Episodic but not Semantic Order Memory Difficulties in Autism Spectrum Disorder: Evidence from the Historical Figures Task

Short Title: Episodic order memory difficulties in ASD

Sebastian B Gaigg[1], Dermot M Bowler[1] & John M Gardiner[1]

[1]City University London, Dept. of Psychology, Northampton Square, London EC1V 0HB

Corresponding author: Sebastian B Gaigg

Department of Psychology

City University London

Northampton Square

London, EC1V 0HB

Tel: +44 0207 040 8544

Fax: +44 0207 040 8581

e-mail: s.b.gaigg@city.ac.uk

Abstract

Considerable evidence suggests that the episodic memory system operates abnormally in Autism Spectrum Disorder (ASD) whereas the functions of the semantic memory system are relatively preserved. Here we show that the same dissociation also applies to the domain of order memory. We asked adult participants to order the names of famous historical figures either according to their chronological order in history (probing semantic memory) or according to a random sequence shown once on a screen (probing episodic memory). As predicted, adults with ASD performed less well than age and IQ matched comparison individuals only on the episodic task. This observation is of considerable importance in the context of developmental theory because semantic and episodic order memory abilities can be dissociated in typically developing infants before they reach the age at which the behavioural markers associated with ASD are first apparent. This raises the possibility that early emerging memory abnormalities play a role in shaping the developmental trajectory of the disorder. We discuss the broader implications of this possibility and highlight the urgent need for greater scrutiny of memory competences in ASD early in development.

Key Words: Autism Spectrum Disorder, Order Memory, Episodic Memory, Semantic Memory, Memory Development

Acknowledgements

Results of this study were presented at the International Meeting for Autism Research (IMFAR), London, UK, May 2008. This study was supported by a grant from the Medical Research Council (MRC; Grant number G0401413). We are thankful to all participants for their help with our work. None of the authors declare any conflict of interest arising from this study.

Introduction

Tulving (2001) argues that the declarative memory system comprises two distinct sub-systems; 1) the *semantic memory system*, which consists of a store of ‘timeless facts’ and 2) the *episodic memory system*, which encompasses an individual’s personally-experienced past, including the spatial and temporal context of particular episodes. Autism Spectrum Disorder (ASD) is a disorder of reciprocal social development that is associated with persistent difficulties in episodic memory (see Boucher, Mayes & Bigham, 2012; Bowler & Gaigg, 2008; Lind & Bowler, 2008 for reviews). Diminished performance is found on free recall tasks, for instance, particularly when conceptual relations amongst to-be-remembered stimuli can be used to facilitate memory or when learning is assessed over multiple trials (Bowler, Gaigg & Gardiner, 2008a; Bowler, Gardiner, Grice & Saavalainen, 2000a; Bowler, Matthews & Gardiner, 1997; Gaigg, Gardiner & Bowler, 2008; Smith, Gardiner & Bowler, 2007; Minshew & Goldstein, 1993; Tager-Flusberg, 1991)[1]. Individuals with ASD also experience difficulties in recalling contextual information that is incidentally encoded during study episodes (Bennetto, Pennington & Rogers, 1996; Bowler, Gardiner & Berthollier, 2004) and their retrieval of autobiographical memories lack in episodic detail as well (e.g. Crane & Goddard, 2008; Goddard, Howlin, Dritschel & Patel, 2007). It has also been shown that the ability to describe possible future events is compromised in ASD (Lind & Bowler, 2010), which is also widely thought to rely on episodic memory (Schacter, Addis & Buckner, 2008). Finally, studies employing the Remember/Know recognition procedure[1] show that individuals with

---

[1] This procedure requires participants to indicate whether they ‘Remember’ any contextual information relating to particular items they recognise or whether simply ‘Know’ that an item had

ASD report significantly fewer instances of ‘Remembering’ but more experiences of ‘Knowing’ than comparison groups, which reflects difficulties with retrieval from the episodic but not the semantic memory system (Bowler, Gardiner & Grice, 2000b; Bowler, Gardiner & Gaigg, 2007), This last finding is of particular interest because it suggests that episodic difficulties may be relatively specific in ASD, leaving knowledge stored in the semantic system spared (see also Crane & Goddard, 2008; Tanweer, Rathbone & Souchay, 2010). Our main aim in the present paper is to determine whether a similar dissociation can be demonstrated in the domain of serial order memory, which is an area of memory that is of great interest in the context of any developmental disorder.

Although memory difficulties have been documented consistently in ASD for over four decades (see Boucher, et al., 2012 for a review), the developmental time course of these difficulties remains entirely unexplored. Until recently this gap in our understanding seemed of little importance because it was widely assumed that particularly episodic memory did not mature until after the period during which the first clinical markers of ASD normally arise. Memory difficulties, therefore, were very unlikely to play a significant role in the development of the disorder. Over the last decade, however, advances in the study of typical memory development have led to the view that critical building blocks of the episodic and semantic memory systems begin to mature differentially already before a child’s first birthday (Bauer, Wenner, Dropik & Wewerka, 2000; Bauer, 2004; Healy, Havas & Parker, 2000) – just before the first reliable behavioural markers of ASD arise around 14-18 months (see Yirmiya & Charman, 2010 for a review). Studies

---

been presented earlier without memory of any additional contextual detail (see Gardiner, 2001; Tulving, 2001 for detailed discussions).

of serial order memory have been particularly important in this context. Thus, infants from around the age of 6 months have been found to imitate familiar sequences of actions in the order in which they observe them but it is not until the age of about 9-12 months that they also begin to imitate arbitrary action sequences in the observed order. Imitation of familiar action sequences is thought to be supported by the developing semantic memory system where the knowledge accumulates that renders the sequences 'familiar'. Imitation of arbitrary sequences, by contrast, is thought to rely on the kinds of flexible relational processes that define the episodic system, which stores memories of the unique spatial-temporal associations that define particular episodes (see Bauer et al., 2000 and Bauer, 2004 for detailed discussions). In the context of this developmental literature it is of great interest to establish whether specific difficulties in episodic memory extend to the domain of serial order memory in ASD. At present, the evidence relating to this question is not entirely clear because episodic and semantic contributions to serial order memory have never been contrasted directly in this disorder.

The study of serial order memory has a long history in ASD that began with the pioneering work by Hermelin and O'Connor in the late 1960s (Hermelin & O'Connor, 1967; Hermelin & O'Connor, 1970; O'Connor & Hermelin, 1965). These authors showed that children with 'low-functioning' ASD, who were characterised by developmental language delay (hereafter LF-ASD), experienced difficulties in remembering short sequences of words when the order of items conveyed meaning (e.g., a coherent sentence) but not when the words were arranged randomly. Contrary to much of the evidence outlined earlier, this would suggest impairments in semantic rather than episodic memory. That is, the children would seem to have had difficulties drawing on their knowledge of syntax, grammar and word meaning to support serial order memory whilst experiencing little difficulties remembering the order of stimuli *per se* (as noted earlier, remembering arbitrary sequences of events is thought to rely heavily on episodic memory). Poirier and colleagues (Poirier & Martin, 2008; Poirier, Martin, Gaigg & Bowler, 2011), however, have warned that particularly the latter conclusion would be premature. They noted that Hermelin and O'Connor matched their participant groups on digit-span performance, which essentially eliminated group differences in the ability to remember arbitrary stimulus sequences. When Poirier et al., (2011) employed more careful matching procedures with a group of higher-functioning adults with ASD, whose language development had followed a relatively typical trajectory (hereafter HF-ASD), they observed significantly attenuated serial order memory for arbitrary digit and word sequences. This observation resolves the apparent inconsistency between early studies of serial order memory and the literature on episodic memory difficulties in ASD. What remains unclear, however, is to what extent semantic memory difficulties may also contribute to poor serial order memory in this disorder.

The task we develop here is informed by the work of Healy, Havas and Parker (2000), who presented participants with a list of US presidents with instructions to order these either according to the chronological sequence in which the presidents served in office (drawing on prior knowledge and therefore probing the semantic memory system) or according to a pseudo-random order shown on a computer screen (requiring recollection of the order of the names presented by the experimenter and therefore probing the episodic memory sytem). Participants were more accurate at reconstructing the order of the first few names during the episodic task, whilst they were more accurate at ordering the most recent presidents' names in the semantic task. Together with the observation that participants also rated the historically more recent presidents as more familiar, these serial position curves supported the idea that performance in the two tasks was mediated by the episodic and semantic memory systems respectively. In the present experiment we required participants to order shorter (7-item) lists of famous Historical Figures either according to their chronological order in history (i.e. semantic task) or according to a randomly generated order presented once on a screen (i.e. episodic task) with the prediction that individuals with ASD would perform worse than a comparison group only on the latter.

Method

Participants

Twenty-two adults with a diagnosis of ASD (5 female, 17 male) and 22 typically developed adults (2 female, 21 male) participated in the experiment. Participants were individually matched on Verbal IQ as measured by the WAIS-R or WAIS-III^{UK} (The Psychological Corporation, 2002) and groups did not differ in terms of Performance IQ, Full scale IQ or age. Following Poirier and Martin's (2008) suggestion, the digit span sub-task was excluded when computing Verbal IQ so as not to match participants on the ability of interest. The relevant data for these group characteristics are set out in Table 1. ASD participants were recruited from an existing pool of more than 50 such individuals and available medical records confirmed that all had received their diagnosis from experienced clinicians through the UK health services. Additional assessment with the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord, Risi, Lambrecht, et al., 2000) by individuals trained to research reliability standards revealed difficulties in aspects of communication and reciprocal social behaviour that were largely consistent with the participant's clinical diagnosis. ADOS assessments were not available for three participants but since their detailed clinical records left no doubt that they too met DSM-IV criteria for Autism Spectrum Disorder (American Psychiatric Association, 2000) they were retained in all analyses. Typical individuals comprising the comparison group were recruited through local newspaper advertisements and brief interviews were administered to screen out any individual with a family history of psychiatric or neurological conditions. None of the participants in either group was taking psychotropic medication or reported the use of recreational drugs and all provided their written informed consent to take part in the study, which was prospectively reviewed and approved by the Senate Research Ethics Committee of City University London.

(Table 1 about here)

Materials & Design

The experimental materials for the current study consisted of seven lists of the names of seven historical figures each (see Appendix 1). These names were chosen from an on-line database of over 1000 historical figures, who lived at any time between 1000 BC – 2007 AD (www.hyperhistory.com/online_n2/History_n2/a.html). Within each list, historical figures were chosen to have lived during non-overlapping periods in history. Across lists, historical figures were matched to cover similar historical periods. Pilot testing ensured that the names were familiar to the majority of adults and that they were identified as the individuals we had intended them to designate.

During the episodic order memory task, the names of each list were presented to participants in a fixed pseudo-random order in the centre of a 12" Toshiba laptop monitor. The names were presented in bold, 38-point Arial font at a rate of 1 name every 1.8 seconds (1.5 seconds word + 0.3 seconds blank intervals). The order of names was controlled such that, across the 7 lists, they appeared in each serial position except for their true position in terms of chronology. For instance, the most distant individual in history would be presented in all serial positions except for position 1. Also, the names of individuals that succeeded each other in history were never presented successively. This ordering of names ensured that participants could not easily rely on any semantic knowledge to facilitate their memory for the episodically defined order. For the semantic task no study-phase was included since this would contaminate participants' semantic knowledge of historical figures with episodically defined information about their chronology.

For the order memory tests, participants were presented with a booklet containing the names of the historical figures of each list in alphabetical order. The seven alphabetised lists were set out in seven columns and next to each column seven underlined spaces demarcated the areas in which participants were to record their answers. For the episodic task participants were instructed to re-order the names of each list according to the order seen on the screen immediately after each list was presented, whilst for the semantic task they were asked to order the names according to their historical chronology. Half of the participants in each group completed the episodic memory task before the semantic memory task whilst the other half completed the tasks in reverse order. After both tasks, participants were given one final booklet containing the alphabetised lists of names with instructions to rate each name on a 10-point familiarity scale (0 = never heard of him/her; 10 = know a lot about him/her).

Procedure

Upon arrival in the laboratory, participants were informed that they would be asked to remember the order of some relatively famous historical figures. They were told that, in one part of the study, they would be presented with short lists of randomly ordered names that they would subsequently be asked to re-construct. In another part of the experiment, on the other hand, participants were to use their knowledge of history in order to arrange the same historical figures in accordance with their actual historical chronology (from most distant in history to the most recent). It was made clear to participants that they should make use of all names when trying to re-arrange them into the respective orders (i.e. random / chronological), even if that meant that they had to guess about what serial position a particular name should occupy. Following these instructions participants commenced either with the episodic or the semantic version of the experiment, continued with the other, and completed the study with the familiarity ratings of the historical figures. Due to time constraints on the day of testing, familiarity ratings for 1 ASD and 2 typical participants were not obtained.

Results

For the analysis of the results, each participant's performance was scored separately for the semantic and episodic task as the proportion of correctly positioned names in each serial position. Since a preliminary analysis of the data revealed no main effects or interactions relating to the order of task completion (i.e. Semantic-Episodic vs. Episodic-Semantic), the data were collapsed across these orders.

Figures 1a and 1b present the serial position curves for the semantic and episodic ordering tasks as a function of group. A 2 (Group) x 2 (Task) x 7 (Serial Position) mixed ANOVA of these data revealed a marginal effect of Task ($F(1, 42) = 3.94$, $MSE = 34.13$, $p = .054$, effect size $r = .29$) and a significant effect of Serial Position ($F(6, 155.6) = 41.10$, $MSE = 89.19$, $p < .001$, Greenhouse-Geisser corrected, effect size $r = .46$). These main effects were further characterised by a Task x Serial Position interaction ($F(6, 169) = 18.60$, $MSE = 30.65$, $p < .001$, effect size $r = .31$), which in turn was qualified by a three-way quadratic interaction with the Group factor ($F(1, 42) = 4.91$, $MSE = 10.16$, $p < .05$, effect size $r = .32$)[2]. Neither the Task x Group nor Serial Position x Group interactions were significant. As Figures 1a and 1b indicate, the interaction between Task and Serial Position, reflects the fact that the primacy region of the serial position curve is enhanced in the episodic task whilst the recency portion of the serial position curve is enhanced in the semantic task. Pair-wise comparisons confirmed this impression. On serial positions 1, 2 and 3, performance on the episodic task (Position 1 M = .90, SD = .15; Position 2 M = .70, SD = .21; Position 3 M = .59, SD = .24) was significantly better than on the semantic task (Position 1 M = .62, SD = .27; Position 2 M = .46, SD = .25; Position 3 M = .41, SD = .28) (Cohen's *d*s > .69) whilst on serial positions 6 and 7, performance was significantly better on the semantic (Position 6 M = .64, SD = .27; Position 7 M = .80, SD = .19) than the episodic task (Position 6 M = .50, SD = .29; Position 7 M = .69, SD = .26) (Cohen's *d*s > .48). Also apparent from Figures 1a and 1b is the source of the 3-way quadratic interaction. Whereas the serial position curves of the ASD and Comparison groups are nearly identical for the semantic task, on the episodic task the ASD group performed relatively worse on serial positions 2 – 5. Between group comparisons confirmed significantly worse ASD than Comparison group performance on serial positions 2 (ASD M = .62, SD = .22; Comparison M = .77, SD = .18; $t(42) = 2.56$, $p < .05$; Cohen's d = .74) and 3 (ASD M = .52, SD = .22; Comparison M = .67, SD = .24; $t(42) = 2.14$, $p < .05$; Cohen's d = .65) and marginally worse performance by the ASD group on serial position 4 (ASD M = .44, SD = .26; Comparison M = .58, SD = .24; $t(42) = 1.89$, $p = .066$; Cohen's d = .56).

(Figure 1a and 1b about here)

Figure 2 shows the ASD and Comparison groups' average familiarity ratings of the historical figures as a function of their chronological order in history (i.e. position 1 = most distant, position 7 = most recent). A 2 (Group) by 7 (Serial Position) ANOVA of these data revealed a main effect of Serial Position ($F(6,168.8) = 66.39$, *MSE* = 45.59, $p < .001$; effect size $r = .53$) but no other main effects or interactions. Further analyses showed that the ratings of the two most recent historical figures (Position 7 *M* = 6.82, *SD* = 1.85; Position 6 *M* = 5.60, *SD* = 1.92) were significantly higher than the average ratings for all other serial positions (Positions 1 to 5 *M* = 4.29, *SD* = 1.76) (Cohen's $d > .71$), which parallels the serial recall findings for the semantic task illustrated in Figure 1a. The association between performance on the semantic task and participants' familiarity ratings was furthermore confirmed by an analysis of correlations between the average familiarity rating of each of the historical figures and their average probability of being correctly positioned in their respective chronological order. Both for the ASD group ($r = .48$, $p < .01$) and the Typical group ($r = .37$, $p < .01$) this correlation was significant. We also calculated point-biserial correlations to quantify the association between each participant's familiarity ratings and their ability to assign each of the historical figures to their correct serial position. The average point-biserial correlation across participants within each group was significantly above 0 (ASD: $r = .18$, $t = 4.71$, df = 20, $p < .01$; Typical: $r = .14$, $t = 2.89$, df = 19, $p < .05$). Finally, it is worth noting that ratings of '0' (i.e. never heard of him/her) were relatively infrequent in both groups. ASD participants used this rating on average 1.9 times (*SD* = 4.4) and typical participants 3.3 times (*SD* = 7.3). This difference is not significant (t = 0.77, df = 39, *ns;* Cohen's $d = .23$) and primarily reflects the ratings of 3 participants (1 ASD and 2 Typical) who rated more than 20 names as 0. Exclusion of these participants from the analyses reported above, however, did not significantly alter the results.

Discussion

The present experiment set out to test the hypothesis that individuals with ASD would exhibit specific episodic but not semantic memory difficulties in a domain that holds great interest in the context of developmental disorders – serial order memory. To test this prediction we drew on the work of Healy et al. (2000) to develop the ‘Historic Figures Task’, which required participants to order the names of 7 relatively famous historical figures either according to a randomly generated sequence (i.e. episodic task), or according to the correct chronological sequence in history (i.e. semantic task). Similar to the findings for much longer lists of stimuli by Healy et al. (2000), we found characteristic differences in the serial position curves resulting from participants’ performance on the two tasks, with enhanced primacy effects in the episodic task but enhanced recency effects in the semantic task. Together with the observation that participants rated the more recent historical figures as more familiar, these observations suggest that the contributions of the semantic and episodic memory system can be dissociated in a procedure that is typically associated with measures of short-term serial order memory (we use this term here very loosely). More importantly, however, our observation of a performance decrement in ASD participants only on the episodic version of the task confirms our prediction that specifically episodic order information poses difficulties for these individuals. Their ability to order a set of stimuli according to temporal information stored in the semantic memory system, by contrast, seems to be preserved. Before we discuss the implications of these observations, we will consider some caveats of our methodology.

The conclusions we draw from the present observations may be questioned on the grounds that the episodic and semantic versions of our Historic Figures Task are not identical in procedure. By definition assessments of episodic memory necessarily involve a study phase, whereas inclusion of a study phase to probe semantic memory would contaminate performance with episodically defined information. This procedural difference invites interpretations of our findings that do not draw on the distinction between episodic and semantic memory. It may be argued, for instance, that poor attention during the study phase of the episodic task contributed to poorer performance by individuals with ASD or that the difficulties of the episodic task reflect general executive function impairments, particularly in the area of working memory. It is also possible that ASD participants experience greater interference effects on the episodic task from knowledge about the actual historical order of the names. Importantly, such interpretations do not deny the fact that ASD is characterised by relatively specific episodic difficulties, they merely offer possible reasons for this. Difficulties in domains such as attention and executive function may all contribute or even fully explain the episodic difficulties we observe in adults. To fully understand how the multiple facets of the complicated cognitive phenotype of ASD interact, however, it is important to examine the cognitive developmental trajectory of the disorder in detail and in this context our observations are of great interest because serial order memory paradigms have been fruitfully employed in studies of typically developing infants to delineate the maturation of semantic and episodic memory (e.g. Bauer, 2004).

There are, in fact, a number of reasons why the study of serial order memory may be of interest in a developmental context in ASD. First, several theoretical frameworks suggest that the maturation of the episodic memory system and the development of certain reciprocal social competences are closely linked and possibly even underpinned by common underlying computational mechanisms (Nelson & Fivush, 2004; Perner, 1991; Perner & Ruffman, 1995). Second, individual differences in the severity of episodic and semantic memory may explain why some individuals with ASD acquire language relatively typically whilst others do not (see Bigham, Boucher, Mayes & Anns, 2010; Boucher, 2012a; Boucher, Mayes & Bigham, 2008 for detailed discussions). Third, considerable evidence implicates abnormalities of the medial temporal lobe and prefrontal cortex in the pathogenesis of ASD (e.g. Bachevalier, 1994; Bachevalier & Loveland, 2006; Bauman & Kemper, 2005) and these regions are well known to play a crucial role in episodic memory (e.g. Brown & Aggleton, 2001; Eichenbaum, 2003; Nicholson, DeVito, Vidal, Sui, Hayashi, et al., 2006). And finally, abnormalities in the development of episodic memory may also play a role in the emergence of stereotyped and repetitive patterns of behaviour that constitutes the least understood diagnostic feature of ASD. This is because the episodic memory system is not only critical for recording past experiences but also for allowing us to re-combine elements of our past to flexibly adapt to and plan for an ever changing environment (Atance & O’Neill, 2001; Eichenbaum, 2004, Schacter & Addis, 2007, see particularly Lind & Bowler, 2010). As Skoyles (2012) has recently argued, stereotyped behaviours and a restricted set of interests may be a sign of a reduction of such flexibility (see Skoyles, 2012).

As the above arguments demonstrate, careful scrutiny of early memory development in ASD holds considerable promise for clarifying aspects of the complex and heterogeneous developmental trajectory that characterises the disorder. Several authors have recently noted that single explanations for the causes of ASD are doubtful and that the heterogeneity of the disorder at all levels of analysis (behavioural, cognitive, genetic, neurobiological) likely reflect the interaction of independent (partially or fully) but interacting causal factors (e.g., Happé & Ronald, 2008; Waterhouse, 2012). The search for these factors is currently largely inspired by the theoretical constructs of Weak Central Coherence (see Happé & Frith, 2006), Executive Dysfunction (see Hill, 2004) and Theory of Mind (see Boucher, 2012b). Considering the domain of memory alongside these established areas of research may prove fruitful not only in further specifying the source of heterogeneity in ASD but also in informing effective intervention programmes (see Gaigg & Bowler, 2012 for discussion).

In conclusion, there is now considerable evidence to show that episodic memory is compromised in ASD, whereas semantic memory is relatively preserved at least in those without concomitant language and general cognitive impairment. In the context of recent demonstrations that episodic and semantic memory begin to mature differentially before the first clinical indices of ASD are normally observed, it is critical to examine the developmental trajectory of episodic and semantic memory in this disorder (see Bigham et al., 2010 for similar arguments). Here we show that the domain of serial order memory will prove invaluable in this context because semantic and episodic memory can be dissociated in this domain across the life-span and because we have now confirmed a dissociation between compromised episodic but preserved semantic serial order memory in adults with ASD. The difficulties individuals with ASD experience on serial order memory tasks, therefore, are representative of the broader pattern of memory strengths and weaknesses in evidence in this disorder. Boucher and colleagues have been calling for closer scrutiny of memory difficulties in ASD for over 3 decades (Boucher & Warrington, 1976, Boucher, 1981; see Boucher, Mayes & Bigham, 2008 for a review). We think that a concerted response to this call by the wider research community is long overdue.

References

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

Atance, C.M., & O'Neill, D.K. (2001). Episodic Future Thinking. *Trends in Cognitive Sciences, 5,* 533 – 539.

Bachevalier, J. (1994). Medial temporal lobe structures and autism: A review of clinical and experimental findings. *Neuropsychologia,* 32, 627-648.

Baird, G., Simonoff, E., Pickles, A.., Chandler, S., Loucas, T., Meldrum, D., & Charman, T. (2006). Prevalence of disorders of the autism spectrum in a population cohort of children in South Thames: the Special Needs and Autism Project (SNAP). *Lancet, 368,* 210-215.

Bauer, P.J. (2004). Getting explicit memory off the ground: Steps toward construction of a neuro-developmental account of changes in the first two years of life. *Developmental Review, 24,* 374-373.

Bauer, P.J., Wenner, J.A., Dropik, P.L. & Wewerka, S.S. (2000). Parameters of remembering and forgetting in the transition from infancy to early childhood. *Monographs of the Society for Research in Child Development, 263(65),* 1-204.

Bauman, M.L., & Kemper, T.L. (2005). Neuroanatomic observations of the brain in autism: a review and future directions. *International Journal of Developmental Neuroscience,* 23, 183-187.

Bennetto, L., Pennington, B.F., & Rogers, S.J. (1996). Intact and impaired memory function in autism. *Child Development*, 67, 1816-1835.

Bigham, S., Boucher, J., Mayes, A., & Anns, S. (2010). Assessing recollection and familiarity in Autistic Spectrum Disorders: Methods and findings. *Journal of Autism and Developmental Disorders, 40,* 878-889.

Boucher, J. (2012a). Research Review: Structural language in autistic spectrum disorder – characteristics and causes. *Journal of child psychology and psychiatry, 53,* 219 – 233.

Boucher, J. (2012b). Putting theory of mind in its place: psychological explanations of the socio-emotional-communicative impairments in autistic spectrum disorder. *Autism, 16,* 226-246.

Boucher, J. (1981). Immediate free recall in early childhood autism: Another point of behavioural similarity with the amnesic syndrome. *British Journal of Psychology, 72,* 211-215.

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

Boucher, J., Mayes, A., & Bigham, S. (2008). Memory, language and intellectual ability in low functioning autism. In J. Boucher & D.M. Bowler (Eds.), *Memory in Autism: Theory and Evidence.* Cambridge: Cambridge University Press.

Boucher, J., Mayes, A., & Bigham, S. (2012). Memory in Autistic Spectrum Disorder. *Psychological Bulletin,* Online First, March 12.

Boucher, J., & Warrington, E.K. (1976). Memory deficits in early infantile autism: Some similarities to the amnesic syndrome. *British Journal of Psychology, 67,* 73-87.

Bowler, D.M. (2007). *Autism Spectrum Disorders: Psychological Theory and Research.* Chichester: John Wiley & Sons Ltd.

Bowler, D.M., & Gaigg, S.B. (2008). Memory in ASD: Emerging themes and future prospects. In J. Boucher and D. M. Bowler (Eds.), *Memory in autism: theory and evidence* (pp. 330-349). Cambridge: Cambridge University Press.

Bowler, D.M., Gaigg, S.B., &, Gardiner, J.M. (2008a). Subjective organisation in the free recall of adults with Asperger's syndrome. *Journal of Autism and Developmental Disorders,* 38, 104-113.

Bowler, D.M., Gaigg, S.B., &, Gardiner, J.M. (2008b). Effects of related and unrelated context on recall and recognition by adults with high-functioning autism spectrum disorder. *Neuropsychologia, 46,* 993-999.

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

Bowler, D.M., Gardiner, J.M., & Berthollier, N. (2004). Source memory in Asperger's syndrome. *Journal of Autism and Developmental Disorders*, 34, 533-542.

Bowler, D.M., Gardiner, J.M., & Gaigg, S.B. (2007). Factors affecting conscious awareness in the recollective experience of adults with Asperger's syndrome. *Consciousness and Cognition*, 16, 124-143.

Bowler, D.M., Gardiner, J.M., & Grice, S. (2000b). Episodic memory and remembering in adults with Asperger's syndrome. *Journal of Autism and Developmental Disorders*, 30, 305-316.

Bowler, D.M., Matthews, N.J., & Gardiner, J.M. (1997). Asperger's syndrome and memory: Similarity to autism but not amnesia. *Neuropsychologia,* 35, 65-70.

Brown, M.W., & Aggleton, J.P. (2001). Recognition memory: what are the roles of the perirhinal cortex and hippocampus? *Nature Reviews: Neurosciences,* 2, 51-61.

Crane, L., & Goddard, L. (2008). Episodic and semantic autobiographical memory in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 38,* 498-506.

Eichenbaum, H. (2004). Hippocampus: Cognitive processes and neural representations that underlie declarative memory. *Neuron,* 44, 109-120.

Gaigg, S.B., & Bowler, J.M. (2012). Relational memory difficulties in autism spectrum disorder: Implications for education. *British Journal of Educational Psychology Monograph Series, 11,* 34 – 52.

Gaigg, S. B., Gardiner, J. M., & Bowler, D. M. (2008). Free recall in autism spectrum disorder: the role of relational and item-specific encoding. *Neuropsychologia,* 46, 986-992.

Gardiner, J.M. (2001). Episodic memory and autonoetic consciousness: A first-person approach. *Philosophical Transactions of the Royal Society London, B,* 356, 1351-1361.

Goddard, L., Howlin, P., Dritschel, B., & Patel, T. (2007). Autobiographical memory and social problem-solving in Asperger Syndrome. *Journal of Autism and Developmental Disorder,* 37, 291-300.

Gupta, P., & MacWhinney, B. (1997). Vocabulaty Acquisition and Verbal Short-Term Memory: Computational and Neural Bases. *Brain and Language, 59,* 267-333.

Happé, F., & Frith (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 36,* 5-25.

Happé, F., & Ronald, A. (2008). The 'fractionable autism triad': A review of evidence from behavioural, genetic, cognitive and neural research. *Neuropsychological Reviews, 18,* 287-304.

Hermelin, B., & O'Connor, N. (1967). Remembering of words by psychotic and subnormal children. *British Journal of Psychology,* 58, 213-218.

Hermelin, B., & O'Connor, N. (1970). *Psychological Experiments with Autistic Children.* Oxford: Pergamon Press.

Healy, A.F., Havas, D.A, & Parker, J.T. (2000). Comparing serial position effects in semantic and episodic memory using reconstruction of order tests. *Journal of Memory and Language,* 42, 147-167.

Hill, E.L. (2004). Executive dysfunction in autism. *Trends in Cognitive Science, 8,* 26-32.

Lind, S.E., & Bowler, D.M. (2008). Episodic memory and autonoetic consciousness in autistic spectrum disorders: the role of self-awareness, representational abilities and temporal cognition. In J. Boucher and D. M. Bowler (Eds.), *Memory in autism: theory and evidence* (pp. 166-187). Cambridge: Cambridge University Press.

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

Lord, C., Risi, S., Lambrecht, L., Cook, E.H., Leventhal, B.L., DiLavore, P.C., Pickles, A., & Rutter, M. (2000). The Autism Diagnostic Observation Schedule-Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30,* 205-223.

Mayes, A., & Boucher, J. (2008). Acquired memory disorders in adults: implications for autism. In J. Boucher and D. M. Bowler (Eds.), *Memory in autism: theory and evidence* (pp. 43-62). Cambridge: Cambridge University Press.

Minshew, N.J., & Goldstein, G. (1993). Is Autism an amnesic disorder? Evidence from the California verbal learning test. *Neuropsychology,* 7, 209-216.

Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural developmental theory. *Psychological Review, 111,* 486-511.

Nicholson, R., DeVito, T.J., Vidal, C.N., Sui, Y., Hayashi, K.M., Drost, D.J., Williamson, P.C., Rajakumar, N., Toga, A.W., & Thompson, P.M. (2006). Detection and mapping of hippocampal abnormalities in autism. *Psychiatry Research: Neuroimaging, 148,* 11-21.

O'Connor, N., & Hermelin, B. (1967). Auditory and visual memory in autistic and normal children, *Journal of Mental Deficiency Research,* 11, 126-131.

Perner, J. (1991). *Understanding the representational mind.* Cambridge, MA: MIT Press.

Perner, J., & Ruffman, T. (1995). Episodic memory and autonoetic consciousness: Developmental evidence and a theory of childhood amnesia. *Journal of Experimental Child Psychology, 59,* 516-548.

Poirier, M., & Martin, J.S. (2008). Working memory and immediate memory in autism spectrum disorders. In J. Boucher & D. Bowler (Eds.). *Memory in autism: theory and evidence* (pp. 231-248). Cambridge: Cambridge University Press.

Poirier, M., Martin, J.S., Gaigg, S.B., & Bowler, D.M. (2011). Short-Term memory in Autism Spectrum Disorder. *Journal of Abnormal Psychology, 120,* 247-252.

Schacter, D.L., Addis, D.R., & Buckner, R.L. (2008). Episodic simulation of future events: Concepts, data and applications. *Annals of the New York Academy of Science,* 1124, 39-60.

Schacter, D.L., & Addis, D.R. (2007). The cognitive neuroscience of constructive memory: remembering the past and imagining the future. *Philosophical Transactions of the Royal Society B, 362,* 773-786.

Skoyles, J.R. (2011). Autism, Context/Noncontext Information processing, and atypical development. *Autism Research and Treatment, Article ID 681627.*

Smith, B.J., Gardiner, J.M., & Bowler, D.M. (2007). Deficits in free recall persist in Asperger's syndrome despite training in the use of list-appropriate learning strategies. *Journal of Autism and Developmental Disorders,* 37, 445-454.

Tanweer, T., Rathbone, C.J., & Souchay, C. (2010). Autobiographical memory, autonoetic consciousness, and identity in Asperger syndrome. *Neuropsychologia, 48,* 900 – 908.

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

The Psychological Corporation. (2000). *Wechsler Adult Intelligence Scale III UK edition (WAIS III^{UK}) (3rd ed.).* London: The Psychological Corporation.

Tulving, E. (2001). Episodic memory and common sense: how far apart? *Philosophical Transactions of the Royal Society London, B*, 356, 1505-1515.

Waterhouse, L. (2012). Rethinking Autism: Variation and Complexity. London: Academic Press.

Williams, D., Botting, N., & Boucher, J. (2008). Language in Autism and Specific Language Impairment: Where are the links? *Psychological Bulletin, 134,* 944-963.

Yirmiya, N., & Charman, T. (2010). The prodrome of autism: Early behavioural and biological signs, regression, peri- and post-natal development and genetics. *Journal of Child Psychology and Psychiatry, 51,* 432-458.

Footnotes

[1] This difficulty in drawing on conceptual relations to facilitate free recall is often described as a ‘semantic’ processing impairment. It is important to note, however, that this use of the term ‘semantic’ refers to the information gained from the hierarchical relations of category exemplars or concept features, which differs from Tulving’s (2001) concept of semantic memory as a store of knowledge pertaining to individual items (‘timeless-facts). To avoid confusion, we will reserve the term ‘semantic’ exclusively for reference to Tulving’s concept of semantic memory.

[2] This interaction remains reliable when age ($F(1, 41) = 4.68$, $MSE = 9.91$, $p < .05$), Verbal IQ ($F(1, 41) = 4.77$, $MSE = 9.86$, $p < .05$) or both of these variables are entered as covariates in the analysis ($F(1, 40) = 4.67$, $MSE = 9.91$, $p < .05$).

Table 1

Psychometric characteristics of the ASD and TD groups.

Measure	ASD (*n* = 22)			TD (*n* = 22)			Cohen's *d*
	M	*Range*	*SD*	*M*	*Range*	*SD*	
Age (years)	37.6	19 – 61	13.4	40.5	22 – 54	10.8	0.24
VIQ[a]	106.6	81 – 134	14.1	107.5	82 – 131	13.6	0.06
PIQ[a]	103.8	77 – 132	16.0	104.8	72 – 138	18.5	0.06
FIQ[a]	103.4	80 – 122	13.4	107.0	77 – 138	16.4	0.24
ADOS Com.[b] (N=19)	2.4	0 – 5	1.5	-	-	-	
ADOS RSI[b] (N=19)	6.8	3 – 12	2.8	-	-	-	
ADOS Tot.[b] (N=19)	9.3	5 – 17	3.3	-	-	-	

[a]Verbal (VIQ), Performance (PIQ) and Full-Scale (FIQ) Intelligence Quotients as measured by the WAIS-R[UK] or WAIS-III[UK]. VIQ is computed exclusive of the digit span subtest.

[b]ADOS-G Communication (Com.), Reciprocal Social Interaction (RSI) and Total (Tot.) algorithm scores.

Figure Legends

Figure 1a, 1b

Average proportions of correctly positioned names as a function of task, serial position and participant group.

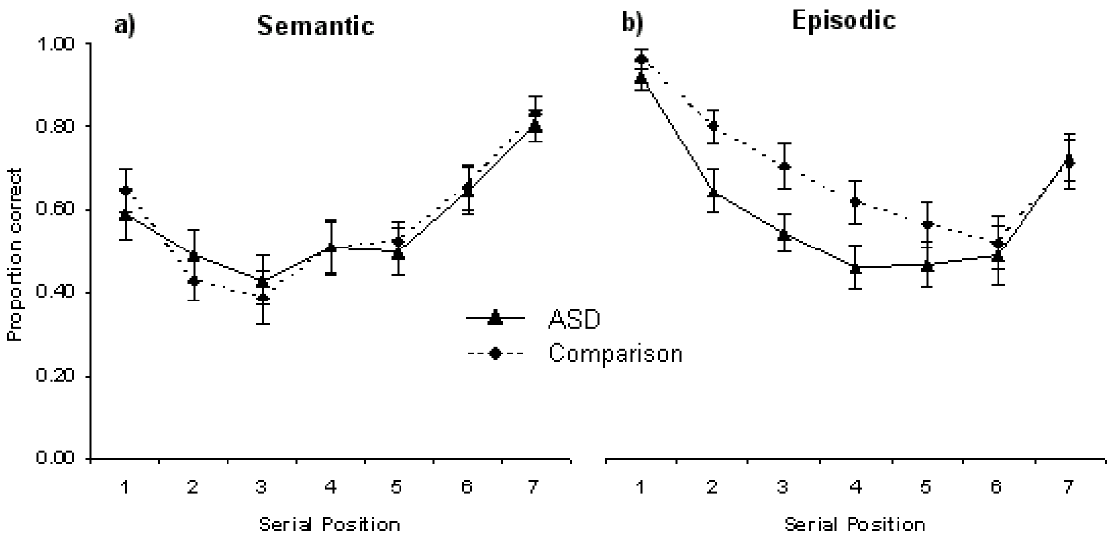
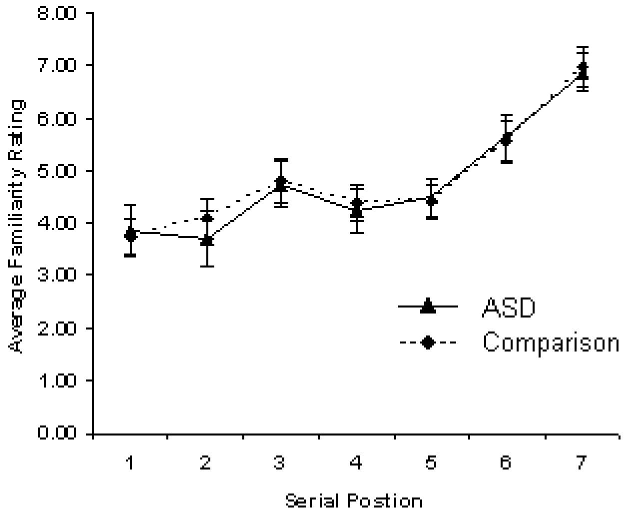


Figure 2

Average familiarity ratings of historical figures as a function of their chronology (1 = most distant, 7 = most recent in history) and participant group.



Appendix 1

Alphabetised lists of the Historical Figures used as the experimental material.

List 1	**List 2**	**List 3**	**List 4**	**List 5**	**List 6**	**List 7**
Gandhi	Archimedes	Caesar	Alexander	Augustus	Copernicus	Aristotle
Henry I	Churchill	Dickens	Buddha	Brunel	Dante	Attila
Hippocrates	Columbus	Galileo	Elvis	Charlemagne	Goliath	Cleopatra
Jesus	George I	Lennon	Genghis	Charles I	Hannibal	Da Vinci
Kepler	Napoleon	Mohammed	Marx	Hitler	Judas	Darwin
Nelson	Nero	Mozart	Pilate	Michelangelo	Lincoln	Ramses
Spartacus	Tutenkhamen	Solomon	Shakespeare	Pythagoras	Newton	Washington