Directed forgetting in high-functioning adults with Autism Spectrum Disorders

Brenda J. Meyer[1], John M. Gardiner[2] and Dermot M. Bowler[2]

[1]Developmental Brain-Behaviour Laboratory, Psychology, Southampton University, Southampton

[2]Autism Research Group, Department of Psychology, City University London

Corresponding author

Email: B.J.meyer@soton.ac.uk

Telephone: +44 (0) 23 8059 8941

Abstract

Rehearsal strategies of adults with autism spectrum disorders and demographically matched typically developed adults were strategically manipulated by cueing participants to either learn, or forget each list word prior to a recognition task. Participants were also asked to distinguish between autonoetic and noetic states of awareness using the Remember/Know paradigm. The ASD group recognised a similar number of to-be-forgotten words as the TD group, but significantly fewer to-be-learned words. This deficit was only evident in Remember responses that reflect autonoetic awareness, or episodic memory, and not Know responses. These findings support the elaborative encoding deficit hypothesis and provide a link between the previously established mild episodic memory impairments in adults with high functioning autism and the encoding strategies employed.

Key words: autism, autonoetic awareness, elaborative rehearsal, episodic memory

Individuals with autism spectrum disorders (ASDs) typically display spared and impaired performance on memory tasks. For example, adults and children with ASDs show mild deficits in the recall of related lists of words, or word-strings, compared with demographically-matched comparison participants, although the recall of unrelated words between ASD and comparison samples, is similar (Bowler et al. 2010; Bowler et al. 2007; Bowler et al. 2000; Bowler et al. 1997; Gaigg et al. 2008; Hermelin and O'Connor 1967; Mottron et al. 2001; Smith et al. 2007; Toichi and Kamio 2003), but see (Beversdorf et al. 1998; Lopez and Leekam 2003; Ramondo and Milech 1984). These deficits have been explained in terms of the ‘week central coherence’ account of autism (Frith and Happe 1994; Happe 1994) that holds that individuals with ASDs show a pattern of neuropsychological deficits consistent with an impaired ability to place information within a wider context. That is, they display a local rather than a global bias (Frith and Happe 1994; Happe 1994). However, the recall of related material by individuals with ASDs can match that of comparison samples when provided with appropriate support, such as cues at test (Boucher 1981; Boucher and Warrington 1976b; Bowler et al. 2004; Bowler et al. 1997). This would imply that the mild memory impairments in ASD populations result from impaired recall, although it has also been hypothesised that recall deficits of particular material results from an encoding deficit, or more specifically, that individuals with ASDs engage in less associative elaborative rehearsal than typically developed (TD) individuals (Bowler et al. 2000; Mottron et al. 2001; Smith et al. 2007; Toichi and Kamio 2003).

Two types of encoding were identified in early memory research that have subsequently become known as maintenance, or rote, rehearsal and elaborative rehearsal (Craik and Lockhart 1972; Woodward et al. 1973). Maintenance, or rote rehearsal can be defined as the technique whereby material is merely repeated or maintained either by internal or external speech. Elaborative rehearsal can be defined as the technique by which material is extended upon, usually by making associative links with other stimuli, or prior knowledge. Studies comparing the effects of maintenance and elaborative rehearsal have established that maintenance rehearsal strengthens the memory trace within the context of the rehearsed item. This has been shown to improve recognition, but appears to have little impact upon free-recall. Elaborative rehearsal creates additional memory traces between the rehearsed item and other items, thus increasing the number of cues for retrieval. Consequently, the effects of elaboration improve the chances of both free-recall and recognition (Craik and Tulving 1975; Geiselman and Bjork 1980; Greene 1987; Rundus 1977).

The advantageous effects of elaborative rehearsal have been offered to explain well established effects within memory research. For example, concrete nouns have been shown to be easier to recall than abstract nouns, due to the imaginative and contextual qualities of concrete words that, in comparison to abstract words, more readily lend themselves to elaboration (Paivio and Csapo 1969). Toichi and Kamio (2003) replicated this 'concrete-noun effect' in a sample of TD adults using Japanese words. In a further study by the same authors, a group of adults with High-Functioning Autism (HFA) recalled fewer concrete nouns, but a similar number of abstract nouns to that of a matched sample of adults without autism. As the free-recall of concrete nouns is considered to be enhanced because they increase the potential to make associative links in comparison to abstract nouns, the authors concluded that the individuals with autism engaged in less associative elaborative encoding than the adults without autism (Toichi and Kamio 2003).

A further well established phenomenon in memory research also linked to rehearsal strategies is the ‘levels of processing’ framework. Asking participants to attend to semantic features (meaning) of words increases the efficacy of recall in comparison to asking participants to attend to phonological features (sound), which in turn is more effective than asking them to attend to graphic, or visual features. Consequently, the efficacy of recall is linked to the depth of encoding (Craik and Lockhart 1972; Craik and Tulving 1975). Toichi and Kamio (2002) found that in a ‘levels of processing’ recognition task, a group of adults with HFA displayed a reduced levels-of-processing effect in comparison to TD adults, even though overall recognition rates were similar between the two groups. As the adults with HFA recognised significantly more words with graphic cues than the comparison group and, unlike comparisons, they did not recognise significantly more words with semantic cues than those with phonological, or graphic cues, the authors suggested a possible superior rote memory in their sample of individuals with HFA which may compensate to a certain extent for a potential elaborative encoding deficit (Toichi and Kamio 2002). The evidence that the individuals with HFA may have employed different strategies from those of the TD individuals in this sample was also supported by the finding that the performance at semantic level significantly correlated with non-verbal reasoning ability (based on Raven’s coloured progressive matrices task) in the HFA group, but not in the comparison group (Toichi and Kamio 2002).

Differences between adults with HFA and comparison groups in the recollective experience of recognition memory have also been established using the Remember/Know paradigm (Bowler et al. 2007; Bowler et al. 2000; Gardiner et al. 2003). Within this paradigm participants are asked, following recognition of an item, to distinguish between two states of awareness (Remember and Know), with Remember responses reflecting autonoetic awareness and Know responses reflecting noetic awareness (Gardiner and Richardson-Klavehn 2000; Tulving 1985). Tulving (2002) defined autonoetic awareness as that which 'allows us to be aware of subjective time in which events happened' (p. 2) and it reflects episodic memory (Tulving 2002). In contrast, noetic awareness of an item/event lacks the association with the time or place that the memory was acquired while maintaining the quality, or strength, of the recognition and reflects semantic memory. Consequently, if participants can link their recognition of an item to the time of learning (e.g. they remember what they thought about when they first saw the word, or remember whereabouts in the list the word fell in relation to the other words), they are asked to give a Remember response. If they are unable to offer this additional information but still have a strong feeling of recognition, they are asked to give a Know response. A group of adults with Asperger's Syndrome (AS), while correctly recognising a similar number of items overall, offered significantly fewer Remember responses than a comparison group matched for age and IQ, thus demonstrating reduced autonoetic awareness, or a mild episodic memory impairment (Bowler et al. 2000). Subsequent studies have established reduced Remember responses in individuals with HFA compared with a matched comparison group in conscious awareness tasks (Bowler et al. 2007) and in a sensory/perceptual source memory task (Souchay et al. 2012).

As the Remember/Know paradigm has also been used to establish a dissociation of the effects of rehearsal, with elaborative rehearsal selectively affecting Remember responses and maintenance rehearsal selectively affecting Know responses (Dobbins et al. 2004; Gardiner et al. 1994; Gardiner and Richardson-Klavehn 2000), these findings also are consistent with the notion that the adults with AS engage in less elaborative rehearsal than TD adults. As yet, there is no conclusive evidence to link the episodic memory impairments in this population specifically to the rehearsal styles employed.

An earlier experiment conducted by us aimed to directly test the rehearsal strategies of a group of adults with AS by means of an overt rehearsal experiment (in which participants were asked to try and learn lists of words by repeating them out loud). While this study failed to show a significant difference in the natural rehearsal strategies employed, it did reveal a trend for the adults with AS to engage in slightly less elaborative rehearsal and slightly more rote rehearsal than a matched comparison group (Smith et al. 2007). However, the overt rehearsal technique places additional task demands that may mask the subtle memory impairments of individuals with ASDs. The main aim of the present study, therefore, was to find a more sensitive technique than the overt rehearsal method that measures covert encoding strategies and avoids additional task demands. A sensitive way to covertly manipulate rehearsal strategies is the ‘directed forgetting’ paradigm. Using this established memory paradigm may effectively reveal potential subtle differences between natural rehearsal strategies of adults with ASDs and a demographically matched comparison sample.

In the directed forgetting paradigm, participants are instructed to either learn or forget words, either after the presentation of each item, or after the entire list has been displayed (Basden and Basden 1996; MacLeod 1999). Typically, in a subsequent recall or recognition test in which participants are unexpectedly asked to recall or recognise words from a list *regardless* of the type of cue (learn/forget), participants show a distinct bias to recall or recognise more to-be-learned words than to-be-forgotten words. In the case of the item method, the 'directed forgetting effect' was suggested to occur because participants only engage in active elaborative rehearsal following the cue to learn, but not following the cue to forget (Basden and Basden 1996; Bjork and Woodward 1973; Woodward and Bjork 1971). The rehearsal strategy of the participants using the directed forgetting task can be further manipulated by introducing a cue-delay (Woodward et al. 1973). Maintaining the overall presentation timing of the word to-be-learned or to-be-forgotten, while introducing a delay prior to the learn/forget cue being presented (cue-delay) was hypothesised by Woodward et al (1973) to increase the use of rote rehearsal (while participants awaited the cue) and decrease the opportunity for elaborative rehearsal.

Using the cue-delay in a directed forgetting recognition experiment that also incorporated the Remember/Know procedure, Gardiner et al., (1994) found improved recognition of to-be-forgotten words after a long cue-delay (5 sec) in comparison to a short cue-delay (0 sec) (Gardiner et al. 1994). Overall, Remember responses (regardless of cue delay) were much higher for to-be-learned words, while Know responses were slightly higher for to-be-forgotten words. These results are consistent with the view that the effects of effortful, elaborative learning strategies increase autonoetic awareness and less effortful, rote strategies increase noetic awareness. This assumption was further supported by the effect of the cue delay. The impact of the increased maintenance rehearsal after the long cue-delay (hypothesised to increase rote rehearsal) was evident in increased Know responses versus Remember. Conversely, the impact of the short cue-delay, (hypothesised to maximise the potential for elaborative rehearsal), was evident in increased Remember responses versus Know. Consequently, while both elaborative and rote rehearsal strategies improve recognition, the effects of each strategy result in a dissociative effect on the type of recognition (Remember or Know). Thus, the Remember/Know paradigm appears to reflect the extent to which each rehearsal strategy (rote/elaborative) is effectively employed.

The study reported here replicated the recognition experiment by Gardiner et al., (1994) with the aim of establishing whether the mild episodic memory impairments previously established in adults with ASDs, may result from the use of less elaborative rehearsal strategies than that of TD adults matched for age and IQ. It was hypothesised that adults with ASDs would display a diminished directed-forgetting effect in comparison to a matched comparison group, as a result of less effective learning strategies for the to-be-learned words. Consistent with this hypothesis, this potential deficit should be evident in Remember responses, not Know (as elaboration only affects R) and should be most apparent in a short cue-delay condition (when the potential to engage in elaborative rehearsal is maximised).

Method

Participants

A total of 32 adults with and without HFA participated in the experiment, 16 (12 men and 4 women) of whom had a diagnosis of AS, supported by ADOS assessments, where possible. All except two participants in the ASD group had received their diagnosis from experienced clinicians within the UK health services. ADOS assessments were not systematically carried out but were available for 9 of the individuals for whom algorithm scores supported the clinical diagnosis according to ICD-10 criteria (World Health Organization 1992) and DSM-IV-TR criteria (American Psychiatric Association 2000), excluding the measure for language development, as this information was often unavailable. There were no evident language impairments in any of the participants during interactions with the experimenter. For two AS individuals, no written confirmation of their AS diagnosis was available but our research experience with this clinical group left us in no doubt that the interactive style of these individuals were consistent with a clinical diagnosis of ASD. Since removing these two participants from the analyses did not alter the trend of the overall observations reported below, we took the conservative decision to retain them in our sample and report the main results of interest with and without these two participants and their appropriately matched TD comparison pair. In total, sixteen participants from the overall sample (10 men and 6 women) were TD adults, selected to match individuals within the ASD group on the grounds of age and verbal IQ scores, as measured on the WAIS III (Wechsler Adult Intelligence Scale, Third Edition, The Psychological Corporation, 1997). All participants had a VIQ score of 84, or above and volunteered to take part following recruitment campaigns, either placed in the local press (for TD adults), or leaflets distributed to Asperger support groups (for ASD participants). All participants gave informed consent prior to taking part in the study. Procedures regarding consent and participation rights met prior ethical approval from the institution and were therefore performed in accordance with the ethical standards laid down by the Declaration of Helsinki (1964) and its later amendments.

Design and Materials

The experiment used a mixed 2 x 2 x 2 design. The between group variable was ASD group vs. TD group. The other experimental design factors were the directed forgetting instructions (learn vs. forget) and the period of cue delay (short vs. long). The materials were 176 concrete nouns taken from (Paivio et al. 1968) lists, each with imagery and concreteness ratings of 5 or above and meaningfulness ratings of 4.5 or above and thus all contained highly elaborative qualities. These were divided into 2 lists of 88 words, each matched on rating scores for imagery, concreteness, meaningfulness and word length overall. One of the two lists was presented as study items, and the other was presented as distracter items during the recognition trial. These were switched between participants in order to counterbalance study items vs. distracters. The study list of 88 words was subdivided into 44 words with a short cue-delay and 44 words with a long cue-delay. Within each of these 44 words, half were designated to-be-learned items and half were designated to-be-forgotten items. The presentation of the words was blocked according to cue-delay. Half of each participant group received the words with a long cue-delay first and half received the words with a short cue-delay first. Within these 2 blocks, the words and types of cue were randomised for each participant, so that they were unable to predict which words were to-be-learned and which were to-be-forgotten. The type of cue was counterbalanced between each half of the list, so that words that were to-be-learned for half of each participant group became to-be-forgotten words for the other half of each group. Consequently, all list words were rotated across each condition.

Procedure

Prior to the recognition trial, participants were given standard directed forgetting instructions (see Appendix 1). Participants were then shown a practice trial so that they experienced both the visual presentation of the words and cues, as well as the change in the timing of the cue and were not taken by surprise during the actual study phase. The practice trial incorporated a total of 10 words drawn from the same source as the study and distracter items, but not included in either experimental phase. The practice items were followed randomly by either LLLL (the cue to learn) or FFFF (the cue to forget). The first 5 practice items were followed by a short cue-delay and the latter half were followed by a long cue-delay. Once participants had indicated that they understood the task, the study phase began.

As in the practice trial, words were displayed individually in black text on a laptop computer screen with a white background. Each word was centred horizontally and vertically on the screen and remained on display for 1 s. The cues were also centred horizontally and vertically. In the short delay condition, the cue appeared directly (0 s.) after the study-word. The cue (LLLL or FFFF) was then displayed for 1 s., followed by a 5 s. interval before the next study-word appeared. In the long-delay condition, the cue appeared after a 5 s. delay following the study word. The next study word immediately followed (0 s.) the cue's 1 s. presentation period. Consequently, the total presentation time was 7 s. for both the short and long delay conditions.

At the end of the study phase, participants were informed that they would take part in a recognition test in which they were unexpectedly asked to identify ALL of the studied items (regardless of the cue). They were also given detailed instructions on the Remember/Know procedure (see Appendix 2). The terms 'Type A' and 'Type B' were used instead of 'Remember' and 'Know', to ensure that the subsequent decisions were not influenced by the use of these words in everyday language. The distinction between Type A and Type B awareness was based on the instructions used in previous experiments with similar samples who did not show any difficulty with the distinction (Bowler et al. 2000). To further ensure that there were no between-group biases with the understanding between these two states of awareness, participants were then given examples of hypothetical descriptions of memory, which they were asked to identify as either 'Type A', or 'Type B' responses (Appendix 2). Once a participant had demonstrated an ability to distinguish between the two types, they took part in a recognition test of the 88 study items plus 88 distractor items (176 words in total). The presentation of the words was randomised, so that the distracter and study items (whether to-be-learned, to-be-forgotten, or short-cued or long-cued) were all intermingled. These items were displayed individually on the same laptop computer in the same font type and size as at test. Participants were reminded that they should give a 'yes' response if they recognised the test item, *even if* they knew it was a word they were instructed to forget. If the participant responded 'yes', they were then asked to indicate whether they had a 'Type A' or a 'Type B' recollection. Responses were self-paced and the experimenter recorded the responses via the keyboard. From time to time the experimenter would ask the participant to clarify the choice of response (A/B) by asking them to describe what they remembered about the word, to check that these descriptions fitted with the A/B distinction. Each participant was instructed not to guess and to only indicate a positive recognition if they were sure that they had seen the word at test (Appendix 2).

Results

The demographic characteristics of the ASD and TD participants were similar and are summarised in Table 1. The mean age of all participants was 37 years and the mean VIQ score was 105. The VIQ and FIQ of the two participants without a formal diagnosis of an ASD were 111 and 135 (VIQ) and 119 and 140 (FIQ), respectively. When the two participants without confirmation of a formal diagnosis of AS, together with their paired TD comparisons were excluded, the overall mean age was 36 years and the mean VIQ score was 103.

(Insert Table 1).

The average proportion of correctly recognised words was calculated for each participant group according to the type of response (Remember/Know) for each condition, as well as words incorrectly identified. The mean proportion (SD) of unstudied words reported as having been seen were very low for both the ASD participants (0.03 [0.03] and 0.07 [0.08]) for Remember and Know responses, respectively) and TD participants (0.01 [0.03] and 0.07 [0.11]) for Remember and Know responses, respectively), thus indicating that response criteria were similarly stringent for each group.

Comparison of the overall recognition data between groups indicate that the proportion of to-be-learned items correctly recognised by the ASD group is considerably lower than the TD group following either a short, or a long cue-delay (Table 2). In contrast, the proportion of to-be-forgotten words is similar for both groups regardless of the delay.

(Insert Table 2).

These data were analysed by a 2 (ASD vs. TD groups) x 2 (learn vs. forget instruction) x 2 (short vs. long cue-delay) x 2 (Remember vs. Know response) ANOVA. Pearson *r* was calculated as an estimate of effect size (.2 = recommended minimum effect size; .5 = moderate effect; .8 = strong effect) as it is reported as a good indicator of strength of association for psychological data that is normally distributed (Ferguson 2009).

The results of the all participant analysis show a significant effect of the type of instruction (F (1,30) = 80.29; p < .01; r = .85). Overall, the recognition of to-be-learned words was higher than the recognition of to-be-forgotten words. There was also a significant main effect of response type (F (1.30) = 11.55; p < .01; r = .53), with there being more Remember responses on average, than Know responses (Table 2). There was a significant interaction between the type of instruction and the length of cue delay (F (1.30) = 11.02; p < .01; r = .52). The recognition of to-be-learned words was greater following a short cue-delay than a long cue-delay; whereas recognition of to-be-forgotten words was similar for both cue conditions (Table 2). There was also a significant interaction between the type of instruction and the type of response (F (1,30) = 32.44; p < .01; r = .72). Overall, more to-be-learned items were recognised with a Remember response (M = 0.48, Se = 0.04) than a Know response (M = 0.20, Se = 0.02) and, conversely, more to-be-forgotten items were recognised with a Know response (M = 0.23, Se = 0.20) than a Remember response (M = 0.20, Se = 0.03). Each of the results reported above remained significant, with p < .01 when the analysis was conducted excluding the two participants without confirmation of a formal diagnosis of AS and their paired TD comparisons.

Of note, there was a significant three-way interaction between the type of instruction, the length of cue-delay, and response type in the all participant analysis (F (1,30) = 6.39; p = .02; r = .42), and in the analysis excluding the two participants without confirmation of a formal diagnosis of AS and their paired TD comparisons (F (1,26) = 6.87; p = .01; r = .46). This interaction therefore indicates that the manipulated factors of the experiment each had a different impact on the type of response of the participants overall.

The between participant ANOVA results of the all participant analysis showed a significant interaction between instruction and group (F (1,30) = 6.90; p = .01; r = .43). This statistically significant interaction was maintained in the analysis excluding the two participants without confirmation of a formal diagnosis of AS and their paired TD comparisons (F (1,26) = 5.33; p = .03; r = .41). As we predicted that the ASD group would be impaired in their recognition of to-be-learned words and not in their recognition of to-be-forgotten words and that this difference would be most notable in the short cue-delay condition, independent t-tests were performed on the mean recognition of to-be-learned and to-be-forgotten words. In the short cue-delay condition, the Levene's test for equality of variances was significant for the to-be-learned words indicating that the assumption of equal variances between groups in this condition had been violated. The t value with adjusted df to account for the inequality of variance was t (23) = 2.52; p = 0.19; Table 2. Levene's test was not significant for either the to-be-forgotten words in this condition, or for the long cue delay condition. The difference in recognition of to-be-learned words between the ASD and TD participants in the long cue-delay condition was nearing significance (*t* (30) = 1.79; p = .08); whereas the difference in recognition between the two groups for to-be-forgotten words was not significant (Table 2). When this analysis was conducted excluding the two participants without confirmation of a formal diagnosis of AS and their paired TD comparisons, there was a significant difference in recognition of to be learned words following a short-cue delay (*t* (18) = 2.82; p = .01) and following a long cue delay (*t* (26) = 2.48; p = .02).

The results of the all participant analysis ANOVA showed a significant three-way interaction between group, type of instruction, and Remember/Know response (*F* (1,30) = 4.65; *p* = .04; *r* = .37). The pattern of results in Table 2 shows that the instruction to learn or forget had a dissociative effect on the Remember versus Know responses in the TD group (i.e. the instruction to learn increased Remember responses compared with Know and the instruction to forget increased Know responses compared with Remember). In the ASD group, however, the instruction to learn increased Remember responses compared with Know, but the instruction to forget resulted in a similar number of Remember and Know responses. However, when the data were analysed excluding the two participants without confirmation of a formal diagnosis of AS and their paired TD comparisons this three way interaction was no longer statistically significant (*F* (1,26) = 3.79; *p* = .06; *r* = .36).

Post hoc analysis

The SDs for to-be-learned words were larger for the ASD group than for the TD with regard to Remember responses (Table 2). The range of scores with a Remember for the ASD group was .05 to .95 compared with .23 to .95

for the TD group for the to-be learned words following a short cue-delay and .14 to 1.0 (ASD) versus .32 to 1.0 (TD) following a long cue-delay. Only 8 of the ASD participants (50%) met or exceeded the first 25th percentile score of the TD group for Remember responses following both a long-, and a short-cue delay. However, the AS participants with the lowest recognition scores in the short cue-delay condition were not the same participants with the lowest scores in the long cue delay condition, indicating that greater variability in the scores was not merely due to particular outliers. In order to investigate this further, and to consider the role of IQ in relation to the deficit in recall of to-be-learned words for the ASD group, Pearson's correlational analysis were conducted to establish a potential relationship between VIQ and recognition Remember outcomes for to-be-learned words following a short and long cue-delay for both ASD and TD groups.

There was a significant correlation between VIQ and the recognition of to-be-learned words with a Remember response following a short cue-delay in the TD sample (r = .55; p = .03), but not for the ASD sample (r = -.05; p = .85). There was no correlation between VIQ and recognition of to-be-learned words with a Remember response following a long cue-delay in the TD sample (r = .25; p = .35), nor in the ASD sample, although this was nearing significance (r = .46; p = .07). Similar analyses were conducted with the PIQ scores and all revealed non-significant results, although PIQ and the recognition of to-be-learned words with a Remember response for the ASD participants following a long cue-delay was also nearing significance (r = .44; p = .09).

Discussion

The overall recognition of to-be-learned words was greater than to-be-forgotten words in both cue-conditions, regardless of participant group. These results indicate that the adults with ASDs and the TD group were subject to the directed forgetting effect (Basden and Basden 1996; Bjork and Woodward 1973; Woodward and Bjork 1971). The statistically significant three-way interaction between instruction, delay and response shows that the manipulation of the cue timing impacted differently upon the instructions to learn or forget and, in turn, on the recollective experience of Remember versus Know. A comparison of the means presented in Table 2 shows that both groups recognised proportionately more to-be-learned words following a short cue-delay (when potential to engage in elaborative rehearsal is maximised), than a long cue-delay. Conversely, the recognition of to-be-forgotten words was proportionally higher following a long cue-delay (when use of rote rehearsal is increased while awaiting for instruction to learn or forget) than a short cue-delay. This pattern of results replicates the previous findings of Gardiner et al., (1994) and Woodward et al., (1973) and is consistent with the theory that the cue delay manipulates the rehearsal strategies employed. Comparison of the data in terms of Remember and Know in Table 2 reveals that the advantageous recognition of to-be-learned words in both groups of participants was *only* evident in Remember responses, not Know. As Remember responses reflect autonoetic awareness, and as the increased recognition of to-be-learned words was evident in Remember responses but not in Know responses for both groups, these results are consistent with previous findings that elaborative rehearsal independently influences Remember responses (Dobbins et al. 2004; Gardiner et al. 1994; Gardiner and

Richardson-Klavehn 2000). It is also consistent with previous findings that both the effortful learning strategies and the effects on subjective awareness are qualitatively similar for participants with ASDs and comparisons (Bowler et al. 2007).

We proposed that the adults with ASDs would display a diminished directed-forgetting effect compared with TD adults as a result of less effective learning strategies for the to-be-learned words. Consistent with this hypothesis, the proportion of to-be-learned words correctly recognised by the ASD group was lower, on average, than those correctly recognised by the TD group, whereas the proportion of to-be-forgotten words was similar between the two groups, regardless of the cue-delay. These results support previous findings that adults with ASDs engage in less effective learning strategies, on average, than TD adults, at least when the words have been selected for their potential to engage in elaboration, as is the case for concrete nouns (Toichi and Kamio 2003). These results are also consistent with the encoding deficit hypothesis previously offered to explain mild memory impairments in similar samples (Bowler et al. 2000; Smith et al. 2007; Toichi and Kamio 2003).

Based on previous findings that adults with HFA display mild episodic memory impairments (Bowler et al. 2000; Gardiner et al. 2003), we hypothesised that any potential deficit in the recognition of to-be-learned words for the ASD group would be evident in Remember responses, but not Know. The results in Table 2 show that the ASD group recognised fewer to-be-learned words with a Remember response, on average, following both a short and long cue-delay than the TD group; whereas the Know responses for each group were similar in both cue-delay conditions. As Remember responses have been previously shown to be increased by elaborative rehearsal and Know responses have been shown to be increased by rote rehearsal (Dobbins et al. 2004; Gardiner et al. 1994; Gardiner and Richardson-Klavehn 2000), the diminished recognition of study items in Remember responses and not Know is consistent with our hypothesis of an elaborative encoding deficit and indicates that the effortful learning strategies employed by the adults with ASDs were typically less effective than those employed by the TD group, either because the ASD participants engaged in less elaborative rehearsal, or the elaborative rehearsal they did engage in did not enhance their recollective experience to the same extent as that of the TD group.

It was also hypothesised that this effect of cue delay might have greater impact on the TD group than the ASD group, particularly if the ASD participants were not able to take full advantage of the additional time available to engage in elaborative rehearsal. The means in Table 2 show that the recognition of both ASD and TD participants was improved by the additional time available following the short cue-delay and both these increased responses are reflected in Remember responses, not Know. However, there was a statistically significant deficit in the overall recognition of to-be-learned words for the ASD group following a short cue-delay in comparison to the TD group. ASD participants also recognised fewer to-be-learned words, on average, than the TD group following a long cue-delay, but not to a significant extent.

Previous research has indicated that task support at the retrieval stage (Boucher 1981; Boucher and Warrington 1976b; Bowler et al. 2004; Bowler et al. 1997) can improve performance for individuals with ASDs, so establishing ways to support and encourage more consistent and effective learning strategies in individuals with ASDs may equalize performance in memory tasks in which some of this population are currently under-performing. However, it is important to note that not all of the participants in the ASD group were out-performed by the TD group in this current task.

The larger SDs for the ASD participants compared with the TD participants for Remember responses of to-be-learned words shows that the performance of the ASD participants was more inconsistent than the comparison sample (as the TD participants' individual performance was more stable across the two conditions). Other trends in the data support the hypothesis that different strategies were being employed, at least by some of the ASD participants.

For example, there was a significant three-way interaction between instruction, response and group in the analysis including all participants, indicating that the instruction to learn, or forget, impacted differently on each group in relation to Remember and Know responses. This level of significance was not maintained when the analysis was conducted excluding the two participants without a confirmed formal diagnosis of AS and their appropriately matched TD pair. However, this may have been due to a lack of power in the data excluding these participants as the results were in the same direction and just missed significance, whereas the effect sizes of each analysis with and without these participants were very similar.

There was also a very slight trend for the ASD participants to recognise more to-be-forgotten words with a Remember response than the TD participants and for the TD participants to recognise more to-be-forgotten words with a Know response than the ASD participants, at least in the short cue-delay condition. The results of the post-hoc analysis was also of interest, as the relationship with VIQ on the recognition performance for to-be-learned words with Remember response differed between the two groups. Specifically, VIQ was related to the recognition of to-be-learned words with a Remember response for the TD group following a short-cue delay, but not following a long-cue delay; whereas VIQ was not related to the recognition of to-be-learned words with a Remember response for the ASD group following a short-cue delay, but neared significance following a long cue-delay. Although not a robust finding in this experiment, this trend for atypical patterning of Remember/Know responses for the to-be-learned versus to-be-forgotten words, together with the atypical correlational trends in VIQ/PIQ and episodic memory performance may provide further justification to assess the potential for individuals with HFA to engage in compensatory learning strategies (Toichi and Kamio 2002). Recent EEG studies during recognition memory tasks in adults with and without ASDs revealed functional neurological differences between the two groups, regardless of task performance (Massand and Bowler 2013; Massand et al. 2013). Specifically, in a context memory task, TD adults showed different ERP patterns according to the type of task, while adults with ASDs showed similar ERP patterns across the tasks (Massand and Bowler 2013). In a yes-no recognition task, ASD adults showed a parietal focus for old-versus new recognition compared with a mid-frontal bias for similar tasks in TD adults (Massand et al. 2013). Together with the inconsistency in performance across conditions for some individuals with ASDs in this current study, these results are suggestive of an executive dysfunction account of autism (Ozonoff et al. 1991; Russell 1997), or if considered in terms of failing to generalise strategies across conditions is consistent with the week central coherence account (Frith and Happe 1994; Happe 1994). Our study did not directly test these skills, so no further inferences can be made in this regard, but our results provide justification to explore and directly compare learning strategies between ASD and comparison samples. In particular, further research to investigate the role of VIQ and PIQ on verbal memory tasks in adults with ASDs appears warranted.

Conclusion

The mild deficits in the ASD group in comparison to the TD group evident in this study were specific to their episodic recollection of words that they were instructed to learn. These findings not only refine our understanding of the mild memory impairments previously established in individuals with ASDs, but provide an important link between the deficits in free-recall and impaired recognition in this population, as elaborative rehearsal has been shown to impact upon both (Craik and Tulving 1975; Geiselman and Bjork 1980; Greene 1987; Rundus 1977). Our findings indicate that adults with ASDs engage in less effective elaborative rehearsal than TD adults. Elaborative rehearsal has been shown to enhance recall of particular material, most notably concrete nouns, or words with associative qualities (Paivio and Csapo 1969; Toichi and Kamio 2003), so the hypothesis of an elaborative encoding deficit can feasibly be offered to explain previous findings of recall deficits in adults with ASDs, such as the reduced levels-of-processing and concrete noun effects (Boucher and Warrington 1976a; Bowler et al. 2000; Bowler et al. 1997; Smith et al. 2007; Tager-Flusberg 1991; Toichi and Kamio 2003). Elaborative rehearsal improves autonoetic awareness and is demonstrated by increased Remember responses in comparison to Know responses (Dobbins et al. 2004; Gardiner et al. 1994; Gardiner and Richardson-Klavehn 2000). Consequently, our findings also establish a link between the impaired episodic memory in adults with ASDs (Bowler et al. 2007; Bowler et al. 2000; Gardiner et al. 2003; Souchay et al. 2012) and the encoding deficit hypothesis.

As yet, there is no evidence to suggest that individuals with ASDs *cannot* engage in elaborative rehearsal as effectively as TD individuals, merely that they do not appear to naturally employ elaborative strategies to the same extent. Our results suggest that some individuals with ASD may have a normal capacity and efficiency to employ elaborative rehearsal strategies. Indeed, the fact that, like the TD group, the individuals with ASDs also benefited from the additional time available in the short cue-delay condition does offer some support for the notion that they are engaging in elaborative rehearsal, but in some cases, they appear to do so less effectively.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Appendix 1

A list of words will appear on the computer screen one word at a time. After each item has appeared on the screen, it will be followed by a cue to learn the word LLLL *or* a cue to forget the word FFFF. Sometimes the cue to learn or forget will appear immediately after the word has been shown and sometimes there will be a few seconds delay before the cue to learn or forget will appear. In each case, remember that if you see the cue LLLL, you are to try and learn the previous word as best as you can, and if you see the cue FFFF, you do not need to try and learn the word, you can forget it. Each cue to learn or forget will always refer to the word you have just seen NOT the word you are about to see.

Appendix 2

You will now be shown another set of words on the computer screen one at a time. Some of the words will be words that were also included in the list you have just been asked to learn or forget, while some of the words are new words that you will not have seen before. As each word appears on the screen, please consider whether that word is a new word, or if it is a word that was included in the list of words you have just been shown *regardless* of the cue to learn or forget, or whether the cue appeared straight away, or after a short delay.

If you are sure that you recognise the word as being one that you saw earlier in this experiment (whether followed by a LLLL cue, or a FFFF cue) then please say “YES” aloud. If you DO NOT recognise the word as being one that you saw earlier in the experiment, then please say “NO” aloud. If you are not sure if the word was one that you saw earlier or not, then please say “NO”. Only say YES if you are SURE that the word is one that you saw on the screen earlier.

After you say “YES”, you will be asked to make another choice about HOW you remember the word. The choice is between TYPE A and TYPE B. TYPE A and TYPE B are two different ways that people remember things.

Memory TYPE A is when you remember seeing the word in this experiment, and you also remember something about when you actually saw the word. You might remember where the word was in the list of words, what it looked like on the screen, something about what you thought about at the time when you saw the word, or you might remember a picture that you had in your head when you saw the word. A TYPE A kind of remembering is when you remember, and you also remember something about the time when you actually saw the word.

TYPE B is the other way that people can remember things. A TYPE B kind of memory is when you are sure that the word was on the list of words in the experiment but you cannot remember any details about the time that you saw it. For example a TYPE B memory is when you can't remember where the word was in the list, or anything that you thought about at the time, or any picture that you might have had in your head at the time. A TYPE B kind of remembering is when you know that the word was on the list of words that you were asked to remember but you can't remember anything about the actual time when you saw the word on the screen.

In case you forget what you have been asked to do during the test, there will be a short description of when to say TYPE A and when to say TYPE B on a card in front of you. You can also look at these written instructions at any time. Please ask for help if you have any problems, or you don't understand what you are to do during the test.

Table 1.

Participant Characteristics (All Participants)

Group	**Mean Age, years (SD)**	**Mean VIQ score (SD)**	Similarities sub-score, mean (SD)	Information sub-score, mean (SD)	**Mean PIQ score (SD)**	**Mean FIQ score (SD)**
ASDs (n = 16)	36.48 (11.72)	105.44 (14.59)	10.50 (2.73)	10.25 (2.49)	103.00 (18.79)	104.88 (17.56)
TD (n= 16)	37.66 (13.91)	105.25 (14.05)	10.25 (2.84)	10.00 (2.0)	106.44 (12.53)	106.25 (13.86)

ASD, Autism spectrum disorders; VIQ, verbal intellegence quota; PIQ, pictoral intelligence quota;

FIQ, full intellegence quota; SD, standard deviation; TD, typically developed

Table 2.

Mean Proportions of Correct Recognition for both R/K Responses According to Condition for Each Group (All Participants).

	ASDs Group (n = 16)			**TD Group (n = 16)**			**Mean Overall Difference (Se difference) ASD vs. TD**	**Cohen's *d***
	R	**K**	**Overall**	**R**	**K**	**Overall**		
				Short cue-delay				
TBL words (SD)	.44 (.30)	.20 (.15)	**.64 (.25)**	.61 (.23)	.20 (.18)	**.82 (.13)**	-.18 (.07)*	.86
TBF words (SD)	.20 (.16)	.21 (.13)	**.41 (.22)**	.13 (.11)	.27 (.18)	**.40 (.21)**	.01 (.08)	.05
				Long cue-delay				
TBL words (SD)	.38 (.31)	.19 (.16)	**.56 (.29)**	.51 (.21)	.21 (.14)	**.72 (.18)**	-.15 (.08)	.60
TBF words (SD)	.24 (.19)	.20 (.13)	**.44 (.26)**	.23 (.16)	.24 (.13)	**.47 (.25)**	-.03 (0.9)	.12

* $p < 0.05$
ASDs; Autism spectrum disorders; R, remember; K, know; TBL, to-be-learned;

TBF, to-be-forgotten; TD, typically developed.

Author Note

Brenda J. Meyer (previously Smith) and John M. Gardiner were both part of the Department of Psychology, School of Life Sciences, University of Sussex, England at the time of study. Dermot M. Bowler is at the Department of Psychology, City University London, England.

John M. Gardiner is now Honorary Visiting Professor at the Department of Psychology, City University London, England.

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Correspondence concerning this article should be addressed to: Dr Brenda Meyer, Developmental Brain-Behaviour Laboratory, Psychology, Shakleton Building 44, Room 3085, Highfield Campus, Southampton, SO17 1BJ. Tel: Telephone: +44 (0) 23 8059 8941. Email: B.J.Meyer@soton.ac.uk.