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Subjective Organisation in the Free Recall Learning of Adults with Asperger's Syndrome

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Running Head: Subjective Organisation in Asperger's syndrome

Abstract

Single trial methods reveal unimpaired free recall of unrelated words in Asperger's syndrome (AS). When repeated trials are used (free recall learning), typical individuals show improved recall over trials, subjective organisation of material (SO) and a correlation between free recall and SO. We tested oral (Experiment 1) and written (Experiment 2) free recall over 16 trials in adults with AS and typical individuals. Across both experiments AS participants showed marginally diminished recall. Poorer SO was seen in the Asperger group only in Experiment 2, but in both experiments, individual differences in SO in the Asperger group were less likely to converge over trials. This lack of convergence suggests that the AS group organise material in idiosyncratic ways.

Key Words

Asperger's syndrome, memory, free recall, subjective organisation, learning

Introduction

Autistic spectrum Disorder (ASD) is now generally agreed to comprise a set of conditions all characterised by impairments of social, communication and symbolic function (Wing & Gould, 1979) as well as by repetitive behaviours (see DSM-IV TR, American Psychiatric Association, 2000). Global cognitive impairment is found in the majority of individuals described as having autism or autistic disorder, whereas this is not the case for those with Asperger disorder who, in addition to social impairments and repetitive behaviours must show no clinically significant delay or deviance in language development.

Over the past two decades, psychological research into ASD has tended to concentrate on three main areas: impaired understanding of mental states in others (Tager-Flusberg, 2002), executive dysfunction (Hill, 2004) and weak central coherence (Happé, 1999). But in recent years, experimental psychologists have begun to take up a strand of research begun by Hermelin and O'Connor in the 1960s and 70s (see Hermelin & O'Connor, 1970) by investigating more basic psychological processes such as attention (Burack, Enns, Stauder et al., 1997), perception (Mottron & Burack, 2001) and memory (see Boucher & Bowler, in press). Research into memory in ASD has produced a fairly consistent pattern of impaired and spared functions. Working and short-term memory appear in the main to be intact, or at least in line with general developmental level (see Hermelin & O'Connor, 1967; O'Connor & Hermelin, 1967, but see Poirier, Bowler & Gaigg, 2004). Syntactic and semantic priming are also intact (Bowler, Matthews & Gardiner, 1997; Gardiner, Bowler & Grice, 2003). Cued recall using either semantic or phonological cues also appears to be intact (Boucher & Warrington, 1976; Mottron, Morasse & Belleville, 2001; Tager-Flusberg, 1991; Toichi & Kamio, 2002). Recognition memory presents a more mixed picture with some studies showing impairments (Ameli, Courchesne, Lincoln, Kaufman & Grillon, 1988; Barth, Fein & Waterhouse, 1995; Boucher & Warrington, 1976; Bowler, Gardiner & Berthollier, 2004; Summers & Craik,1994) and others not (Bennetto, Pennington & Rogers, 1996; Bowler, Gardiner & Grice, 2000a; Bowler Gardiner, Grice & Saavalainen, 2000b). As Bowler et al. (2004)

observe, there is a confound between presence or absence of global cognitive impairment and type of testing used (yes/no versus forced choice) that makes it impossible to decide precisely what factors might contribute to impaired recognition in this group. Free recall also presents a mixed picture. Boucher and Warrington (1976), Bowler, Matthews and Gardiner (1997), Smith, Gardiner and Bowler (in press) and Tager-Flusberg (1991) all found similar levels of free recall for lists of unrelated nouns. But when lists of items that were semantically or associatively related were employed, people with ASD with or without global cognitive impairment) were less able than matched comparison participants to make use of these relations to maximise performance (see also Bowler et al., 2000b; Smith et al. in press).

This last set of findings is consistent with Hermelin and O'Connor's (1970) observation that autism is a failure to '…encode information meaningfully' (p.129) and that people with ASD have some sort of semantic deficit. Yet the findings on semantic processing are mixed. The results just described for free recall are clear, yet high-functioning adults with ASD have been found to be as susceptible as typical individuals to associatively-generated illusory memories (Bowler et al., 2000b, but see Beversdorf, Smith, Crucian et al. 2000), a finding that is inconsistent with a semantic deficit hypothesis, as are the findings of intact semantic cueing described above. Moreover, semantic categorisation skills were found to be unimpaired in lower-functioning children with ASD by Tager-Flusberg (1985a,b) and by Ungerer and Sigman (1987). Prototype formation, in which participants form an abstract mental representation or prototype on the basis of studied exemplars of a particular category was found to be impaired in children with ASD and cognitive impairment (Klinger & Dawson, 2001) but not in adults with Asperger's syndrome (Molesworth, Bowler & Hampton, 2005), suggesting that global cognitive impairment but not ASD *per se* may impair this capacity.

A possible reason for the pattern of memory performance seen in ASD relates to the way in which to-be-remembered material is learned. To date, most of the investigations of memory in individuals with ASD have tested recall on a single trial; few studies have employed learning paradigms to explore the evolution of memory across trials. Minshew and Goldstein (1993) tested high-functioning adults with ASD using the California Verbal Learning Test (CVLT), part of which involves the learning and free recall of a list of 16 words from four categories over five consecutive trials. They found a significant ASD-related impairment in recall on the fifth trial, indicating poorer learning in the ASD group. Bennetto et al. (1996) also used the CVLT to test high-functioning adolescents with ASD and found significant impairment in the ASD group on trials 3,4 and 5. Minshew and Goldstein also report diminished category and serial clustering in their ASD group, indicating that they were less efficient at re-grouping the presented material in order to enhance the efficiency of their recall.

The effects of level of organisation on learning of verbal material attracted considerable research attention in the 1960s and 1970's (see Tulving, 1968 for a review), and continue as a focus of research activity (see Kahana & Wingfield, 2000). One of the first studies to investigate this relationship was by Tulving (1962), in which participants were asked to learn a list of 16 unrelated words, presented in a different order on each of 16 trials. Free recall was tested at the end of each trial. The results showed that recall improved over trials and that participants tended to organise the order of items in free recall in ways that differed from the order in which they were presented. Moreover, such *subjective organisation* (SO) was found to correlate with learning; participants who imposed greater subjective organisation – those who grouped items in consistent ways, irrespective of how they were presented – tended to recall more items.

Reduced subjective organisation has been demonstrated in people with frontal lobe damage (Eslinger & Grattan, (1994); Gershberg & Shimamura, 1995) as well as in typically ageing individuals (Davis, Small, Stern et al., 2003), although all these studies utilised procedures that differed in one or more respects from the original Tulving (1962) study. The findings from frontal lobe damage and from typical ageing are particularly important in the context of ASD first because of the well-documented difficulties with some executive tasks seen in these individuals (see Hill, 2004a,b) and because of parallels with ASD in the patterning of their memory performance (Bowler et al, 2004).

In view both of the findings from ageing and frontal lobe injury, as well as from the patterning of performance on other memory measures in people with ASD, we can make a number of predictions regarding recall, learning and SO. The findings on unimpaired free recall for unrelated items, would lead us to predict no group differences in either of these measures, at least on early trials. Given that it has been shown that individuals with ASD are less efficient at learning lists of items over repeated presentations (Minshew & Goldstein, 1992; Bennetto et al., 1996) and given that they have difficulties in using semantic relatedness to aid free recall (Bowler et al. 1997; Tager-Flusberg, 1991), we would predict diminished SO and a lower correlation between SO and learning for this group. To test these predictions we replicated Tulving's (1962) procedure with a group of adults with Asperger's syndrome and a matched group of typical individuals. We modified Tulving's procedure by asking for oral rather than written recall.

Experiment 1: Subjective organisation during oral recall.

Method

Participants

Sixteen individuals with Asperger's syndrome (10 Males; 6 Females) and a group of 16 typical individuals (13 Males; 3 Females) were recruited. Comparison participants were individually matched to the Asperger participants within 6 points of Verbal IQ measured using the Wechsler Adult Intelligence Scale (WAIS-R UK or WAIS-III UK). Table 1 summarises the ages and IQ scores for the two groups. All individuals with Asperger's syndrome were diagnosed by experienced clinicians and a review of records confirmed that all met ICD-10 or DSM-IV criteria for Asperger Syndrome excluding the requirement for absence of clinically significant delay or abnormality of language development. Participants whose records did not identify the basis on which diagnoses were made were not included. The Comparison group was recruited through local newspaper advertisements and none had a history of mental illness. Two of the participants with Asperger's syndrome were taking medication for depression. Analysis of the data when these participants were removed did not affect the overall pattern of results reported below.

INSERT TABLE 1 ABOUT HERE

Materials and Design

Sixteen words taken from Tulving (1962) (*accent, barrack, drumlin, finding, garden, hoyden, issue, jungle, lagoon, maxim, office, pomade, quillet, treason, valley, walker*) were presented to participants on 16 trials. The words were presented in lower case 48 point Arial font via a Sony Laptop 15'' monitor at a rate of one word per second. Words appeared at the centre top of the screen and the last word in each trial was followed by a recall cue (i.e. a fixation cross with brief recall instructions). Following Tulving (1962) the order of words across the 16 trials was pre-determined so that every word appeared in each position once and was followed and preceded by every other word once. These 16 presentation orders were rotated across the 16 participants in each group in a similar manner in order to fully counterbalance the order of presentation of the words across participants.

Procedure

Participants were tested individually in a quiet laboratory room or at their home (N = 2). Individuals read instructions explaining that their task would be to try and learn a list of 16 words, which they would see one at a time on 16 separate trials. After each trial they would be required to try to say all of the words they could remember. It was made clear to participants that the order in which they recalled the words did not matter and that they should simply try to recall as many words as possible on each trial. Following these instructions participants were presented with the 16 experimental trials and their oral recall was tape-recorded for later transcription and analysis. No strict time limit for recall was imposed but participants were prompted to move on to the next trial if they did not recall any more words for a period of about 10 seconds. Following the experiment individuals were fully debriefed and paid for their participation.

Computation of indices of organisation

Following transcription of responses, scores were computed for recall performance and ordering of the recalled items. For the recall scores, minor mispronunciations (e.g. *drumlet* instead of *drumlin*) were ignored.

For the computation of the various indices of organisation, extra list intrusions were excluded and repetitions were allowed (Tulving, 1962). We then computed Tulving's subjective organisation (SO) score (for details see Tulving, 1962; Sternberg & Tulving, 1977). A maximum score of 1 indicates that all 16 items on all 16 trials were recalled in the same order; a score of 0 results from all items being recalled on all trials in the order in which they were presented. We also calculated gSO (group subjective organisation) for each trial across participants to determine how homogeneous participants in each group were in terms of use of organisational strategies. As Tulving (1962) illustrated, with repeated presentation of items, individuals become more similar in how they order words during recall.

Results

Free Recall

The number of errors (minor mispronunciations, see above), intrusions and repetitions are summarised in Table 2, which shows that overall there was a relatively large number of repetitions across the 16 trials whereas the number of errors and intrusions was relatively low. Because the data for the number of errors and intrusions were not normally distributed, nonparametric tests were employed to compare groups and indicated that the Asperger group made significantly more errors ($z = 1.97$, $p < .05$; two-tailed) and more intrusions ($z = 2.66$, $p < .05$; two-tailed). Groups did not differ in terms of the number of repetitions ($t = .17$, df = 30, ns). Mean recall on trial 1 was 3.44 (SD = 1.55) for Asperger participants and 4.06 (SD = 1.44) for the comparison group, a difference that was not significant ($t = 1.36$, df = 30, ns).

INSERT TABLE 2 ABOUT HERE

Illustrated in Figure 1 are the learning curves across the 16 trials for the Asperger and Comparison groups. Data were analysed via a 16 (Trial) x 2 (Group) mixed ANOVA. Because the assumption of Sphericity was violated by the trial factor, the Greenhouse-Geisser adjustment was applied where appropriate. There was a main effect of Trial ($F(15,16) = 66.90$, $p < .001$) and Group ($F(1,30) = 6.41$, $p < .05$.

INSERT FIGURE 1 ABOUT HERE

As Figure 1 suggests, although individuals with Asperger's syndrome seem to learn the list as effectively as Comparison participants over the first few trials, they tend to reach a plateau earlier. This impression was confirmed by a significant quadratic trend in the interaction between the Group and Trial factors (F $(1,30) = 6.02$, $p < .05$) suggesting a shallower curvilinear relationship between trials and number of words recalled for the Asperger as compared to the Comparison group. In order to confirm that both groups had reached asymptote in terms of learning the list of 16 items, we carried out an additional 2 (Group) by 4 (Trial) ANOVA on the recall performance over the last block of four trials. This revealed a main effect of Trial (F $(3,28) = 4.33$, $p < .05$) and a marginally significant effect of Group (F $(3,28) = 3.88$, $p = .058$) but no interaction between the factors (F $(3,28) = 0.56$, ns). Post-hoc comparisons showed that the main effect of Trial was mainly due to recall performance on trial 16 being significantly better than on trial 15 ($t = 3.07$,df = 31, $p < .01$). Thus, although the additional learning over the last two trials suggests that neither group had reached complete learning asymptote, the lack of the interaction between the factors suggests that in this respect the groups were similar. Thus it is unlikely that the attenuated recall performance of individuals with ASD during later stages of learning are due to group differences in reaching learning asymptote.

Indices of organisation

The mean SO score for the Asperger group was .253 (SD = .067); for the Comparison group it was .284 (SD = .080), a difference that was not significant (t = 1.19, df = 30, ns). The SO score does not take chance organisation into account, which means that the observed values include an unknown proportion of pair wise repetitions that are simply due to chance. Since the Asperger group recalled significantly fewer words the chance of recalling two words in succession more than once over the 16 trials would be expected to differ between groups. Since it is mathematically not possible to correct the SO score for baseline chance, we adopted Tulving's (1962) strategy of creating random sequences of recall outputs and calculating their SO. This was done by taking each individual's recall output and randomising the order of words in each output, which resulted in an SO value of .199 (SD = .032) for the Asperger group and .187 (SD = .023) for the Comparison group. If the Asperger group did indeed organise the material to a lesser extent across all 16 trials one would expect a smaller difference between their actual and random outputs than for Comparison participants. A 2 (Random/Actual) x 2 (Group) ANOVA revealed a main effect of Random/Actual (F (1,30) = 36.56, p < .001) indicating that the randomised outputs led to significantly lower SO scores than the participant's actual responses. There was no main effect of Group whereas the interaction between the factors was marginally significant (F (1,30) = 3.08, p = .083) suggesting that the organisation imposed on the study material during recall by the Asperger group did not differ as much from a random organisation as was the case for the comparison group. Post-hoc t-tests however showed that actual outputs were significantly more organised than random outputs for both the Asperger (t = 3.30, df = 15, p < .01) and Comparison group (t = 5.14, df = 15, p < .001).

Tulving (1962) reported a significantly positive correlation between SO and learning in his study. In the present experiment, both groups showed a similar positive correlation (Asperger: r = .55, N = 16, p < .05; Comparison: r = .62, N = 16, p < .05), indicating that the positive association between levels of organisation and levels of free recall held for the two groups of participants.

We also computed gSO scores for each trial across participants in order to determine how homogeneous groups were in terms of their organisational strategies. As in the analysis just reported, we computed gSO for the group's actual responses and for a randomised version of their recall in order to determine how much of the observed organisation might be due to chance alone. Figure 2 summarises these results and for illustrative purposes the graph has been smoothed by averaging scores across all possible combinations of 3 successive trials.

INSERT FIGURE 2 ABOUT HERE

Because the calculation of gSO requires that the data for individuals within each group were collapsed, each trial yielded only a single data point. This meant that the analysis required aggregating the trials data into the first 5, middle 6 and last 5 trials prior to using a 2 (Group) x 2 (Actual/Random) x 3 (Trial Block) ANOVA. This revealed main effects for Group (F, (1, 13) = 54.02, p < .001), Actual/Random (F (1,13) = 14.39, p < .05), Trial Block (F (2,13) = 6.93, p < .001) and a significant interaction between Group and Trial Block (F (2,13) = 11.09, p < .01). The interaction reflects the fact that as participants are presented with the study list over successive trials, the difference between the average gSO (Random + Actual) of the two groups becomes greater. Inspection of Figure 2 also shows that this difference results from the Actual gSO of the Comparison participants becoming greater than that of the Random gSO over trials, whereas that of the participants with Asperger's syndrome does not.

Experiment 2. Subjective Organisation during Written Recall

In Experiment 1 we deviated from Tulving's (1962) original procedure in that we asked individuals to recall words orally rather than in writing after each trial. Although the results of Experiment 1 suggest that oral recall did not prevent individuals from adopting organisational strategies, these results may have been affected by the large number of repetitions, which were included in the computation of indices of organisation. It is difficult to exclude such repetitions when computing indices of organisation as this would lead to recall outputs that include word pairs, which were actually not recalled in succession. A further factor that might have affected our measurements of organisation in Experiment 1 was the presence of several very unusual words (e.g. drumlin, hoyden, quillet, pomade) in the list, which was taken from Tulving (1962). Several participants commented on these words and indicated that they were not at all familiar with them. As a result individuals often grouped these words together into a category of 'unknown' words, altering their use of organisational strategies. Finally groups differed in the number of intrusions and errors, which might indicate that the task was more difficult for the Asperger participants than the comparison participants. This could also introduce a confound in the measurement of organisational strategies. For these reasons we conducted Experiment 2 in which we used a second set of 16 more usual words and tested written rather than oral recall to reduce the number of repetitions.

Method

Participants

Sixteen individuals with Asperger's syndrome (10 Males; 6 Females) and 16 typical individuals (10 Males; 6 Females) were recruited for this experiment. Eleven individuals with Asperger's syndrome and 2 typical individuals had also participated in Experiment 1. Again participants were individually matched to within 6 points of Verbal IQ measured with the Wechsler Adult Intelligence Scale –III (WAIS-III). Table 1 summarises the ages and IQ scores for the two groups. All individuals with Asperger's syndrome were diagnosed according to criteria outlined in Experiment 1. All individuals were free of medication.

Materials & Design

With the exception of using a different set of 16 items (border, demon, fortune, gospel, mankind, hardship, ration, segment, suspect, token, upright, vacuum, margin, donor, device, physics), the design of the experiment was identical to that used in Experiment 1.

Procedure & computation of scores

The procedure was identical to that described in Experiment 1 with the exception that participants were asked to write down their responses after each trial. The same scores as described in Experiment 1 were computed.

Results

Recall

As expected the use of written recall instructions dramatically reduced the number of repetitions. For the Asperger group the total number of repetitions across all 16 trials was 1.3 (SD = 1.49) with the comparison group showing a mean of 2.0 (SD = 1.59). No participant made any intrusions and the number of minor errors was negligible. Mean recall on trial 1 was 3.91 (SD =) for the Asperger participants and 4.31 (SD = 1.620) for the comparison group, a difference that was not significant (t = 0.64, df = 30). Figure 3 illustrates the learning curves for the Asperger and Comparison groups. As in Experiment 1 the Trial factor violated the assumptions of Sphericity and we employed the Greenhouse-Geisser correction where appropriate. A 16 (Trial) x 2 (Group) mixed ANOVA resulted in a significant main effect of Trial (F

(15,16) = 82.03, p < .001) and a marginally significant main effect of Group (F (1,30) = 3.19, p < .084). There was however no indication of an interaction between Group and Trial suggesting that writing responses allows individuals with Asperger's syndrome to learn the list at a similar rate to comparison participants despite remembering overall somewhat fewer words. As in experiment 1, we also carried out an additional 2 (Group) x 4 (trial) mixed ANOVA on the recall performance over the last block of 4 trials. Neither the main effect of trial (F (3,28) = 1.17, ns) nor the interaction between trial and group (F (3,28) = 0.41, ns) was significant, indicating that both groups had reached asymptote in terms of their learning. In keeping with our finding from our main analysis, the effect of group was marginally significant (F (3,28) = 3.30, p = .08) over these last 4 trials.

INSERT FIGURE 3 ABOUT HERE

Indices of Organisation

As in Experiment 1, we also computed SO and gSO and then randomised the output of the actual data in order to compute the same indices on the random outputs. For the actual recall outputs the Asperger and Comparison groups obtained SO scores of .234 (SD = .051) and .269 (SD = .035) respectively, which, unlike in Experiment 1, represents a significant group difference (t = 2.22, df = 30, p < .05). The equivalent scores for the randomised outputs were .184 (SD = .028) for the Asperger and .189 (SD = .018) for the Comparison group. A 2 (Random/ Actual outputs) x 2 (Group) ANOVA replicated the results of Experiment 1 by yielding a significant main effect of Random/Actual (F (1,30) = 62.75, p < .001) and a marginally significant interaction between the factors (F (1,30) = 3.05, p = .091). Unlike in Experiment 1 however, we also observed a main effect of group (F (1,30) = 4.59, p < .05), which as noted above and suggested by the interaction, was due to significantly lower SO scores for the Asperger's actual recall outputs.

Similarly to our findings from Experiment 1 we found that the Asperger group did not seem to apply organising strategies homogeneously as a group. This is illustrated in Figure 4, which represents gSO scores for Asperger and Comparison groups, together with randomised counterparts of the two groups' actual recall outputs. For illustrative purposes the graph was smoothed by averaging scores across all possible blocks of 3 successive trials and for the analysis scores were averaged across trials 1-5, 6-11 and 12-16. The 2 (Random/Actual) x 3 (Trial Block) x 2 (Group) mixed ANOVA yielded main effects of Random/Actual (F (1,13) = 199.57, p < .001), Trial Block (F(2,13) = 6.94, p < .01) and Group (F (1,13) = 115.46, p < .001) and a Group by Random/Actual interaction (F (1,13) = 48.07, p < .001). Post-hoc comparisons within each group showed that although the actual recall led to higher gSO scores for both the Asperger (F (1,13) = 8.41, p < .05) and Comparison group (F (1,13) = 406.48, p < .001), gSO for actual outputs was much higher for the Comparison than the Asperger group (F (1,13) = 16.16, p < .01).

General Discussion

Four important findings emerge from the results of the two experiments reported here. First, we confirm existing research (Bowler et al., 1997; Smith et al., in press; Tager-Flusberg, 1991) that Asperger participants are unimpaired in their free recall of unrelated words when given a single trial. Second, the findings show diminished oral free recall and subtly diminished written free recall in individuals with Asperger's syndrome when free recall is measured over successive trials. It could be argued that the improvement in the Asperger group seen in Experiment 2 was a result of 11 of these participants having taken part in the first study, as opposed to only 2 from the comparison group. But the two experiments took place at an 18-month interval, making any carry-over effects unlikely. It could also be argued that the words used in Experiment 2 were simpler, thereby helping recall. However, such an argument would need to explain why no such effect was seen in the Comparison group. Our second finding is that for oral recall, the Asperger participants made significantly more intrusion errors than did the comparison participants. This echoes a finding by Bowler et al. (2000b) and suggests that people with ASD have difficulty in inhibiting articulation of words that come to mind when recalling items. It is interesting that this phenomenon is not in evidence when written recall is required, a finding that suggests that the testing procedure can in some way overcome certain executive difficulties. This observation extends the Task Support Hypothesis developed by Bowler et al. (1997; 2004) which proposes that memory in ASD is better when procedures that provide support (such as cued recall or recognition) are utilised. The finding of fewer intrusions in a written recall condition suggests that errors in memory are less likely in this population when there is a lasting record of output.

Our third finding is that individuals with Asperger's syndrome are also characterised by a tendency to engage in less subjective organisation of studied material than comparison participants. Thus in a situation where behaviour has to be organised over time in order to optimise performance, individuals with Asperger's syndrome seem to be more bound to the structure of the incoming stimuli and less reliant on their stored representations. In the present task, this impairs their free recall performance to a small extent, yet in common with comparison participants, individuals with Asperger's syndrome who engage in greater organisation also recall more items. A tendency to organise recall according to the structure of the learned list rather than to more abstract features such as semantic or associative relatedness among items is not limited to AS. Brébion, David, Jones & Pilowsky (2004) compared the recall by people with schizophrenia and comparison participants of lists of semantically related and unrelated items using a single-trial paradigm. They found that although the schizophrenia group showed similar levels of serial clustering (organising recall order on the basis of the order of items in the learned list) to those of comparison participants, they made less use of semantic clustering, especially on lists of related items, where the choice of such a strategy is more apparent. A task for future research in ASD is to establish the relation between semantic and serial clustering across related and unrelated materials in the same participants in order to determine the ASD-specificity of a preference for stimulus-bound rather than conceptually-based strategies to drive recall. Future studies could also investigate how the provision of different types of cue would affect both recall and organisation of recalled material.

Our fourth, and perhaps most striking finding is the idiosyncratic character of the Asperger participants' patterns of organisation. Whereas in the comparison group, these tended to converge towards a common pattern, those of the Asperger participants did not. This lack of convergence suggests that the basis for organisation in the latter group was not based on parameters that were shared by all the Asperger participants. By contrast, the comparison participants (all of whom were unknown to each other) were evidently using some shared knowledge base around which to organise their memory for the studied words. The most obvious candidate for such a shared system is some kind of pre-existing semantic or associative network that would prompt certain words to be recalled together in clusters. Although existing research shows some semantic or associative sensitivity in individuals with Asperger's syndrome (Bowler et al. 2000b), their failure to make use of such associations in free recall (Bowler et al. 1997; Smith et al. in press; Tager-Flusberg, 1991) suggests that such sensitivity is not as strong as that found in the typical population.

Semantic and associative relatedness are, to some extent socially and culturally defined aspects of the world and it is perhaps not surprising that, because of their social impairment, individuals with ASD should be less likely to use them as a basis for organising their learning of new material. Indeed it is possible to speculate that a tendency to organise material idiosyncratically on the basis of combinations of local and global features that differ across individuals severely constrains the possibility that a common, global focus might emerge at the level of semantic associativeness. This argument resonates with that of Tomasello, Kruger and Ratner (1993), who argue that the development of children with autism may be atypical case because they are unable to develop the shared representations of the world necessary for the cultural transmission of knowledge. Instead, they build up representations that are to some extent specific to each individual, thereby making communication with others more difficult.

This last observation begs the question of why other groups who show impaired subjective organisation or semantic clustering do not show similar social symptomatology to that seen in people with ASD. A likely reason for this is, and one that highlights the developmental nature of ASD is that people with frontal lobe damage, or typically ageing individuals begin to suffer problems in adolescence or adulthood, after a long period (and, crucially, the period of childhood) of unimpaired functioning. People with ASD, by contrast have the condition from birth or very shortly afterwards and as a consequence undergo an atypical developmental trajectory. The case of schizophrenia is interesting in that it is a condition that can be accompanied by negative symptoms of social withdrawal (Andreasen, Nopoulos, Schultz et al, 1994). Although schizophrenia is a condition that often develops in late teens or early adulthood (Loranger, 1984), there is evidence that children who later develop the condition show abnormalities on measures of sociability and neuromotor functioning (Schiffman, Walker, Ekstrom et al., 2005). Thus it remains possible that any psychopathological condition that encompasses social difficulties may be characterised by atypicalities in subjective organisation.

On the basis of the present findings, we cannot specify the precise basis on which the Asperger participants organised their memory for the learned items. It may be that they use a more idiosyncratic set of associative or semantic links, or it may be that they linked items together on the basis of phonological properties of spoken words or of visual-perceptual aspects of written words. The fact that they showed increasing subjective organisation over trials renders it unlikely that they were adopting a simple strategy of serial recall – simple repetition of the study list order – on each trial. Their possible tendency to organise learned material according to a range of aspects of studied material is in line with a number of theoretical perspectives on autism. The literature on local and global processing in individuals from the autistic spectrum shows that when people with ASD view hierarchical stimuli, such as a large letter X made up of small letters O (Navon, 1977) they are less likely than typical individuals to show a global bias by responding to the larger, global stimulus; they are just as likely to respond to the global as to the local stimulus (Mottron, Burack, Iarocci et al., 2003). This diminution of the tendency to focus on the global form at the expense of local detail has echoes in the theory of Weak Central Coherence (WCC) put forward by Frith and Happé (1994) and which has been used to explain aspects of the symptomatology of autistic spectrum syndrome. In the present case, we can speculate that the Asperger participants tend to organise the word list according to idiosyncratic and differently weighted combinations of features including semantic relatedness, thus yielding non-converging organisational patterns. By contrast, the comparison participants may have tended to opt for semantic or associative relatedness as a basis for their organisation, with the result that their organisation patterns showed a greater degree of convergence.

The foregoing analysis is also consistent with the Enhanced Perceptual Functioning model proposed by Mottron and Burack (2001, see also Mottron, Dawson, Soulières, Hubert & Burack, 2006), who argue that in tasks that draw on both conceptual (high-level) and perceptual (low-level) processes, people with ASD will tend to show a bias towards the latter, even when overall levels of performance remain comparable to those of comparison participants. Empirical support for this position can be found in the work of Mottron, Morasse & Bellevile (2001), who tested cued recall in participants with high-functioning ASD and typical development. Overall levels of performance was the same for both groups, but whereas semantic cues were superior to phonological cues in the typical participants, both types of cue were equally effective in the participants with ASD. A similar finding was reported by Toichi and Kamio (2002), who asked participants with high-functioning ASD and a typical comparison group to learn lists of words written in two types of Japanese characters. At study, questions were asked about the kinds of characters used, the sounds of the words or about their meaning, representing graphic, phonemic and semantic levels of analysis. As in the Mottron et al. (2001) study, overall levels of performance were similar for both groups, but whereas recall of the semantically-processed words was higher than that of the graphically or phonemically-encoded ones for the typical group, no such difference emerged for the participants with Asperger's syndrome.

In the context of the present findings, the studies by Mottron et al. and Toichi and Kamio suggest that individuals with ASD do not have the same tendency to neglect superficial, lower-level features of stimuli in favour of more semantic abstraction. In some tasks, such as those of Mottron et al. and Toichi and Kamio, this does not affect their overall level of performance, whereas in the task used in the present studies, performance is compromised to a small but significant extent. The present findings also suggest that this equal reliance on high-level and low-level features of stimuli has the consequence of an individual organisational style that may inhibit the construction of shared social representations of material. What now needs to be established is which low-level stimulus features are attended to by persons with ASD and whether these are consistent within and between individuals.

References

Ameli, R., Courchesne, E., Lincoln, A., Kaufman, A. S. & Grillon, C. (1988). Visual memory processes in high-functioning individuals with autism. Journal of Autism and Developmental Disorders, 18, 601-615.

American Psychiatric Association (2000). Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition – Text Revision. Washington, DC: The Association.

Andreasen, N. C., Nopoulos, P., Schultz, S., Miller, D., Gupta, S., Swayze, V., & Flaum, M. (1994). Positive and negative symptoms of schizophrenia: past, present, and future. Acta Psychiatrica Scandinavica, Suppl. 384, 51-59.

Barth, C., Fein, D. & Waterhouse, L. (1995). Delayed match-to-sample performance in autistic children. Developmental Neuropsychology, 11, 53-69.

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

Beversdorf, D. Q., Smith, B. W., Crucian, G. P. Anderson, J. M., Keillor, J. M., Barrett, A. M., Hughes, J. D., Felopulos, G. J., Bauman, M. L., Nadeau, S. E. & Heilman, K. M. (2000). Increased discrimination of “false memories” in autism spectrum disorder. Proceedings of the National Academy of Sciences of the United States of America, 97, 8734-8737.

Boucher, J. & Bowler, D. M. (in press). Memory in autism. Cambridge: Cambridge University Press.

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., 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., & Grice, S. (2000a). Episodic memory and remembering in adults with Asperger's syndrome. Journal of Autism and Developmental Disorders, 30, 305-316.

Bowler, D. M., Gardiner, J. M., Grice, S., & Saavalainen, P. (2000b). Memory illusions: False recall and recognition in adults with Asperger's syndrome. Journal of Abnormal Psychology, 109, 663-672.

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.

Brébion, G., David, A., Jones, H., Pilowsky, L. (2004). Semantic organization and verbal memory efficiency in patients with schizophrenia. Neuropsychology, 18, 378-383.

Burack, J. A., Enns, J. T., Stauder, J. E. A., Mottron, L. & Randolph, B. (1997). Attention and autism: Behavioural and electrophysiological evidence. In D. J. Cohen & F. R. Volkmar (Eds.) Handbook of Autism and Pervasive Developmental Disorders, pp. 226-247. New York: Wiley.

Davis, H. F., Small, S. A., Stern, Y., Mayeux, R., Feldstein, S. N. & Keller, F. R. (2003). Acquisition, recall and forgetting of verbal information in long-term memory by young, middle-aged and elderly individuals. Cortex, 39, 1036-1091.

Eslinger P. J., & Grattan L. M. (1994). Altered serial position learning after frontal lobe lesion. Neuropsychologia 32 729-739.

Frith, U. & Happé, F. (1994). Autism: Beyond "theory of mind". Cognition, 50, 115-132.

Gardiner, J. M., Bowler, D.M. & Grice, S. (2003). Perceptual and conceptual priming in autism: An extension and replication. Journal of Autism and Developmental Disorders, 33, 259-269.

Gershberg, F. B., & Shimamura, A. P. (1995). Impaired use of organizational strategies in free recall following frontal lobe damage. Neuropsychologia, 33, 1305-1333.

Happé, F. (1999). Autism: Cognitive deficit or cognitive style? Trends in Cognitive Sciences, 3, 216-222.

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

Hermelin, B. & O'Connor, N. (1971). Psychological experiments with autistic children. Oxford: Pergamon.

Hill, E. L. (2004b). Evaluating the theory of executive dysfunction in autism. Developmental Review, 24, 189-233.

Kahana, M. J. & Wingfield, A. (2000). A functional relation between learning and organization in free recall. Psychonomic Bulletin and Review, 7, 516-521.

Klinger, L. G., & Dawson, G. (2001). Prototype formation in Autism. Development and Psychopathology, 13, 111-124.

Loranger, A. W. (1984). Sex difference in age at onset of schizophrenia. Archives of General Psychiatry, 41, 157-161

Minshew, N. J., Goldstein, G. Is autism an amnesic disorder?: Evidence from the california verbal learning test. Neuropsychology, 7, 209-216.

Mottron, L., Burack, J. (2001). Enhanced perceptual functioning in the development of autism. In J. A. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds). The development of autism : Perspectives from theory and research. Erlbaum : Mahwah, N.J., pp. 131-148.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S. & Enns, J. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism: evidence from multiple paradigms. Journal of Child Psychology and Psychiatry, 44, 904-913.

Mottron, L., Dawson, M., Soulières, I., Hubert, B. & Burack, J. (2006). Enhanced perceptual functioning in autism: an update and eight principles of autistic perception. Journal of Autism and Developmental Disorders, 36,

Mottron, L., Morasse, K., Belleville, S. (2001). A study of memory functioning in individuals with autism. Journal of Child Psychology and Psychiatry, 42, 253-260.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 9, 353-383.

O'Connor, N. & Hermelin, B. (1967). Auditory and visual memory in autistic and normal children. Journal of Mental Deficiency Research, 1, 126-131.

Poirier, M., Bowler, D. M. & Gaigg, S. B. (2004). Digit span in adults with Asperger's syndrome. Poster presented at the International Meeting for Autism Research, Sacramento, 2004.

Russell, J. (1997). (Ed.), Autism as an executive disorder. Oxford: Oxford University Press.

Schiffman, J., Walker, E., Ekstrom, M., Schulsinger, F., Sorensen, H. & Mednick, S. (2004). Childhood videotaped social and neuromotor precursors of schizophrenia: A prospective investigation. American Journal of Psychiatry, 161, 2021-2027.

Smith, B. J., Gardiner, J. M. & Bowler, D. M. (in press). 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,

Sternberg, R. J., & Tulving, E. (1977). The measurement of subjective organization in free recall. Psychological Bulletin, 84, 539-556.

Summers, J. A. & Craik, F. I. M. (1994). The effects of subject-performed tasks on the memory performance of verbal autistic children. Journal of Autism and Developmental Disorders, 24, 773-783.

Tager-Flusberg, H. (1985a). Basic level and superordinate level categorization by autistic, mentally retarded, and normal children. Journal of Experimental Child Psychology, 40, 450-469.

Tager-Flusberg, H. (1985b). The conceptual basis for referential word meaning in children with autism. Child Development, 56, 1167-1178.

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

Tager-Flusberg, H. (2002). A re-examination of the theory of mind hypothesis of autism. In J. Burack, T. Charman, N. Yirmiya, & P. Zelazo (Eds.),Ê The Development Of Autism: Perspectives From Theory And Research (pp. 173-193). Mahwah, NJ: Erlbaum

Toichi, M. & Kamio Y. (2002). Long-term memory and levels-of-processing in autism. Neuropsychologia, 40, 964-969.

Tomasello, M., A. Kruger, & Ratner, H. (1993). Cultural learning. Behavioral and Brain Sciences, 16, 450-488.

Tulving, E. (1962). Subjective organisation in the free recall of “unrelated” words. Psychological Review, 69, 344-354.

Tulving, E. (1968). Theoretical issues in free recall. In T.R. Dixon and D.L. Horton (Eds.), Verbal behavior and general behavior theory (pp. 1-68). Englewood Cliffs: NJ. Prentice-Hall.

Ungerer, J. A., & Sigman, M. (1987). Categorization skills and receptive language development in autistic children. Journal of Autism and Developmental Disorders, 17, 3-16.

Wing, L. & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. Journal of Autism and Developmental Disorders, 9, 11-29.

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Table 1: Age and IQ scores for the Asperger and Comparison group.

	Asperger (N=16)			Comparison (N=16)		
	Mean	SD	Range	Mean	SD	Range
Experiment 1						
Age (years)	31	10.4	18-48	34	8.6	18-45
VIQ[a]	99	12.5	85-121	102	11.3	88-123
PIQ[b]	99	17.0	74-129	102	13.4	87-136
FIQ[c]	99	14.2	80-122	102	12.4	89-131
Experiment 2						
Age (years)	39	13.1	19-59	34	12.3	19-57
VIQ[a]	102	13.1	80-123	103	11.7	84-128
PIQ[b]	99	17.4	74-129	103	10.0	87-122
FIQ[c]	101	15.8	77-122	104	11.0	88-129

[a] Verbal IQ (WAIS-R UK or WAIS-III UK)
[b] Performance IQ (WAIS-R UK or WAIS-III UK)
[c] Full-Scale IQ (WAIS-R UK or WAIS-III UK)

Table 2: Average number of errors, intrusions and repetitions across all 16 trials in Experiment 1.

	Asperger (N=16)			Comparison (N=16)		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Errors	7.31	8.80	0-26	2.19	4.14	0-14
Intrusions	3.62	4.83	0-17	0.37	0.80	0- 3
Repetitions	20.06	13.99	0-61	19.31	11.34	1-43

Figure Captions

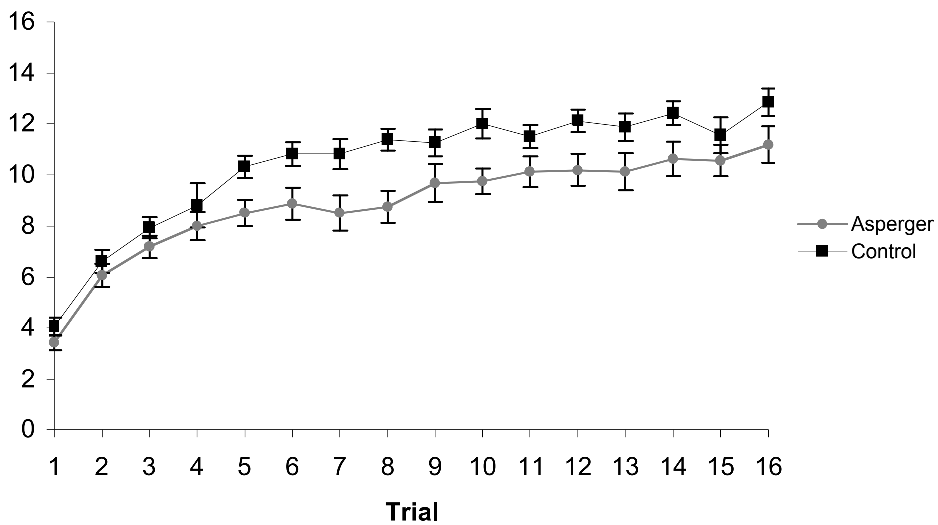
Figure 1: Learning curves for Asperger and Comparison participant groups in Experiment 1 (Bars represent +/- 1 S.E.).

Figure 2: Subjective organisation across individuals for each trial for group's actual and randomised responses in Experiment 1.

Figure 3: Learning curves for Asperger and Comparison groups in Experiment 2 (Bars represent +/- 1 S.E.) .

Figure 4: Subjective organisation across individuals for each trial for group's actual and randomised responses in Experiment 2.

Figure 1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Trial
Asperger
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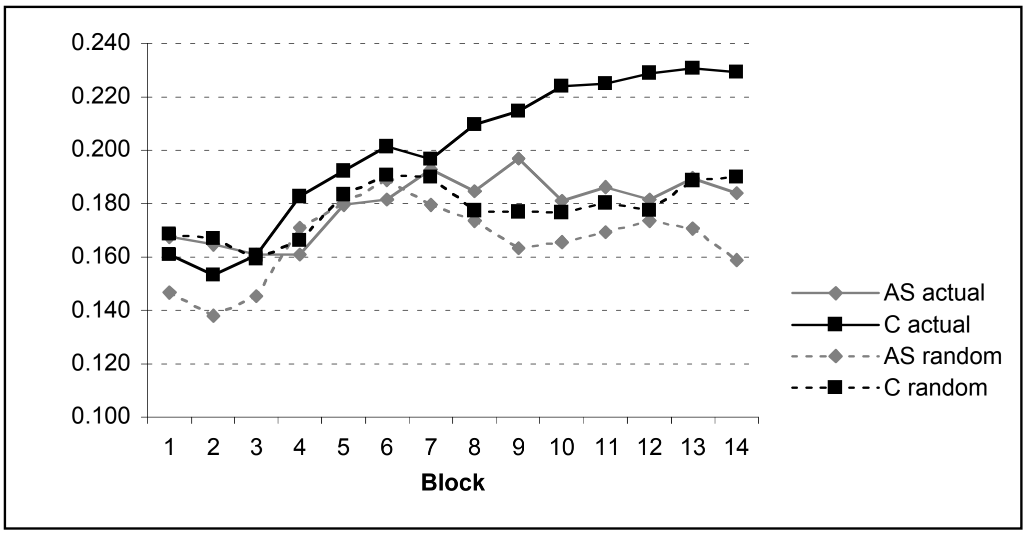
Figure 2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AS random
C random

Figure 3

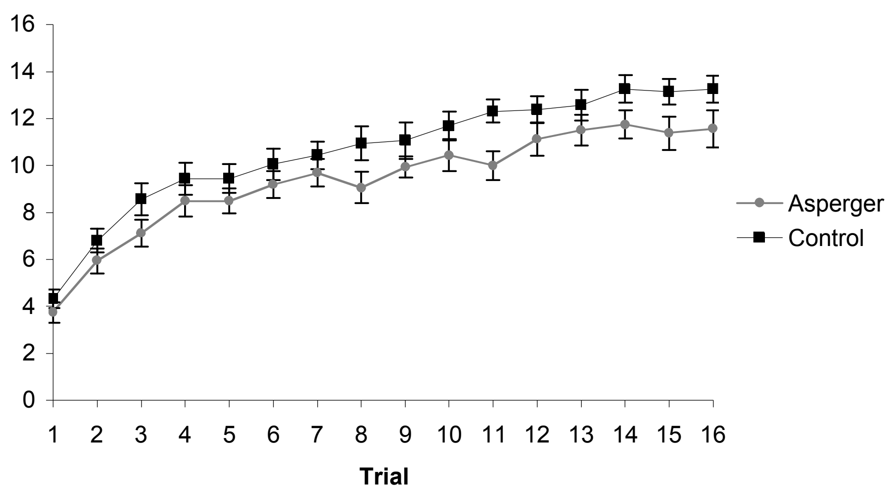
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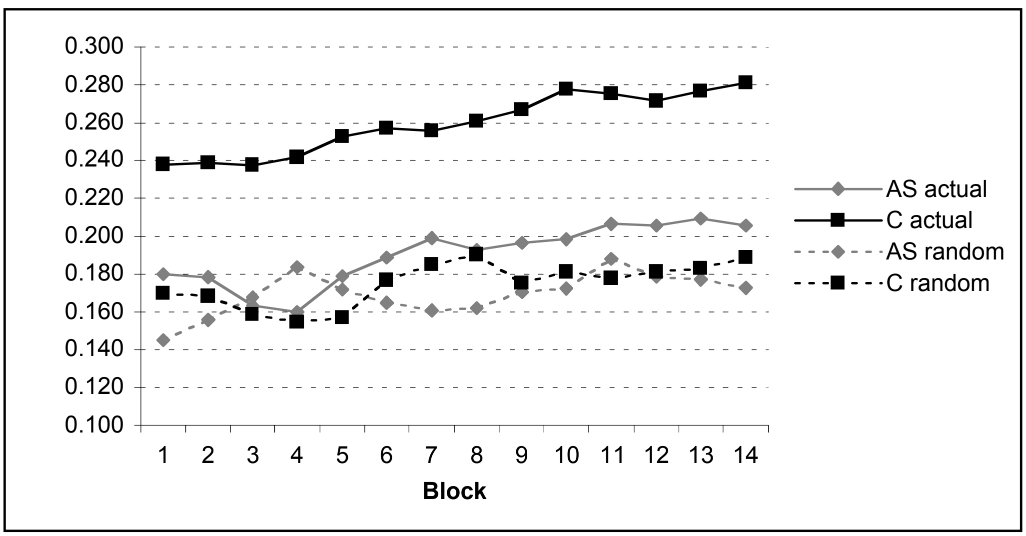
Figure 4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Block
AS actual
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C random