Fractionation of visual memory: agency detection and its impairment in autism

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Abstract

It is known that the adult visual memory system is fractionable into functionally independent cognitive subsystems, selectively susceptible to brain damage. In addition, there have been hints from studies with individuals with autism that these cognitive subsystems can fractionate developmentally. However, there has been a paucity of systematic investigations. The present study involves the analysis of visual memory of a population of individuals with autism and age- and VIQ-matched comparison individuals. The individuals with autism presented selective impairments in face recognition in comparison to both the age- and VIQ-matched comparison populations. In addition, they were impaired relative to the age-matched comparison group on recognition memory for potential agents (i.e. objects capable of self-propelled motion) whether they were living (cats and horses) or non-living (motorbikes). In contrast, they were selectively superior relative to the VIQ-matched comparison group on recognition memory for such objects as topographical stimuli (buildings) and leaves that clearly do not have agency. The data is interpreted in terms of reduced sensitivity to agency cues in individuals with autism and general information processing capacity.

Keywords: Fractionation; Visual memory; Agency detection; Autism

1. Introduction

Studies of patients with acquired neurological lesions have informed us about the degree to which neuro-cognitive systems fractionate in the adult brain. For example, with reference to visual memory, two types of visual memoranda have been shown to be dissociable. Thus, patients have been reported to show selective difficulties in recognising unfamiliar buildings and landmarks [10,42,49,64]. However, despite these impairments, some of these patients have been found to have preserved recognition memory for other visual stimuli, such as unknown faces [34]. Conversely, Maguire and Cipolotti [38] described a patient whose topographical recognition memory for unknown buildings, landscapes and outdoor scenes was preserved whilst her recognition memory for unfamiliar faces was impaired. They propose that this double dissociation indicates that the adult visual memory system is fractionable into functionally independent cognitive subsystems that are selectively susceptible to brain damage.

An interesting, related question is the degree to which neuro-cognitive systems fractionate developmentally; i.e. are there individuals who show appropriate development for some systems in the context of profoundly dysfunctional development in others. Such, and related, questions are beginning to receive considerable attention in the developmental literature [29,37]. Thus, as regards visual memory development, are there individuals who show appropriate development of some visual memory systems in the context of profoundly dysfunctional development in other visual memory systems? Previous work with individuals with autism suggests that this may be the case [12,19,25].

Three studies have investigated visual recognition memory in individuals with autism using a variety of
memoranda, two concluding that there was no impairment [1,7], the third suggesting that there was [13]. However, the results of this divergent study are difficult to interpret as the memoranda used were verbalisable and, therefore, the poor performance of the individuals with autism could have been due to poor verbal rather than visual memory skills.

Three studies have specifically investigated recognition memory for unfamiliar faces in individuals with autism [12,19,25]. Boucher and Lewis [10] assessed recognition memory for unfamiliar faces and buildings in children with autism. Unfamiliar face recognition was found to be impaired relative to normal peers, non-verbal ability matched controls and verbal ability matched controls. In contrast, recognition of buildings was comparable to that of the comparison populations. This study suggests that individuals with autism may have a selective deficit in visual memory for unfamiliar faces. However, this study failed to include a population of normally developing controls matched for non-verbal mental age. Therefore, it was not possible to conclude whether recognition memory for unfamiliar buildings is preserved in autism or whether children with autism show a comparable decrement in performance relative to normally developing controls in both forms of recognition memory. Ellis et al. [25] found that six out of seven of their subjects with Asperger syndrome (a milder form of autism; [65]) achieved scores on the Recognition Memory test for Unfamiliar Faces [60] that were below the 10th percentile. However, Ellis et al. [25] did not investigate other forms of visual recognition memory in this population so it is possible that they presented with a generalised recognition memory impairment. Cipolotti et al. [19] studied in detail a 29 year old male (PE) with multiple developmental disorders including autism. This individual showed significantly impaired recognition memory for unfamiliar faces in the context of appropriately developed recognition memory for unknown buildings, landscapes and outdoor scenes. However, PE was an individual with multiple developmental disorders thus making generalisation to other individuals with autism difficult.

The data obtained with PE did suggest that recognition memory is developmentally fractionable; the development of visual recognition memory for faces was impaired while that for topographical stimuli was intact. However, it is quite possible that his selective pattern of developmental abnormality was not due to difficulties in the functioning of modular processes but instead due to a differential process of modularisation as a consequence of experience (cf. Ref. [37]). There are suggestions that expertise with faces results in individuals extracting “second-order relational features” that are “distinctive variations of a shared configuration” [16,24]. PE’s impairment in unfamiliar face recognition may be due to a lack of interest in faces and thus a failure to develop expertise. Certainly, individuals with autism do show less interest in attending to the faces of other humans [48,65].

An alternative explanation of PE’s selective developmental impairment, and the one that Cipolotti et al. [19] favoured, referred to the theory of Mandler and McDonough [40] of concept formation. Mandler and McDonough [40] showed that children from approximately 9 months are able to differentiate their behavioural responses to animate items (objects that move by themselves) and inanimate items (objects that do not move by themselves). Animate items activate a representation of their movement’s potential goals [30]. All animate items show these cues of agency. Cipolotti et al. [19] suggested that it is these cues that crucially drive the development of attention and specially dedicated memory processes. Individuals with autism, like PE, may be less responsive to these cues. Impairment in a system sensitive to such cues might prevent the development of visual recognition memory for faces. Indeed, they noted evidence from human and non-human primates of the presence of regions in the temporal lobe, particularly superior temporal sulcus, that are sensitive to rotational movement, visual motion and biological motion [11,47,50,51]. These regions have also been shown to be sensitive to faces [14,17,18,23]; see, for a review, Ref. [33]. They concluded that PE’s selective impairments in visual memory are due to early damage to a neural substrate in the right temporal lobe that is crucial for the development of these systems. Consistent with this possibility are reports of medial temporal lobe abnormalities in individuals with autism [4,20,43].

The aim of the present study was to extend the Cipolotti et al. [19] findings by investigating the following issues. First, will other individuals with autism show selective impairments in face recognition memory? If they do, this would certainly be indicative that some feature of the disorder is a risk factor for the atypical development of this form of recognition memory. Secondly, does the recognition memory impairment extend to other animate objects? The Cipolotti et al. [19] position would predict that it does but an account based around developing expertise would not. The present study investigated these issues with a population of individuals with autism.

2. Method

2.1. Subjects

2.1.1. Autism group

The group of individuals with autism consisted of 15 volunteer participants all with a DSM-IV diagnosis of autism. After initial neuropsychological testing, two of
these volunteers were excluded due to problems of distractibility and lack of concentration that were sufficiently severe to lead to the termination of the testing session. A final individual was excluded because of severe visual-perceptual impairment. As can be seen in Table 1, the autism group, therefore, consisted of 12 male adults whose chronological age ranged from 18–45 (mean = 29.92; S.D. = 7.62). All of these individuals spoke English as their first language with the exception of one whose first language was Dutch.

A series of Theory of Mind (TOM) tests were administered to all the participants in the autism group; two first order and two second order mental state tasks. First order tasks require the representation of another’s mental state. Second order tasks require the ability to represent another person’s thoughts regarding a third person’s mental state. Six of the 12 participants in the autism group failed the second order TOM tasks. One subject showed difficulties in both first and second order TOM tasks. Overall, these results indicate that the ability to mentalise, as tested by this set of tasks, was impaired for the majority of the autism group. This is consistent with a large number of previous studies.

2.1.2. Comparison groups

The performance of the individuals with autism was contrasted with that of two comparison groups. The first was made up of 12 participants (nine male and three female) who were matched for chronological age and verbal IQ as measured by the WAIS-R; see Table 1. These individuals were seen in the day centres for adults with learning difficulties that they attended. The second was made up of 54 healthy participants who were matched for chronological age with the individuals with autism. This comparison group was used in test design to ensure that the experimental tasks were matched for difficulty.

2.2. Neuropsychological assessment

The autism group were administered a battery of cognitive tests. This battery included standardised measures of general intellectual functioning, verbal memory, naming, reading, visual perception and frontal executive skills. The VIQ comparison group was administered the measures of intellectual functioning, one visual perception task and one measure of frontal executive skills. The performance of both groups on these measures is given in Table 1.

2.3. General intellectual function

In order to obtain a measure of current intellectual functioning a shortened version of the WAIS-R consisting of four verbal and three performance subtests was administered to both the individuals with autism and the VIQ comparison group. Verbal and performance IQs were obtained by pro-rating verbal and performance subtest scores. The Raven’s Standard Progressive Matrices [52] was also administered to the individuals with autism.

The majority of the autism group obtained scores for verbal IQ between the average and low average ranges with the exception of two subjects who scored at the

<table>
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<th>Table 1</th>
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<td>Characteristics of the participant populations</td>
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<tr>
<td>Autism group (N = 12)</td>
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<tr>
<td>Age</td>
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<tr>
<td>VIQ</td>
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<tr>
<td>(10.43: 67–97)</td>
</tr>
<tr>
<td>PIQ</td>
</tr>
<tr>
<td>FIQ</td>
</tr>
<tr>
<td>Stroop reading time</td>
</tr>
<tr>
<td>(5.76: 7–25)</td>
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<tr>
<td>Stroop interference time</td>
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<tr>
<td>Stroop interference errors</td>
</tr>
<tr>
<td>(0.65: 0–2)</td>
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<tr>
<td>RM Words</td>
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<td>(2.80: 47–50)</td>
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</tbody>
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Key: VIQ, verbal intelligence quotient; PIQ, performance intelligence quotient; FIQ, full intelligence quotient; RM Words, recognition memory test for words.
borderline and the defective range. Performance IQ scores for the majority of this group were within the average or low average range. A one-way ANOVA revealed that there was no significant difference between the individuals with autism and the VIQ comparison group in terms of verbal IQ \( (F(1,23) = 1.33; \text{n.s.}) \). This group’s performance IQ scores ranged between 56 and 106. However, a second one-way ANOVA revealed that the performance IQ scores of the individuals with autism group were significantly higher than those of the VIQ comparison group \( (F(1,23) = 4.05; P < 0.05) \).

2.3.1. Summary

The general intellectual functioning of the individuals with autism group and the VIQ comparison group was similar. The two groups were matched in terms of verbal IQ.

2.4. Naming skills

The Oldfield Picture Naming Test [46] was administered to the individuals with autism to obtain a measure of nominal skills. As can be seen from Table 1, the majority of the autism group obtained scores of 24 or more which in clinical practice is considered to be satisfactory. Two subjects obtained mildly weak scores for naming, one being the participant whose first language is Dutch.

2.4.1. Summary

Overall, the autism group presented with satisfactory naming ability.

2.5. Reading skills

All of the individuals with autism other than one were administered the Schonell Graded Word Reading Test [54]. It was found that reading ages ranged from 10.5 to 17.3 years \( (\text{mean} = 14.13, \text{S.D.} = 2.13) \). The participant who did not receive the Schonell was given the National Adult Reading Test (NART; [45]) and received a score that lies above the 50th percentile.

2.5.1. Summary

The reading ages of the participants in the autism group were poor.

2.6. Visual–perceptual skills

Two subtests from the Visual Perceptual and Space Perception Battery (VOSP; [62]) were used to obtain a measure of the perceptual skills of the individuals with autism (Object Decision and Incomplete Letters). Overall, subjects in the autism group obtained scores which were above the 5% cut off scores for these tests, with the exception of AR who obtained a score on the Object Decision sub-test which was below the 5% cut off score. The Incomplete Letters sub-test of the VOSP was also administered to the participants in the VIQ comparison group. All subjects in this group obtained a score that was above the 5% cut-off score. A simple one-way ANOVA revealed that there was no significant difference between the two groups in terms of scores on the Incomplete Letters sub-test \( (F(1,23) < 1; \text{n.s.}) \).

2.6.1. Summary

In general, the autism group and the VIQ matched group presented with intact visual perceptual skills.

2.7. Frontal executive functions

Verbal Fluency tests [56], the Wisconsin Card Sorting Test (WSCT, modified version; [44]), the Weigl test [63] and the Stroop Colour–Word Interference Test [57] were administered to all the individuals with autism to assess frontal ‘executive’ functions. Two versions of the Verbal Fluency test were administered to the individuals with autism. Fluency for the letter S and fluency for the category of animals. The majority of the individuals with autism scored within or above one standard deviation of the mean according to the Spreen and Strauss [56] age related norms for both versions. Results of the WCST show that only two individuals with autism obtained a number of categories below the 50th percentile. One individual with autism (MJ) was not tested on the WCST due to time constraints. This subject was administered the Weigl test as a comparison task, which he passed.

The Stroop Colour-Word Interference Test (SCWIT) is the National Hospitals’ version of the Stroop task. It comprises of words printed in different colours. The subject was first required to read the words and subsequently to name the colours of the printed material while ignoring the content of the words. Two measures from each part of the test were obtained; the number of errors made and the time needed to complete it. This test has not been standardised, therefore, the VIQ matched group were also administered the SCWIT so that their scores served as comparison to the autism group’s results. Simple one-way ANOVAs revealed that there was no significant difference between the two groups in terms of time taken or errors made during the reading or interference phases of the SCWIT \( (\text{reading time: } F(1,23) < 1; \text{n.s.}; \text{interference time: } F(1,23) < 1; \text{n.s.}; \text{interference errors: } F(1,23) < 1; \text{n.s.}); \text{see Table 1.} \)

2.7.1. Summary

Overall, the autism group’s performance on the selection of tests used to measure frontal ‘executive’ functions was satisfactory.
2.8. Verbal recognition memory skills

In order to assess verbal recognition memory, all subjects in both the autism and VIQ matched groups were administered the Recognition Memory Test for Words (RM Words; [60]). This is a standardised test that produces a normal distribution of scores in a healthy population. 50 words which are 4–6 letters in length and of A or AA frequency on a Thorndike–Lorge count are presented at a rate of one item every 3 s. The subject is required to respond ‘Yes’ or ‘No’ according to whether s/he judges the item to be pleasant or unpleasant. Recognition is then tested by a two alternative forced choice paradigm immediately after the presentation of the test stimuli. The distracter items are taken from the same pool of words as the targets.

As can be seen in Table 1, the autism group all obtained scores that were at or above the 50th percentile on RM Words with the exception of one subject. The VIQ comparison group obtained a wide range of scores for RM Words. Interestingly, a simple one-way ANOVA revealed that the individuals with autism group obtained significantly higher scores for this verbal recognition memory test than the VIQ comparison group (F(1,23) = 4.34; P < 0.05).

2.8.1. Summary

The verbal memory skills of the individuals with autism were satisfactory. Indeed, their performance as a group was significantly superior to that shown by the VIQ comparison group.

2.9. Experimental investigation

Our aim in this section was to document all subject’s visual recognition memory for different types of memoranda. The visual memoranda chosen was unfamiliar human faces, cats, horses, motorbikes, leaves and buildings.

The participants were administered the Recognition Memory (RM) Test for Faces [60], newly designed recognition memory tests for cats, horses, motorbikes and leaves and the recognition memory test for unknown buildings [64]. The RM Faces test is a stringent standardised test that produces a normal distribution of scores in healthy populations. It requires the recognition of 50 unknown non-distinctive faces that are paired with 50 visually similar distracter items. As for the Recognition Memory Test for Words, the subject has to respond ‘Yes’ or ‘No’ as to whether s/he judges each face to be pleasant or unpleasant during the study phase.

The RM tests for cats, horses, motorbikes, leaves and buildings had not been standardised. However, RM Buildings has been used with adult patients with neurological lesions and is known to be approximately matched for difficulty with RM Faces test [64]. The RM cats, horses, motorbikes and leaves all consisted of 30 coloured photographs of the memoranda. The RM Cats involved images of cat’s faces, the RM Horses of whole body horses taken from a side view. The RM Buildings consisted of 50 black and white photographs of previously unknown buildings. For all tasks the stimuli were presented at a 3 s rate with the participant required to give a ‘Yes’ or ‘No’ response. For RM Cats this was for whether they liked the cat, for RM Horses whether the horse could be ridden, for RM Motorbikes whether they would like to own the motorbike, for RM Leaves whether the leaf stayed on the tree during the winter and for RM Buildings whether they liked the architecture. For all tasks, a two alternative forced choice recognition memory test followed. The distracter items were different cats, horses, motorbikes, leaves or buildings that were visually similar to the target stimulus.

3. Results

3.1. Within group results

Initially, repeated measures ANOVAs were conducted to investigate within group differences for the visual recognition memory tests. These revealed that the individuals with autism were significantly poorer on RM faces than buildings (F(1,11) = 47.86; P < 0.01). In striking contrast, and as expected given that these two tests had been designed to be matched in difficulty, the VIQ comparison group showed no significant difference in their ability on the RM faces and buildings tasks (F(1,11) < 1; n.s.). Interestingly, and consistent with the position proposed by Cipolotti et al [19], the individuals with autism were significantly poorer on the animate RM tests (Cats and Horses) when compared with the living, but not animate, memoranda (Leaves): F(1,11) = 4.94, P < 0.05; F(1,11) = 3.77, P < 0.05 (one tailed), respectively. Again consistent with the position proposed by Cipolotti et al [19], the individuals with autism were also significantly poorer on the non-living ‘animate’ RM test (Bikes) when compared with RM Leaves (F(1,11) = 2.98; P < 0.06; one tailed). As can be seen in Table 2, work with the chronological age matched comparison group had ensured that in normally developing individuals the tasks were of comparable difficulty. In line with this, the VIQ comparison group showed no significant differences between their performance on the three ‘animate’ RM tests (Cats, Horses and Bikes) relative to the non-animate RM test (Leaves); F(1,11) < 1 in all cases; n.s.).
Table 2
Group and individual participant with autism performance on recognition memory tests (S.D.s in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Age comparison group (N = 54)</th>
<th>VIQ comparison group (N = 12)</th>
<th>Autism group (N = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRM Faces</td>
<td>–</td>
<td>41.58</td>
<td>38.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.09)</td>
<td>(4.34)</td>
</tr>
<tr>
<td>RM Cats</td>
<td>23.12</td>
<td>21.50</td>
<td>20.08</td>
</tr>
<tr>
<td></td>
<td>(2.93)</td>
<td>(2.97)</td>
<td>(2.94)</td>
</tr>
<tr>
<td>RM Horses</td>
<td>23.12</td>
<td>21.25</td>
<td>20.58</td>
</tr>
<tr>
<td></td>
<td>(3.13)</td>
<td>(2.67)</td>
<td>(3.53)</td>
</tr>
<tr>
<td>RM Motorbikes</td>
<td>23.04</td>
<td>21.08</td>
<td>20.33</td>
</tr>
<tr>
<td></td>
<td>(2.72)</td>
<td>(2.64)</td>
<td>(3.55)</td>
</tr>
<tr>
<td>RM Leaves</td>
<td>22.52</td>
<td>20.50</td>
<td>22.58</td>
</tr>
<tr>
<td></td>
<td>(2.68)</td>
<td>(2.15)</td>
<td>(2.78)</td>
</tr>
<tr>
<td>RM Buildings</td>
<td>44.68</td>
<td>40.75</td>
<td>45.25</td>
</tr>
<tr>
<td></td>
<td>(3.17)</td>
<td>(4.69)</td>
<td>(4.16)</td>
</tr>
</tbody>
</table>

Key: VIQ, verbal intelligence quotient; HRM, hard recognition memory test; RM, recognition memory; –, not tested.

3.2. Between group results

Following Cipolotti et al [19], it was predicted that the individuals with autism should show particular difficulty with the recognition memory tests for face stimuli, other animate living categories (cats and horses) and animate non-living categories (motor cycles). In contrast, the individuals with autism should show no difficulty with recognition memory for topographical stimuli or inanimate, living categories (leaves).

3.2.1. Recognition memory for unfamiliar faces

Initially, subject by subject comparisons revealed that all the participants with autism obtained scores that were below the 50th percentile for RM Faces. An ANOVA was conducted to compare the performance of the individuals with autism and the VIQ comparison group. This revealed that the individuals with autism as a group performed RM faces significantly more poorly than the VIQ comparison group ($F(1, 22) = 3.29; P < 0.05$; one-tailed).

3.2.2. Recognition memory for cats

Initially, subject by subject comparisons revealed that all of the participants with autism obtained scores that were below the mean of the age comparison group. For seven of the twelve, their scores were greater than one standard deviation below the age comparison group’s mean. Two ANOVAs were conducted to compare the performance of the individuals with autism with the age comparison and VIQ comparison groups. These revealed the individuals with autism were performing significantly more poorly than the VIQ comparison group ($F(1,35) = 4.92; P < 0.05$). However, the individuals with autism were not performing RM Motorbikes significantly more poorly than the VIQ comparison group ($F(1,22) = 1; n.s.$).

3.2.3. Recognition memory for horses

Initially, subject by subject comparisons revealed that only two of the 12 participants with autism obtained scores that were above the mean of the age comparison group while three scored greater than one standard deviation below the age comparison group’s mean. Two ANOVAs were conducted to compare the performance of the individuals with autism with the age comparison and VIQ comparison groups. These revealed the individuals with autism were performing significantly more poorly than the age comparison group ($F(1,35) = 6.59; P < 0.05$). However, the individuals with autism were not performing RM Horses significantly more poorly than the VIQ comparison group ($F(1,22) < 1; n.s.$).

3.2.4. Recognition memory for motorbikes

Initially, subject by subject comparisons revealed that only two of the 12 participants with autism obtained scores that were above the mean of the age comparison group while eight scored greater than one standard deviation below the age comparison group’s mean. Two ANOVAs were conducted to compare the performance of the individuals with autism with the age comparison and VIQ comparison groups. These revealed the individuals with autism were performing significantly more poorly than the age comparison group ($F(1,35) = 6.59; P < 0.05$). However, the individuals with autism were not performing RM Motorbikes significantly more poorly than the VIQ comparison group ($F(1,22) < 1; n.s.$).

3.2.5. Recognition memory for leaves

Initially, subject by subject comparisons revealed that six of the 12 participants with autism obtained scores that were above the mean of the age comparison group. Moreover, only two of the individuals with autism scored greater than one standard deviation below the
age comparison group’s mean. Two ANOVAs were conducted to compare the performance of the individuals with autism with the age comparison and VIQ comparison groups. Strikingly, these revealed that the individuals with autism were performing as well as the age comparison group \( (F(1,35) < 1; \text{n.s.}) \). In contrast, they performed significantly more capably than the VIQ comparison group \( (F(1,22) < 4.56; \text{P} < 0.05) \).

3.2.6. Recognition memory for unknown buildings

Initially, subject by subject comparisons revealed that nine of the 12 participants with autism obtained scores that were above the mean of the age comparison group. Moreover, only three of the 12 individuals with autism scored greater than 1 S.D. below the age comparison group’s mean. Two ANOVAs were conducted to compare the performance of the individuals with autism with the age comparison and VIQ comparison groups. Again, these revealed the individuals with autism performed as well as the age comparison group \( (F(1,35) < 1; \text{n.s.}) \). In contrast, they again performed significantly more capably than the VIQ comparison group \( (F(1,22) < 6.18; \text{P} < 0.05) \).

4. Discussion

In this study, we have described an investigation of the visual memory skills of a population of individuals with autism. This study revealed that the pathology associated with autism has clear implications for the development of the neural circuits subserving visual memory. In line with earlier findings [12,19,25], the visual recognition memory performance of all of the individuals with autism for unknown faces was significantly poorer than that shown by the age and VIQ comparison groups. In comparison to the age comparison group, the individuals with autism were significantly poorer on the RM tests for cats, horses and motorbikes but unimpaired on RM leaves and buildings. In comparison to the VIQ comparison group, the individuals with autism were performing significantly better on the RM tests for leaves and buildings but were not performing significantly better on the RM tests for cats, horses and motorbikes.

The results of the current study strengthen the argument that the visual recognition memory system is developmentally fractionable. Boucher and Lewis [12] had previously demonstrated that recognition memory for unknown faces is impaired in individuals with autism. However, it was unclear from their data whether this population had a more general visual recognition memory impairment. Cipolotti et al. [19] showed in a single case study, PE, with multiple developmental disorders, including autism, intact, indeed superior, development of RM for unknown topographical stimuli but impaired development of RM for faces and animals. In the current study we showed that the individuals with autism presented with intact development of recognition memory for unknown buildings but impaired development of recognition memory for faces. Thus, the current results, in conjunction with Cipolotti et al.’s [19], suggest the development of RM for faces is dissociable from the development of RM for topographical material. In other words, RM for faces is dissociable from RM for topographical stimuli in its development as well as dissociable in its functioning in the mature adult [34,38]. However, we cannot yet conclude that the development of recognition memory for faces is independent of the development of topographical recognition memory. It is possible that topographical recognition memory is a necessary prerequisite for the development of recognition memory for faces even if the reverse is clearly not the case. To conclude that the development of recognition memory for faces is independent of the development of topographical recognition memory, we need to find evidence for a developmental double dissociation. There is some evidence that individuals with Williams Syndrome, despite widespread developmental impairments, present with selectively appropriate development of recognition memory for faces [8,9,58,59]. However, whether the development of recognition memory for faces is typical in individuals with Williams Syndrome has been questioned [22,36]. Moreover, the development of topographical recognition memory has not been investigated in this population.

PE presented with autism [19]. However, he also presented with other developmental disorders and consequently it was not possible to conclude that the pathology associated with his autism might be a risk factor for the development of recognition memory for faces. The Boucher and Lewis [12] data suggested that the pathology associated with autism might be a risk factor. However, it was not possible to determine from their study the degree to which the pathology associated with autism might be a risk factor for the development of recognition memory more generally. However, the present results are clearly indicative that some feature of the disorder of autism is a risk factor for the development of this form of recognition memory. Moreover, they strongly suggest that this pathology also affects RM for cats, horses and motorcycles but does not affect RM for buildings and leaves.

What about the pathology associated with autism could be the risk factor that determines their distinctive recognition memory profile? Could it be related to the lack of interest in individuals with autism in attending to the faces of other humans [2,48,65]. There are suggestions that expertise with faces results in individuals extracting “second-order relational features” that are “distinctive variations of a shared configuration”
This ability allows superior recognition memory for faces. However, while such a factor may be exacerbating the difficulties of the individuals with autism in the current study it is unlikely to provide a full explanation of the recognition memory profile shown by this group of individuals. It certainly would not explain why the development of recognition memory for cats, horses and particularly motorcycles is differentially affected relative to buildings and leaves. In particular, it would not explain why individuals with autism are significantly better at RM for leaves and buildings than the VIQ comparison group.

An alternative explanation of the data might group the objects according to whether they would favour a feature-based recognition strategy rather than a holistic recognition strategy. It is well known that faces are processed holistically (e.g. Ref. [24]). It is plausible that the faces of animals and possibly even full horse bodies might also be processed holistically. Moreover, individuals with autism do indeed present with impairments in processing stimuli holistically (e.g. Refs. [28,32]). However, it is unclear how we should determine whether a stimulus is likely to activate a feature-based recognition strategy rather than a holistic recognition strategy. Specifically, for example, it is difficult to know why the recognition of motorcycles activates a holistic strategy while the recognition of leaves activates a feature-based strategy. Thus, while such an explanation cannot be ruled out, it requires an a priori method for distinguishing objects that should be processed holistically from those that should be processed in a feature-based fashion.

Cipolotti et al. [19] attempted a preliminary account of their patient, PE’s, developmental dysfunction in recognition memory for faces and other animate objects at both the cognitive and anatomical levels. They suggested that animacy cues, such as movement, “crucially drive the development of attentive and specially dedicated memory processes” (p. 463). They suggested that their patient and perhaps other individuals with autism might be less responsive to such cues and/or the specifically dedicated memory processes that processed stimuli associated with these cues might be dysfunctional. At the anatomical level, they made reference to the temporal lobe, in particular superior temporal sulcus. Studies in human and non-human primates have shown that this area is sensitive to faces [14,17,18,23]; see, for a review, Ref. [33]. Moreover, superior temporal sulcus is also sensitive to rotational movement, visual motion and biological motion [11,47,50,51]. Superior temporal sulcus has been found to be activated by human faces and animals, including animals without faces [18]. Finally, superior temporal sulcus is part of the neural circuit that includes medial frontal cortex and occipital cortex that is thought to mediate Theory of Mind (see Ref. [27]). Individuals with autism usually show severe Theory of Mind impairment (see, for reviews, Refs. [5,28]).

However, it is not sufficient to refer only to animacy cues for a full explanation of the current results. In fact the current results suggest that the individuals with autism did have some sensitivity to agency cues. Without a degree of sensitivity, they should have processed the faces, cats, horses and motorbikes as if they were inanimate objects and should have shown no recognition memory impairment. However, it appears that the individuals with autism were sensitive enough to animacy cues to process these stimuli differently from inanimate objects with the consequence that they relied on recognition memory systems that were dysfunctional. There is also other data that may suggest sensitivity to animacy cues in individuals with autism. Thus, Baron-Cohen et al. [6] showed that while children with autism could not sequence pictures that involved intentional interactions between protagonists, they could sequence pictures that were either “mechanical” (depicting physical causal relations) or “behavioural” (depicting individuals engaged in behaviour). It could be argued that the ‘behavioural’ pictures were associated with animacy cues. In addition, it is possible that some individuals show little difficulty in processing animacy cues. Thus, for example, there is a case of a very high functioning individual with autism who became a successful biologist with specialist understanding of the behaviour of animals [31]. Interestingly, in the current study, one individual with autism, the least impaired in face recognition, was also relatively spared in recognition memory for cats, horses and motorbikes and may thus have been more able than the others to process animacy cues.

As stated above, it is not sufficient to refer only to animacy cues to have a full explanation of the current results. For a potential full account, we suggest that it is necessary to make reference to the role of dissociable systems for particular forms of recognition memory (perhaps movement versus non-movement based) and also the role of intelligence. Anderson [3] has develop a model of intelligence that distinguishes between an innate capacity that is determined by the speed of a basic processing mechanism (BPM) reflected in the concept of g [55] and ‘modular’ processes that function independently of the BPM. In the current case, these ‘modular’ processes would include the components of visual recognition memory described above. Standard psychometric intelligence assessments confound the contribution of modular and central (BPM-dependent processes). The speed of the BPM determines rate of knowledge acquisition and complexity of knowledge representations. Indeed, an individuals intelligence level has considerable predictive power for their level of performance on recognition memory tests [60,64]. However, failure in individual ‘modular’ processes can result in striking patterns of cognitive breakdown.
 Individuals with autism have been found to show comparable speed of processing to age matched control groups and significantly faster speed of processing than mentally handicapped children without autism [33]. We believe that if there was no damage to any of the components of visual recognition memory in individuals with autism these individuals would perform like the age comparison group, and significantly better than the VIQ matched group, on all the RM measures. In other words, they would not just perform better on the RM tasks for leaves and buildings. We believe that the comparable performance of the individuals with autism to the age comparison group reflects their comparable level of speed of processing and the intact development of those aspects of visual memory concerned with non-moving and topographical stimuli. In contrast, we believe that the individuals with autism are dysfunctional in those regions of temporal cortex, particularly superior temporal sulcus, that are crucial for encoding faces, moving objects and goal directed behaviour [11,23,27,33]. The idea is that objects consistently associated with movement, perhaps particularly apparently self-propelled movement, come to be represented in this region. These objects will be mostly biological but would also include quasi self propelled objects, at least to the young child, such as motorbikes and cars. Objects that consistently do not move, for example leaves, would be represented elsewhere in cortex. The representational detail provided by these neurons is utilised in recognition memory tasks. This is not to say that all moving objects will be represented in this region with comparable detail. Indeed, recent imaging work suggests that superior temporal sulcus is more strongly activated by static images of faces rather than images of animals without faces [18] although both activate this region very significantly more strongly than images of buildings (though this may not hold for other regions of temporal cortex [35]). We believe that this, and perhaps their relative lack of expertise, explains why the individuals with autism are particularly poor on RM for faces, even relative to the VIQ comparison group.

The position outlined above makes several testable predictions. First, it predicts that developmentally typical individuals who acquire lesions to superior temporal sulcus should show comparable RM cognitive profiles to the individuals with autism. They should show impaired RM for faces, animate biological entities (cats and horses) and moving objects (motorbikes) and spared RM for topographical material and non-moving biological entities (leaves) and objects (furniture). Secondly, the position predicts that individuals should show superior temporal sulcus activation, though not fusiform cortex activation [35], to moving objects such as motorbikes and cars than to non moving objects, even though this activation may not be as great as to faces. These predictions are currently being tested.

It should be noted that the position outlined above does not predict that individuals with prosopagnosia should show the symptoms of autism. According to Bruce and Young’s model of face recognition [15], different parallel systems process unfamiliar and familiar faces. In line with this position, the abilities to process unfamiliar and familiar faces have been found to dissociate [39,61]. Prosopagnosia, the inability to recognise familiar faces, is most strongly associated with lesions in the region of the parahippocampal gyrus and fusiform gyri rather than superior temporal sulcus [21,41]. Indeed, PE presented without prosopagnosia despite his severe impairment in unfamiliar face recognition [19] (see also Ref. [38]). Therefore, patients with lesions to the systems for processing familiar faces, even if those lesions occurred early in life [26], would not be predicted to present with Theory of Mind impairments or other symptoms of autism.

In conclusion, the suggestion is that individuals with autism present with dysfunction in superior temporal sulcus that disrupts RM for moving objects. RM for non-moving objects including topographical material is unaffected. Of course, it is unclear whether the superior temporal sulcus dysfunction is primary — and perhaps the ultimate cause of the Theory of Mind failure in this population — or secondary to dysfunction elsewhere in cortex. Certainly, superior temporal sulcus has been considered part of the circuit that mediates Theory of Mind [27] that is impaired in individuals with autism [5,28]. It is possible that because of the connections between other regions of the Theory of Mind circuit such as medial frontal cortex, a potential primary dysfunction in these regions might result, developmentally, in impairment in superior temporal sulcus. Alternatively, it is possible that the genetic risk factors for autism affect the development of many of the areas implicated in the circuitry for Theory of Mind, including superior temporal sulcus.

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References


