate novel ideas and behaviours (Turner, 1999). It is most commonly assessed using tests of “fluency”, which typically involve, for example, asking participants to generate as many ideas for potential uses of objects as possible within a set time period. Although there have been a number of inconsistent findings, some studies have found that individuals with ASD show significantly diminished performance on such tasks (see Hill, 2004).

No previous study (to our knowledge) has sought to investigate episodic future thinking in ASD. However, the value of conducting such an investigation may be considerable. As stated above, episodic future thinking is thought to play a key role in forming successful plans, and increasing behavioural flexibility and the capacity for self-regulation. If individuals with ASD have problems with mentally simulating plans of action, and problems with considering various possible courses of action, through episodic future thinking, they may have to fall back on familiar, over-learned routines to guide their behaviour. In this way, impairments in episodic future thinking may potentially contribute to the behavioural inflexibility that characterises ASD.

Aims and Hypotheses

Thus, the main aim of the present study was to test the hypothesis that individuals with ASD have a diminished capacity for episodic memory *and* episodic future thinking. If this hypothesis is correct, individuals with ASD should (a) have difficulty with recalling/imagining specific events and (b) have a diminished sense of mentally re-experiencing or pre-experiencing events in memory or imagination.

One way to evaluate sense of re- or pre-experiencing events is to explore points of view in memory and imagination. According to Gillihan and Farar (2005, p.90), memories of personally experienced events should only be considered episodic if recall is experienced from a first-person, self-perspective – or “through the eyes of the self”. Indeed, Nigro and Neisser (1983) established that it is possible to retrieve personally

experienced events not only from a first-person, “field” perspective but also from an “observer” perspective, in which one sees oneself in one’s memory from an external point of view. Thus, if episodic memory and episodic future thinking necessarily involve a field perspective, individuals with ASD should be less likely to take a field perspective in memory or imagination.

In order to explore these issues, we adopted a standard method (based on D'Argembeau & Van der Linden, 2004), which involved asking participants to recall/imagine and describe a series of specific personal experiences and to complete accompanying questionnaires, designed to assess particular phenomenal qualities (i.e., subjectively perceived characteristics) associated with remembered past and imagined future experiences – specifically, the extent to which participants felt they were mentally re-experiencing or pre-experiencing the event in question (i.e., degree of auto-noetic awareness) and whether they took a field or observer perspective whilst recalling or imagining. Given that we were interested in exploring the possibility that impairments in *accessing* stored information might contribute to the predicted episodic memory and episodic future thinking impairments in ASD, additional letter, category, and ideational fluency tasks were also implemented.

Predictions

(1) It was predicted that, relative to comparison participants, participants with ASD would show impairments in *both* episodic memory and episodic future thinking – that is, recall and imagine significantly fewer specific events.

(2) Given that episodic memory and episodic future thinking are thought to (at least partially) rely on the same underlying neurocognitive system, and that previous studies have established significant relationships between these variables amongst typical individuals (e.g., D'Argembeau, Raffard, & Van der Linden, 2008), it was predicted that these variables would be significantly correlated within the comparison group. However, an alternative prediction was set out in relation to the ASD group. If the neurocognitive system that typically underlies episodic memory and episodic future thinking is compromised in ASD (as we hypothesise it is), it is possible that individuals within the ASD group may resort to “compensatory strategies” to perform the task. In other words, for individuals with ASD, performance on the experimental task may not be mediated by the system typically responsible for episodic memory and episodic future thinking. In which case, such a strong association between episodic future thinking and episodic memory task performance may not emerge within this group.

(3) Furthermore, if individuals with ASD show reduced episodic remembering and episodic future thinking, this may be reflected in their questionnaire responses. Thus, it was predicted that individuals with ASD would (a) report less of a sense of re-

experiencing or pre-experiencing recalled or imagined events (i.e., reduced auto-noetic awareness) and (b) report fewer instances of taking a field perspective in memory and imagination.

(4) It was also predicted that letter, category, and ideational fluency would each be impaired amongst individuals with ASD.

(5) Finally, it was predicted that within the ASD group episodic memory and episodic future thinking scores would be significantly correlated with imagination/creativity scores on the Autism Diagnostic Observation Schedule – Generic (ADOS; Lord et al., 2000), which is a semi-structured, standardized assessment of social interaction, communication, play, and imaginative use of materials, used in the diagnosis of ASD.

Method

Participants

Ethical approval for the study was obtained from the Senate Research Ethics Committee at City University London. All participants gave their informed, written consent to take part and were paid standard university fees for their participation. Prior to commencing the study, participants completed a brief, semi-structured interview to establish their age, whether they took any prescribed medication or illegal recreational drugs, and whether they had been diagnosed with any neurological or psychiatric illness. Intellectual ability

was assessed using the Wechsler Adult Intelligence Scale – Third UK Edition (Wechsler, 1999). Exclusion criteria included (a) having a full-scale IQ of less than 70; (b) being younger than 18 years of age; (c) being older than 60 years of age; (d) use of psychotropic medication or illegal recreational drugs; and (e) neurological or psychiatric illness (other than ASD). The sample consisted of 14 (3 female, 11 male) high-functioning (full scale IQ \geq 70) adults with ASD and 14 typical adults (3 female, 11 male). Participants with and without ASD were individually matched on sex, age (to within 5 years), and verbal IQ (to within 7 points). Participant characteristics are presented in Table 1.

[Table 1 here]

The groups did not significantly differ on age, verbal IQ, performance IQ, or full scale IQ and the effect sizes (*rs*) were all negligible to small, indicating close matching. The ASD group consisted of adults who had been diagnosed by local health authorities and/or experienced clinicians, and met established criteria for Asperger’s disorder or autistic disorder (American Psychiatric Association, 2000; World Health Organisation, 1993). As an additional diagnostic check, participants within the ASD group were also assessed using the Autism Diagnostic Observation Schedule – Generic (ADOS; Lord et al., 2000) and the Autism-spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001).

As stated above, the ADOS is a semi-structured, standardized assessment of social interaction, communication, play, and imaginative use of materials, used in the diagnosis of ASD. The AQ is a 50 item questionnaire, suitable for administration with adults with intelligence within the average or above average range, which provides a quantitative index of self-reported autistic-like traits. All participants within the ASD group met the ASD cutoff (7 points) on the Social + Communication Total Score of the ADOS ($M = 10.57$; $SD = 3.57$; range: 7-17). AQ scores are summarized in Table 1. Only one participant from the ASD group scored below 26, the recommended cutoff for distinguishing individuals with and without ASD (Woodbury-Smith, Robinson, & Baron-Cohen, 2005). This should not be a cause for concern, however, given that the AQ has only 78% discriminant validity. Indeed, this participant met criteria for ASD on the ADOS (obtaining a total score of 11).

Comparison participants were recruited through local newspaper advertisements. All comparison participants completed the AQ in order to screen for possible undiagnosed ASD and all scored below the recommended cutoff of 26 points. Moreover, the group difference in AQ scores was highly significant, with a large effect size.

Materials and Procedure

Participants were individually tested in a sound-attenuated laboratory. It was initially explained that they would be asked to try to remember some things that happened to them in the past and to try to imagine some things that might happen to them in the future. The

task itself involved two separate, past and future conditions. The order in which the past and future conditions were completed was counterbalanced across participants. Prior to commencing each condition, participants were provided with detailed written instructions, presented in Arial 11 font on one side of A4 paper. The instructions explained that they would be asked to try to recall/imagine (past/future condition) a series of events from different time periods. It was emphasised that they should try to recall/imagine personally experienced events with durations of a few minutes to a few hours and not more than a day. Examples of appropriate and inappropriate responses were provided. It was explained that after each event described, they would be given 1 minute to think about the event in detail, and then be asked to complete a questionnaire. Additionally, the experimenter reiterated these instructions, providing a verbal explanation of the task requirements. Participants were then asked to complete a practice trial in order to ensure they had properly understood the instructions. For the past and future conditions, respectively, the practice trials involved the cues: “Try to remember an event involving a television” and “Try to imagine an event involving a car”. If the participant gave an appropriate response, they immediately progressed onto the test phase. Participants who gave inappropriate responses were provided with further guidance and opportunities for practice, until they had fully grasped the nature of the task.

The experimental task (including the practice trials) was presented on a laptop computer and programmed using Eprime. In the past and future conditions, participants were presented with cues in the following formats, respectively: “Try to remember an

event that happened to you [specified time period]” and “Try to imagine an event that might happen to you [specified time period]”. In each condition, participants were asked to try to remember/imagine events from (a) today, (b) yesterday/tomorrow, (c) a week ago/in a week, (d) a month ago/in a month, (e) a year ago/ in a year, (f) 5 years ago/in 5 years, and (g) 10 years ago/in 10 years. These cues were presented in a random order without replacement. Once the participant indicated that they had thought of a specific event, they were asked to provide a verbal description of that event. Verbal responses were recorded for later scoring. After providing each event description, the participant was asked to close their eyes for one minute and try to recall/imagine the event in as much detail as possible.

Participants were then asked to respond to the following items, which were selected from the Memory Characteristics Questionnaire (MCQ) (Johnson, Foley, Suengras, & Raye, 1988) and modified appropriately for the future condition:

1. While remembering/imagining this event, I feel as though I am reliving/experiencing it (1 = not at all, 7 = completely).
2. When you remember/imagine this event, how do you see it? From the following three options, choose the one that corresponds to your memory/representation.

- (a) In your memory/representation, you see the scene in the same way as an external observer would see it. In other words, you can see yourself in your memory/representation as well as other aspects of the situation.
- (b) In your memory/representation, you see the scene from your own point of view and not from that of an external observer. In other words, you see the scene through your own eyes.
- (c) Neither of these above mentioned perspectives corresponds to your memory/representation of the event. If this is the case, how would you describe your memory/representation?

Letter fluency was assessed using the “FAS” Controlled Oral Word Association Test (Benton, 1968). This involved asking participants to generate as many words as possible (excluding proper nouns and repeated words with different endings – e.g., “fly” and “flying”) in a one minute period beginning with the letters F, A, and S, respectively. Category fluency was assessed using a task which involved asking participants to generate as many category members as possible in a one minute period for the categories: animals, countries, and foods, respectively (Turner, 1999). Participants also completed an ideational fluency task based on the procedure used by Turner (1999). Participants were given 2.5 minutes to generate as many uses as possible for the following objects: newspaper, brick, pencil, mug, and toothpick. For each object, the experimenter said to the participant: “How could we use a [object]? Tell me something useful that we could

do with it?" In each case, the experimenter provided examples of conventional (e.g., newspaper: you could read it) and unconventional (e.g., newspaper: you could wrap a present with it) uses for each object. Participant responses for each of the fluency tasks were recorded for later scoring.

Scoring

In order for an event description in the memory/future thinking task to qualify as episodic, it had to refer to a *specific* personal experience that (a) occurred or would occur at a particular time in a particular place, (b) lasted or would last for a duration of less than a day, and (c) occurred or would occur on only one occasion (see Conway & Rubin, 1986). Error responses included omissions (i.e., the participant was unable to remember or imagine anything at all) and *general* memories/images. General memories/images included "extended" memories/images that referred to events occurring over extended time periods of longer than a day (e.g., "I can imagine next summer my family will be away on holiday and I will be home alone") and "categoric" memories/images that referred to repeated events (e.g., "I remember when I used to go on bike rides in the country") (Williams & Dritschel, 1992). "Episodic memory scores" and "episodic future thinking scores" were established by calculating the proportion of *specific* memories/images described within the past and future conditions, respectively. Thus, the maximum score in each case was 1.00.

Item 1 on the questionnaire, which assessed degree of re-/pre-experiencing the event, was rated by participants on a scale of 1 to 7. Past and future “autonoetic awareness” scores were established by taking each participant’s average rating on the item across the seven events in each condition, respectively. Item 2 on the questionnaire, which assessed point of view, was rated categorically, with responses falling into three possible categories: “field”, “observer”, and “neither”. The proportions of responses falling into each of these categories in each of the conditions were calculated.

Letter, category, and ideational fluency scores were established by averaging the number of different (a) words generated across the three letter prompts, (b) category members generated across the three category prompts, and (c) ideas for uses of objects generated across the five object prompts, respectively (credit was not given for repetitions or rule breaks).

Reliability

The responses of the participants on the episodic memory/future thinking task were scored by the experimenter (SL) as well as a second, independent rater, who was blind to the diagnoses of the participants and the predictions of the study. An interrater reliability analysis using the Kappa statistic was performed to determine consistency between the raters. Interrater reliability was found to be $Kappa = .67, p < .001$. This value represents “substantial agreement” (Landis & Koch, 1977). It was established that the majority of disagreements were due to the fact that one rater classified event descriptions that

included both categoric (general) and specific elements (e.g., I collect money for Children in Need every year. Last year I did a sponsored walk for Children in Need.....) as categoric and the other rater classified them as specific. Through discussion it was agreed that specific instances (with unique features) of repeated events should be classed as specific.

Results

Group Differences in Episodic Memory and Episodic Future Thinking Scores

The mean episodic memory and episodic future thinking scores (proportions of specific events recalled/imagined) for the ASD and comparison groups are displayed in Figure 1.

[Figure 1 here]

A 2 (Group: ASD/comparison) x 2 (Condition: past/future) mixed ANOVA revealed significant main effects of Group, $F(1,26) = 5.54, p = .03, r = .42$ (moderate effect size), and Condition, $F(1,26) = 6.01, p = .02, r = .43$ (moderate effect size), but no significant interaction effect between Group and Condition, $F(1,26) = 0.06, p = .81, r = .05$ (negligible effect size). This reflects the fact that participants with ASD performed less well than comparison participants in each condition (i.e., obtained significantly lower episodic memory *and* episodic future thinking scores), and participants within both groups performed significantly less well in the future condition than in the past condition (i.e., obtained significantly lower episodic future thinking scores than episodic memory

scores). The proportions of extended, categoric, and omission error responses for each of the groups in the past and future conditions are displayed in Table 2.

[Table 2 here]

Relationship Between Episodic Memory and Episodic Future Thinking Scores

In order to investigate the relationship between episodic memory and episodic future thinking within each of the groups, Pearson's correlation analyses were conducted. It was found that episodic memory scores and episodic future thinking scores were significantly (strongly and positively) correlated within the comparison group, $r = .72, p < .01$, but not within the ASD group, $r = -.25, p = .38$. In order to determine whether these relationships were significantly different in terms of strength of association, Fisher's Z transformations were computed. This procedure indicated that the correlation was significantly stronger within the comparison group than within the ASD group, $Z_{r1-r2} = 2.78, p < .01$.

Memory Characteristics Questionnaire Responses

Autonoetic awareness ratings.

The mean autonoetic awareness ratings from Item 1 of the MCQ for each of the groups in each of the conditions are displayed in Table 3.

[Table 3 here]

A 2 (Group: ASD/comparison) x 2 (Condition: past/future) mixed ANOVA revealed no significant main effect of Group, $F(1,26) < 0.01, p = .94, r = .02$ (negligible effect size), a marginally significant main effect of Condition, $F(1,26) = 3.81, p = .06, r = .36$ (moderate effect size), and no significant interaction effect between Group and Condition, $F(1,26) = 0.14, p = .72, r = .07$ (negligible effect size).

Self-perspective ratings.

The mean proportions of “field”, “observer”, and “neither” perspective responses from Item 2 of the MCQ for each of the groups in each of the conditions are displayed in Figure 2.

[Figure 2 here]

A 2 (Group: ASD/comparison) x 2 (Condition: past/future) x 3 (Perspective: field/observer/neither) mixed ANOVA revealed no significant main effect of Group, $F(1,26) < 0.01, p > .99, r < .01$ (negligible effect size), no significant main effect of Condition, $F(1,26) = 0.96, p = .34, r = .19$ (small effect size), but a significant main effect of Perspective, $F(2,26) = 40.72, p < .001, r = .78$ (large effect size). None of the two way interactions was significant, all $F_s < 0.51, all p_s > .61$. However, the three-way interaction between Group, Condition, and Perspective was significant, $F(2,26) = 4.22, p = .02, r = .37$ (moderate effect size).

Exploratory follow-up analyses revealed that this interaction arose because of a difference amongst participants with ASD and comparison participants in the relative likelihood of reporting a field rather than observer perspective in the past condition versus the future condition. Table 4 displays these results numerically.

[Table 4 here]

Hence, in the *future* condition, the ratio of field to observer perspectives reported was very similar in the ASD and comparison groups. In this respect, the reports made by participants from each group were alike. In the *past* condition, patterns of reporting were somewhat different in each group. Whereas comparison participants were 8 times more likely to report taking a field perspective than an observer perspective, participants with ASD were only 2.4 times more likely to report taking such a perspective.

Group Differences in Fluency Scores

The mean letter, category, and ideational fluency scores for each of the groups¹ are displayed in Table 5.

[Table 5 here]

Independent *t*-tests were used to assess group differences in performance on the fluency tasks (see Table 5). No significant group differences were observed on any of the fluency tasks and the effect sizes were all negligible to small.

Relationship Between Imagination Scores on the ADOS and Episodic Memory/Future Thinking Scores

In order to investigate the relationship between ADOS imagination scores and episodic memory and episodic future thinking scores, respectively, correlation analyses were conducted within the ASD group only (given that only participants within the ASD group had ADOS scores). Spearman's rather than Pearson's coefficients were used, given that the ADOS imagination scores were restricted to a three-point scale and did not meet the assumptions for Pearson's analyses. It was found that ADOS imagination scores were significantly correlated with episodic future thinking scores, $r_s = -.58$, $p = .03$, but not episodic memory scores, $r_s = .04$, $p = .90$. It should be noted that on the ADOS, the lower the imagination score, the greater the degree of imaginative behaviour demonstrated – hence the negative correlation. Thus, the significant negative correlation indicates that better imagination was associated with better episodic future thinking scores.

Discussion

In line with predictions, participants with ASD recalled/imagined significantly fewer specific events than comparison participants, reflecting impaired episodic memory and episodic future thinking. Although there were significant between-group differences in *levels* of performance, *patterns* of performance were comparable across both groups. Participants within each group showed significantly better episodic memory than episodic

future thinking. This performance pattern is likely to reflect the fact that episodic future thinking is more cognitively demanding than episodic memory. Whereas episodic memory involves reconstructing an event from a *pre-specified* set of features, based on an actual past experience, episodic future thinking is essentially an imaginative process that involves the selective, recursive sampling and *recombination* of features from memory, in addition to other shared cognitive resources (Corballis, 2003).

Also in line with predictions, it was found that episodic memory and episodic future thinking were significantly correlated only within the comparison group. Indeed, the significant (strong and positive) correlation within the comparison group was found to differ significantly from the non-significant (weak and negative) correlation within the ASD group. The results from the comparison group replicate previous research (e.g., D'Argembeau, Raffard, & Van der Linden, 2008) and support the notion that episodic memory and episodic future thinking rely on overlapping processes. The lack of a significant relationship within the ASD group may reflect the fact that individuals with ASD are less likely to draw on elements from *episodic* memory in order to imagine possible future experiences, as typical individuals do. Rather, in trying to envisage future events, individuals with ASD may draw more heavily on elements from *semantic* memory.

One possible consequence of the observed impairments in episodic memory and episodic future thinking in ASD may be diminished temporally extended self-awareness. Temporally extended self-awareness refers to awareness of one's continuing existence

through time (Neisser, 1988; Povinelli, 2001). As Lind (in press) has argued, impairments in episodic memory and episodic future thinking imply that individuals with ASD have difficulties with *re*-experiencing past states of self and *pre*-experiencing future states of self. The ability to become aware of past or possible future states of self is essential to grasping the self's continuity through time. Therefore, this grasp may be weaker amongst individuals with ASD (see Lind & Bowler, 2009b).

In terms of the subjective measures of episodic memory and episodic future thinking, derived from the MCQ, it was found that, contrary to predictions, participants with ASD did not report diminished levels of auto-noetic awareness during the task. It must be acknowledged that this null finding may potentially be attributable to low statistical power (given the relatively small sample size). However, it should also be noted that the effect size for the group difference in ratings was negligible, suggesting that the effect would be unlikely to reach statistical significance even with much larger groups. Therefore, the findings superficially seem to suggest that individuals with ASD show intact auto-noetic awareness.

Partially in line with predictions, group differences in self-perspective emerged in relation to episodic memory but not episodic future thinking. It was found that participants with ASD were less likely than comparison participants to take a field (self) perspective and more likely to take an observer perspective during the recall of past events. This suggests that the phenomenal placement of self during event memory may be somewhat atypical in ASD – individuals with the disorder seem to show a reduced

propensity for re-experiencing events “through the eyes of the self”. According to Gillihan and Farar (2005), a field perspective is a key hallmark of episodic memory. Thus, these findings are in keeping with the notion of diminished episodic memory in ASD.

It is important to note, at this point, that self-report measures should always be interpreted with caution amongst individuals with ASD. It is widely thought that individuals with ASD have limited introspective abilities (Hurlburt, Happé, & Frith, 1994; Williams, in press). For example, it is found that individuals with ASD tend to under-report the severity of their autistic features (Johnson, Filliter, & Murphy, 2009) and show diminished awareness of their mental states (Williams & Happé, 2009, 2010). If individuals with ASD have diminished introspective abilities, this may mean that their MCQ responses do not accurately reflect their actual inner experiences during remembering the past and imagining the future. This may help to explain some of the apparently contradictory findings, not only between the (arguably more valid) objective measures and the subjective measures, but also between the two subjective measures (the self-reported degree of auto-noetic awareness and visual perspective items). For example, in the past condition, individuals with ASD reported typical levels of auto-noetic awareness but fewer instances of field perspectives – findings which seem incompatible. How can one have a sense of reliving or experiencing an event without seeing it from one’s own point of view? This provides some evidence for the suggestion that the subjective reports may not be reliable or valid amongst the ASD group. In some

instances, individuals with ASD may *think* they are mentally re-experiencing or pre-experiencing events when in fact they are not fully doing so.

It was found that participants with and without ASD showed similar levels of performance on each of the fluency tasks, with no significant group differences observed. Although the groups performed almost identically on the category fluency task (effect size $r < .01$), it is possible that group differences on the letter and ideational fluency tasks may have reached statistical significance with a larger sample. Interestingly, although the ASD group showed a trend towards *inferior* performance on the *ideational* fluency task (consistent with predictions), they showed a trend towards *superior* performance on the *letter* fluency task (inconsistent with predictions). Although some previous studies involving children with ASD have observed performance deficits on fluency tasks (e.g., Turner, 1999), consistent with the current findings, recent research involving high-functioning adults has found no such impairments (e.g., Crane & Goddard, 2008). The current findings seem to suggest that by and large the participants with ASD did not have difficulties with strategically accessing stored information. Therefore, it can be tentatively concluded that episodic memory and episodic future thinking impairments in ASD are unlikely to stem from difficulties with accessing stored information.

One alternative explanation is that difficulties in episodic memory and episodic future thinking stem from an impaired ability to utilise the “episodic buffer” component of working memory (Boucher, 2007). The episodic buffer is one possible mechanism by which the type of featural binding that is required for episodic memory and episodic

future thinking may be accomplished. According to Baddeley's (2000) working memory model, the episodic buffer is "a limited capacity system that provides temporary storage of information held in a multimodal code, which is capable of binding information from the subsidiary systems [i.e., the visuospatial sketchpad and phonological loop], and from long-term memory, into a unitary episodic representation" (Baddeley, 2000, p.417).

Hence, the episodic buffer may provide the mental space in which to reconstruct past events or simulate future events (Schacter & Addis, 2007a).

Given that the episodic buffer is thought to be responsible for binding together information during episodic memory retrieval, this view is consistent with the fact that individuals with ASD have little difficulty with remembering individual items but have significant difficulty remembering combinations of items² (Bowler, Gaigg, & Gardiner, 2008). Impairments in the episodic buffer mechanism may also potentially explain the imaginative deficits in ASD. Boucher hypothesizes that imagination in ASD may be largely "limited to rerunning images on the visuospatial scratchpad or rerunning sequences of words in the phonological loop" (p.262). This may mean that individuals with ASD have difficulty with simulating dynamic sequences of "non-actual" events – and this would equally impact upon episodic future thinking. Therefore, hypothesised impairments in the episodic buffer may potentially explain why individuals with ASD have co-occurring impairments in episodic memory, episodic future thinking, and imagination. However, further research will be required to establish the validity of this theory.

Partially in line with predictions, it was found that imagination scores on the ADOS were significantly correlated with episodic future thinking scores but not episodic memory scores. These findings suggest that the co-variance is attributable to the fact that both episodic future thinking and imagination require the selective recursive sampling and recombination of elements from episodic and semantic memory, whilst episodic memory does not.

Limitations

The present study had two main limitations, which must be taken into account when interpreting the findings. Firstly, the small sample size employed means that conclusions should only be drawn tentatively and, in particular, any null findings should be interpreted with caution. Given these concerns, it may be advisable to focus on the established effect sizes rather than p -values.

A second limitation of the study concerns the possible confounding effects of co-morbid psychiatric conditions. Although the presence of psychiatric diagnoses other than ASD was an exclusionary criterion of the study, we cannot be certain that participants did not have previously *undiagnosed*, co-morbid psychiatric conditions (given that we did not assess these as part of the study). If a participant had undiagnosed, co-morbid depression, for example, this may have affected their performance on the experimental tasks.

Conclusions

The present findings should be taken as confirmation of impaired episodic memory in ASD and as preliminary evidence for impaired episodic future thinking. However, given the limitations of the study, it will be important to replicate these findings before drawing absolute conclusions. Possibly the most parsimonious explanation for the finding that both episodic memory and episodic future thinking appear to be impaired in ASD is that each of these abilities rely on the same underlying neurocognitive system – as many other researchers have suggested is the case – and this system is dysfunctional in ASD. What remains unclear is whether the system as a *whole* is compromised or whether one or more specific *components* of the system are compromised.

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Footnotes

¹Letter, category, and ideational fluency data for three participants with ASD, and letter fluency data for one comparison participant were unavailable due to faulty audio files.

²This pattern of results could equally be attributed to difficulties with binding at encoding rather than retrieval.

Table 1

Participant Characteristics

Characteristic	ASD (<i>n</i> = 14)			Comparison (<i>n</i> = 14)			<i>t</i> (26)	<i>p</i>	<i>r</i>
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range			
VIQ	107.86	12.37	86-134	110.71	15.75	82-134	0.53	.60	.10
PIQ	102.86	16.13	76-128	103.64	19.04	72-136	0.12	.91	.02
FSIQ	105.86	14.52	80-132	108.57	18.20	77-135	0.44	.67	.09
Age (years)	41.38	12.71	21-57	43.83	10.39	23-57	0.56	.58	.11
AQ	34.79	6.91	22-45	16.43	6.72	4-25	7.13	<.001	.81

Note: VIQ = verbal IQ; PIQ = performance IQ; FSIQ = full scale IQ; AQ = Autism-spectrum Quotient.

Table 2

Proportion of Extended, Categorical, and Omission Error Types Within the ASD and Comparison Groups in the Past and Future Conditions

Error type	Past		Future	
	ASD	Comparison	ASD	Comparison
Extended	.19 (.15)	.14 (.16)	.16 (.15)	.14 (.13)
Categorical	.02 (.05)	0	.17 (.18)	.08 (.12)
Omission	.05 (.11)	0	.05 (.11)	.01 (.04)

Table 3

Mean (SD) Autonoetic Awareness Ratings for the ASD and Comparison Groups in the Past and Future Conditions

Condition	Group	
	ASD	Comparison
Past	4.13 (1.56)	4.29 (1.28)
Future	3.86 (1.43)	3.97 (1.32)

Table 4

Mean Proportions of Field and Observer Perspectives and Ratios of Field:Observer Perspectives for Each of the Groups in Each of the Conditions

Condition	Mean Proportions (SD)				Ratio of field:observer perspectives	
	Field		Observer			
	ASD	Comparison	ASD	Comparison	ASD	Comparison
Past	.65 (.22)	.80 (.27)	.27 (.25)	.10 (.13)	2.4:1	8:1
Future	.72 (.27)	.66 (.32)	.20 (.24)	.21 (.24)	3.6:1	3.1:1

Table 5

Fluency Task Scores

Task	ASD	Comparison	<i>t</i>	<i>df</i>	<i>p</i>	<i>r</i>
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)				
Letter	15.00 (5.10)	13.56 (4.00)	0.77	22	.49	.16
Category	25.03 (8.92)	25.10 (3.27)	0.02	23	.98	< .01
Ideational	8.33 (3.27)	9.49 (3.24)	0.88	23	.39	.18

Figure Captions

Figure 1

Mean Episodic Memory and Episodic Future Thinking Scores (Proportions of Specific Events Recalled/Imagined) for the ASD and Comparison Groups (Error Bars Represent One Standard Error)

Figure 2

Mean Proportions of “Field”, “Observer”, and “Neither” Perspective Responses for Each of the Groups in Each of the Conditions (Error Bars Represent One Standard Error)

Figure 1

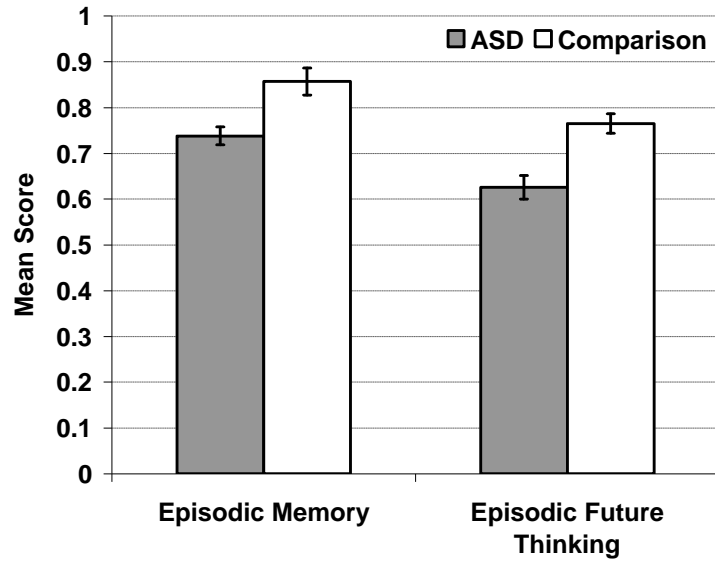


Figure 2

