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A test of central coherence theory: Can adults with high-functioning autism or Asperger syndrome integrate fragments of an object?

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Abstract

Visuo-conceptual integration was explored in normally intelligent adults with either autism or Asperger syndrome. This was a test of central coherence theory (Frith, 1989), that is, that autism impairs one's ability to integrate information. A modified version of the Hooper Visual Organisation Test was used in which line drawings depicting simple objects had been cut into pieces or fragments and arranged in a puzzle-like fashion. The participant is required to mentally (conceptually) integrate the fragments in order to identify what each object would be if the fragments were correctly put together. A second condition presented just a single element or part of an object and participants were required to identify the object from just seeing the single part. As predicted, both clinical groups were significantly impaired in their ability to integrate fragments holistically, but they were unimpaired in their ability to recognise an object from a single part. This demonstrates that individuals with an autism spectrum disorder are less able to integrate visual elements so as to identify an object. Of the two clinical groups, the autism group had the greater deficit and it applied to the majority of the group. Possible explanations for the clinical groups' difficulty are explored, along with suggestions for future research.

Frith (1989) commented that normal individuals have a need and desire to achieve high-level 'meaning'. She called this central coherence, and argued that it could be achieved in various ways, e.g. in the form of establishing some gestalt, context or gist. Essential to her theory is the need to integrate information, which is variously described as top-down processing, global processing, parallel processing, processing wholes and integrating information in context. Her theory is rather general and descriptive in nature which at present is loosely defined because of both a paucity of research and an attempt to offer a broad theory which addresses the strengths and weaknesses in autism.

This capacity for central coherence is proposed by Frith to be diminished in autism, with the result that their processing seems to be devoid of high-level meaning. Thus the central coherence hypothesis makes the prediction that such individuals will experience certain disadvantages in situations which require them to integrate elements, whilst experiencing advantages in situations which require them to process in a local or piecemeal way. Several studies support this prediction. Thus children with autism fail to integrate elements of a stimulus and thus do not succumb to visual illusions to the same degree as normal children (Happé, 1996). Such children are assisted in more accurate perception by their failure to 'see' induced lines which arise from context. When the inducing lines were artificially disembedded from the context, by the use of depth and colour cues, group differences were no longer apparent. This suggests that children with autism may demonstrate a failure in low-level visual integration.

In a case report, a normally intelligent adult with autism experienced difficulties in perceiving the geometric 'impossibility' of Impossible Figures (Mottron & Belleville, 1993). Such figures (e.g., the Penrose triangle) are locally congruent, but globally incongruent. Mottron and Belleville believe that this difficulty stems from a defect in integrating parts of the figure, a process upon which the detection of geometric impossibility depends. Furthermore, Mottron (Mottron, Belleville & Ménard, 1996) found that unlike normal controls, individuals with autism were not hindered by the 3-D impossibility of Impossible Figures, when the time taken to copy the figure was used as a performance measure. Normal control individuals took significantly longer to draw these figures, whereas they had similar response times when drawing possible figures, objects and non-objects.

Both pieces of evidence suggest that individuals with autism do have difficulty in integrating elements into gestalts. This evidence supports the central coherence theory (Frith, 1989) at the visual *perceptual* level, which involves low-level meaning. There are as yet no studies which address the central coherence hypothesis at the visual *conceptual* level, which is high-level meaning. This is despite the fact that weak central coherence is thought by Frith to be cognitive in

nature and thus involve a dysfunction in central thought processes. This paper seeks to fill this gap in the literature, by investigating whether individuals with autism or the related condition of Asperger syndrome have an impaired ability to conceptually integrate visual information. In order to test this, a modified version of the Hooper Visual Organisation Test (HVOT, Hooper, 1983) was used.

The HVOT was originally developed for use with patients with organic brain conditions as a measure of their ability to mentally integrate separate visual elements. Therefore the test examines visuo-conceptual functions. It consists of 30 line drawings depicting simple objects. Each line drawing is cut into pieces and arranged in a puzzle-like fashion. The patient is asked to identify what each object would be if it were put together correctly. The objects used are familiar to most people and would be easily recognised if shown in their usual configuration.

Walker (1956, 1957) and Nadler (Nadler, Grace, White, Butters & Malloy, 1996) found that whereas brain damaged groups did not differ significantly in terms of the quantitative scoring procedures, they often differed significantly in terms of one of Hooper's (1983) qualitative scoring categories. Hooper differentiated four major qualitative categories: isolate, perseverative, bizarre and neologistic responses. Whereas the latter two types of response are probably self-explanatory, "Isolate responses" refers to the use of only one part of the picture to formulate a response, for example, a "pipe" for the tail of a mouse (Walker, 1957). Such a response is said to occur with patients who exhibit fragmentation. "Perseverative responses" are of two kinds: (i) repeating a previously correct or incorrect response on a later item or (ii) providing responses that are unrelated to the current stimulus item but are related to a previous item, for example, "pliers," "drill," "screwdriver," for subsequent items after successful identification of the "hammer" item. Such responses are relatively rare, particularly with adults. Patients who show qualitative anomalies tend to identify most of the items correctly, thus demonstrating that they understand the instruction to integrate fragments. Yet, on one or more of the three items that contain one piece most clearly resembling an object in its own right, patients who have a tendency to view their world in a very fragmented manner will interpret that one piece without attending to any of the others in the item.

Some single case studies in autism have used the HVOT as part of a battery of tests (Mottron & Belleville, 1993; Stevens & Moffit, 1988). For instance, an adult with Asperger syndrome produced 5 "isolate" errors, which is said to reflect a concrete or fragmented cognitive style and a difficulty integrating visual information holistically (Stevens & Moffit, 1988). In contrast, another adult with high-functioning autism was found to be unimpaired (Mottron & Belleville, 1993). Given that these were single case studies and had conflicting results,

interpretation of these results is unclear. Furthermore, the test did not assess central coherence theory directly, and contains some methodological problems, addressed next.

The first problem pertains to the nature of the stimuli employed. Of the items which make up this test, half can be recognised from a single element, and therefore do not necessarily require the individual to mentally integrate the elements at all. For instance, the "apple" item can be recognised as such from the top segment, so there is no requirement for this to be integrated with its lower two segments. This is a major drawback for a test which purports to assess visual integration abilities. Secondly, this test is not a pure measure of visual integration ability because performance measures are confounded by object recognition abilities. Specifically, there is no control task which assesses the individual's ability to name the objects employed in the test, thus one cannot be sure whether deficits on this task reflect impairments in visual integration or impairments in object recognition.

The experiment reported in this paper modifies the HVOT in two main ways. Using a completely new set of stimuli, two conditions were created. One condition presented fragments of objects which had to be integrated for the object to be successfully identified. Thus none of the objects in this condition could be recognised from a single element. This was established through a pilot study. The second condition presented just a single element or part of an object and (again, as established through a pilot study) this object could be identified from the single part presented. A quarter of the stimuli in the first condition (the multiple fragments condition) had an element which was meaningful, which could give rise to an incorrect interpretation of the item if an individual had a tendency to make isolate errors. Inclusion of these type of stimuli was necessary not only to check for problems with fragmentation but also to check for problems with 'mental disengagement', as an individual who has trouble mentally disengaging from a fragment may be impaired at integrating multiple fragments, and particularly so on items where one element was particularly salient (Russell, 1997).

This modified HVOT thus tests two cognitive abilities: integration of elements and recognition of objects. Integration of elements requires participants to mentally integratse the elements from several locations so as to construct a structural description of the object. Object recognition requires matching this structural description with a stored visual representation, so as to identify the object. Since the single part in the 'part' condition does not require the binding of elements to create a structural description (as it is recognisable by itself), it is sufficient in itself to be matched with a stored visual representation, in order to identify what is being portrayed.

If individuals with either autism or Asperger syndrome have weak central coherence, then this predicts that they will be less proficient at conceptually inegrating the elements so as to construct a structural description. Central coherence theory would not however predict a problem in matching this description with a stored visual representation, so object recognition (performance on the control task) should be unimpaired. These predictions were tested here.

Participants

Over the last twenty years there has been much debate about whether or not there is a unitary condition of autism which varies in severity levels, or whether there are different types of autism which form part of a spectrum. In the last ten to fifteen years there has been increasing use of the label Asperger syndrome, which has as one of its diagnostic requirements no clinically significant delay in early language development (ICD-10, World Health Organisation, 1992). Thus single words have to be used by 2 years and phrase speech by 3 years. It seems then that this type of autism is distinguishable from Kanner's classical cases all of whom had clinical delays in early language development (Kanner, 1943).

Recently there has been a lot of interest both in defining autism and in interpreting diagnostic systems. The DSM-IV (American Psychiatric Association, 1994) makes clear that one can have autism with and without language delay. It also makes clear that on the basis of the number and type of symptoms shown that a diagnosis of autism can prevail over Asperger syndrome. We chose to distinguish individuals with a history of autism on the basis of their early language development. This gave rise to two groups one of which clinicians regarded as meeting the criteria for Asperger syndrome and the other which clinicans regarded as meeting the criteria for autism (DSM-IV).

We recruited our clinical participants nationally. Some were recruited via an advert in the UK National Autistic Society's "Communication" magazine, and some from letters sent out by us to support groups. Others were located through clinicians. Most of our clinical participants were or had been patients at the Maudsley Hospital (London) where experienced clinicians had determined the individuals' diagnostic status. A few were or had been patients at Charing Cross Hospital (London) where again an experienced clinician had made the diagnosis. The remainder of the participants came from the National Autistic Society's Elliot House, which is a UK centre for the diagnosis of social and communication disorders.

For every participant clinicians were contacted (with the patients' and parents' consent) and medical files were inspected. In cases where either the clinican or the parents could not be sure about early language development these individuals were excluded. To assist in this checking process parents were also given the revised Howlin (1995) screening questionnaire to complete. [This was devised at the Maudsley Hospital, makes use of DSM-IV criteria and seeks to identify the presence of autistic symptomatology and whether there was a clinically significant delay in early language development]. There was agreement on early language development in all but one case, and this case was excluded. Individuals whose early language development was considered to be borderline were also excluded. The screening questionairre and inspection of medical files resulted in the loss of a dozen participants.

Inevitably, the Asperger group contained a number of individuals who had not received a diagnosis until adulthood, the remainder were diagnosed in childhood or adolescence. Thus for the former group clinicians made their diagnosis retrospectively. For the latter group, and for a couple of individuals, clinicians revised their diagnosis of autism to that of Asperger syndrome on the basis that these individuals did not have a clinically significant delay in early language development. Whereas it is possible that the DSM-IV might regard some of the Asperger participants as having autism without language delay, we have not questioned the clinicians' diagnosis of Asperger syndrome, especially since this leaves unaffected the key differentiator between the two groups; early language development. Thus in the autism group all were clinically delayed in language development and would therefore have been considered to have had a history of classical autism. Whilst in the Asperger group none were clinically delayed in their language development.

Of the clinical participants approached to take part, 6 refused to participate, and 1 participant with Asperger syndrome dropped out half way through. There was 51 adults who participated in this experiment. These comprised 17 with autism, 17 with Asperger syndrome and 17 normal adult control participants. The normal adults acted as a comparison group for the two clinical groups.

We had a pool of nearly a 130 potential control participants, all of whom were taken from the general population of Cambridge. The 17 control participants selected had been recruited in various ways. Thirteen were obtained via an advert at the local job centre; 8 of whom were seeking work and 5 of whom were in employment and looking for additional work. Two participants were recruited via a staff notice at one of the Cambridge colleges and one came from a notice placed in the local sixth form college.

All participants were required to be of at least normal intelligence (i.e., scoring ≥ 85) on the WAIS-R (Wechsler, 1981, full scale, performance and verbal IQ). All 3 groups prior to their recruitment were screened to check whether they had any history of psychiatric disorder, neurological disorder or a head injury. Individuals were excluded if they reported any of these factors, and for the clinical groups parents and professionals were consulted. All participants were also required to be medication-free at the time of testing. There was also screening criteria specific to to the clinical and control groups. The control group had to be free of any family history of autism or Asperger syndrome. The clinical groups were selected on the basis of their ability to pass both first- and second-order belief tasks[1] and they were screened to exclude those who might be depressed, since depression is much more common in autism and Asperger syndrome and can affect judgement as well as social functioning.

The control participants were chosen to match the clinical groups as closely as possible with respect to the characteristics of age, IQ, sex, and handedness. Because of the difficulty matching on all these measures, participants were not pair-wise matched, but rather a stratified approach was employed. Table 1 gives the participant details of chronological age (CA), verbal IQ (VIQ), performance IQ (PIQ) and full-scale IQ (FSIQ). Four one-way ANOVA's revealed no significant differences between groups on any of these variables: CA $F(2, 48) = 0.59$, $p = .56$; VIQ $F(2, 48) = 0.51$, $p = .60$; PIQ $F(2, 48) = 0.58$, $p = .57$ and FSIQ $F(2,48) = 0.10$, $p = .91$.

insert Table 1 here

Over the past couple of decades it has been assumed that individuals with autism have a verbal IQ which is less than their performance IQ. However, the presumed typical pattern was not found in our sample of high-functioning adults with autism. This failure to find a relatively lower verbal ability is reminiscent of a number of studies which similarly fail to document this pattern (Ehlers, Nydén, Gillberg, Dahlgren Sandberg & Dahlgren, 1997; Lockyer & Rutter, 1970; Manjiviona & Prior, 1995; Minshew, Goldstein, Muenz & Payton, 1992; Rumsey & Hamburger, 1990; Tymchuk, Simmons & Neafsey, 1977). Of interest is the same finding from a recent study which was set up specifically to test whether VIQ < PIQ in a very large group of rigorously diagnosed high-functioning children and adults with autism (Siegel, Minshew & Goldstein, 1996). Thus the presumed prototypic pattern has not been consistently found. Rumsey (1992) suggested

[1] Participants were given first- and second-order theory of mind tests. The first-order task was a version of Perner's (Perner, Frith, Leslie & Leekam, 1989) Smarties task. The second-order task was Baron-Cohen's (1989) ice cream van test. Whereas all participants passed the first-order task, 5 out of 51 participants failed the second-order task. These included 1 participant with Asperger syndrome, 2 with high-functioning autism and 2 normal control

that in autism any unique pattern in test scores may depend on ability level, such that VIQ and PIQ differences become smaller or may not be present in samples with average range IQ scores. Rumsey's point is important because our sample was composed of individuals with average or above average intelligence.

The sex ratio in all 3 groups was 15:2 (m:f), reflecting the sex ratio found in these clinical groups in other studies (Klin, Volkmar, Sparrow, Cicchetti & Rourke, 1995; Wing, 1981). The sex ratio was the same across groups, because the Modified Hooper test has a spatial element to it and aspects of spatial ability are known to be superior in males (Maccoby & Jacklin, 1975; Voyer, Voyer & Bryden, 1995). The groups were closely matched on handedness, there being 15 right handed and 2 left handed individuals in the normal and high-functioning autism group, and there being 14 right handed and 3 left handed in the Asperger group. All participants were born in England and English was their first language. All three groups contained participants from various socio-economic backgrounds [in each group: two individuals were in socio-economic class 1; three or four were in socio-economic class 2; three or four were in socio-economic class 3; two or three were in socio-economic class 4; two or three were in socio-economic class 5; three or four were in socio-economic class 6] and the three groups were broadly equivalent in terms of educational attainment [five or six individuals within each group were educated to university level; four or five were educated to A-Level or BTEC standard, four or five to GCSE or O-Level standard; two or three had no formal qualifications]. Eight of the individuals in each group were in employment and 8 or 9 were seeking full-time or part-time employment.

The majority of clinical participants were tested in their place of residence, except where some preferred to be tested at the university. All control participants were tested in a quiet room at the university.

Materials

The stimuli presented were black line drawings of objects. Each object appeared on a separate card measuring 9 x 9 cm. Each card was plain white and laminated.

In the initial piloting phase of the experiment there were 40 drawings of objects. These were presented to 9 normal individuals in order to ascertain whether they were relatively easy to

participants. These participants were re-tested on a new variation of the second-order belief task and all were found to

name. Since the objects were easy to name they were all employed in the second piloting phase. In the second phase the same objects were used but they were presented differently. Half of the objects (20) were presented fragmented into pieces (ranging from 2 to 5 fragments) which had been tilted with respect to each other. The other half (20) presented just a *single* part of an object. These sets and 3 trial items for each set were presented to 20 different normal subjects who had to identify what the objects were from fragments and a single part. From this second piloting phase items were selected to make both sets comparable in terms of frequency and difficulty. The frequencies were based on norms taken from an english research corpus (TEC, 1999). The difficulty was determined by selecting stimuli which resulted in the performance means and frequency ratings being approximately equal on the fragments and part sets. Thus items were selected which resulted in the performance means on each set being the same when rounded to the nearest whole number. Similarly, the selected items took into account the frequency of the stimuli such that the mean frequency ratings did not differ between sets [$t(30) = 0.08$, $p = .93$ two-tailed].

Whilst matching the sets on mean frequency ratings the stimuli within each set had differing frequencies. This reflects the natural world where objects do not occur with equal frequency, and it also avoided the test being rendered too easy or too difficult as a result of pitching frequencies at a certain level. Examples of the stimuli used in this experiment are shown in the Appendix. The full set of stimuli can be obtained from the authors.

The test stimuli consisted of 32 of the original 40 objects. The 32 objects constituted two sets of 16 objects in each. Again these sets consisted of the fragmented objects (F) and a single part of an object (P). Again the objects in their complete form were used, but this time as naming controls for the F and P sets - the naming control sets being labelled FNC and PNC respectively. Thus the test stimuli consisted of 4 sets of test cards: the F and P sets and the FNC and PNC sets. Again the same 3 trial items for each set were employed as training stimuli for the test items.

A stopwatch was used in order to time how long it took the participant to determine what each object was. In order to assist in the recording of response times, there was a large square of blank white card measuring 18 x 18 cm, the purpose of which was to cover the test cards. This could be removed rapidly, and therefore allowed greater accuracy in recording response times than could be achieved if one just turned over the test card and then started the stopwatch.

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pass.

Procedure

Each participant was tested individually in a room free from distractions. The experimenter sat opposite them, so that she could conceal more easily the names of the objects which were to be checked off on a score sheet. Four sets of cards were presented, one set at a time. The set being presented was placed face up on the table directly in front of the person, and on top of this pile of cards there was the large square of card, which was used to control participants' response times with greater accuracy.

The trial and test items

The 3 trial items of the Fragments set were presented first and in a fixed order to each participant. The participant was told that he/she was going to see some pictures of objects and that they were to look at some trial items before beginning the actual test items. The first item to be uncovered was a balloon which had been fragmented into two pieces. Participants were asked what the object would be if the two pieces were put together. The participant was then shown this item made up from the trial items of set FNC. The experimenter then presented in an identical manner the remaining two trial items. All participants found the trial items relatively easy.

After the 3 trial items, the experimenter told the participant that the procedure for the test items would be the same as for the trial items, except that now their responses would be timed and that they would not get to see the items complete until the end of the test when they would be asked to name them. They were also informed that they could not amend their decision as to what the object was, otherwise their response times would be distorted. Participants were then given the 16 test cards of the Fragments set, these were shuffled and placed face up on the table, but under the covering card. Each participant received a different random order in order to ensure that there would be no order effects. Furthermore, after each response to an item, the loose card which covered the pile of cards was replaced back on top of the pile and the top card just viewed was slid away from underneath and placed to one side face downwards on the table. This made it possible for the next card to be ready for presentation.

Upon completion of the Fragments set, participants were given the *trial* items of the Part set. These were introduced in a similar manner to the previous set's trial items, but here participants were told that with these cards they would now be seeing just a part of an object and that they were to guess what the whole object was just from seeing this part. After completing the 3 trial items of this set without having any difficulty, participants were given the 16 test items.

Each participant always received the Fragments set, followed by the Part set, since there was a strong possibility that had the clinical groups been given the Part set first, they could get used to activating a particular response schema, i.e. that of attending very closely to a *single* element. Such a response bias could prevent the visual integration of *multiple* fragments which was the requirement of the fragment integration task. Since it was predicted that the clinical groups might be less efficient on the fragment integration condition, having this condition first and the 'part' condition second enabled the latter to act as a control for both attentional or fatigue effects.

Upon completion of the two conditions (Fragments (F) and Part (P)), participants were given the naming control sets. For consistency, test set FNC (Fragments Naming Control Set) was always presented first, followed by set PNC (Part Naming Control Set) and the pictures within each set were again randomised for each participant. Participants were told that they had to simply name the objects portrayed. This easy task functioned solely to ensure that any apparent deficit in visually integrating fragments was not in fact due to either unfamiliarity with some of the objects used in the test, or to a deficit in naming whole object representations *per se*. Participants' responses were not timed on these sets, as it was important only to assess naming.

Scoring

For both the Fragments and Part conditions, there were two performance measures for each participant: the response time (the time taken to determine what the object was), and the accuracy score (the number of correct identifications). In both the FNC and PNC conditions, there was a single performance measure, an accuracy score (the number of items correctly identified).

The recording of response times was achieved as follows: timing was started as soon as the blank card was removed from the pile of test cards. As soon as the participant reported what the object on the top of the pile was, the experimenter recorded the response time which was entered on the score sheet next to the object's name. If the participant made an error, or omitted to make a response, this was also recorded; in the first case the participant's decision as to the object portrayed, and in the second case as a 'o'. All response times were scored in seconds and hundredths of a second, since participants could recognise some of the objects very rapidly. It was assumed that any timing inaccuracies resulting from the experimenter's operating of the stopwatch would average out across the test items or groups. Participants were given as long as they wanted to make their decision, but amendments were not permitted since they would lead to a distortion in response times. The timing was to make sure that the clinical groups were not failing due to being

impulsive, which would be expected to result in faster response times overall, and particularly so on failed items.

In all four conditions the letter either C (correct) or I (incorrect) appeared on the score sheet next to the object's name. This was circled depending on whether the participant had named the item correctly or incorrectly. Responses which were synonyms e.g. "settee" and "sofa" were classed as correct. The accuracy scores for each of the four sets were denoted by the number of circled letter C's.

Results

Accuracy

Accuracy scores were the number of correctly recognised objects, which could range from 0 to 16 for each of the two conditions (see Table 2).

insert Table 2

The accuracy scores were approximately normally distributed and the variances were approximately equal, so a two-factor repeated measures ANOVA was performed on the mean accuracy scores for each of the three groups. This ANOVA had a between-participant variable of Group, and a within participant variable of Condition (Fragments and Part). The ANOVA revealed significant main effects of Condition [$F(1,48) = 30.48$, $p < .01$] and Group [$F(2,48) = 6.04$, $p < .01$]. Their was also a higher-order interaction of Group by Condition, which was as predicted significant [$F(2,48) = 19.75$, $p < .01$]. See Figure 1.

insert Fig. 1

This Group by Condition interaction means that this interaction must at least in part be due to there being different Group effects for the two conditions. To examine whether the general group effect applies to one or more of the conditions, simple effects were examined which compared the different Groups on each Condition. As predicted analysis of simple effects showed the effect of Group to be significant only for the Fragments condition [$F_{Fragments}(2,48) = 16.19$, $p < .01$; $F_{Part}(2,48) = 0.24$, $p = .79$].

The Group effect and this Group by Condition interaction was investigated further using t-tests. Planned contrasts of the cell means indicated that the Fragments mean of the autism and Asperger groups were as predicted significantly lower than that of the normal control group [$t_{aut.}$ (48) = 5.60, $p < .01$; $t_{Asp.}$ (48) = 2.84, $p < .01$]. We also found an unpredicted difference on the Fragments mean between the autism and Asperger groups [$t(48) = 2.76$, $p < .05$] which suggests that the autism group was significantly less efficient than the Asperger group.

Given that the Condition effect was significant, it is useful to examine whether there were different Condition effects for the three Groups. Simple effects were examined which compared the two conditions for each group. Analysis of simple effects showed the effect of Condition to be significant for the autism group [$F (1, 48) = 56.46$, $p < .01$] and the Asperger group [$F (1, 48) = 11.67$, $p < .01$], but not the normal group [$F(1, 48) = 1.87$, $p = .18$]. Observation of the means (see Table 2 and Figure 1) show the autism and Asperger groups to be significantly *worse* on the Fragments condition relative to their own performance on the Part condition, whereas the normal control group were more level in their performance on both conditions, being neither significantly better nor significantly worse on either of the two conditions.

It is important to see whether the clinical groups' inefficiency in integrating fragments determined by just a few individuals in each group or characterised the majority of these groups. To this end, the number of participants in each group scoring above (and below) the control group mean was calculated. This was compared to the numbers of participants in the normal group scoring above (and below) their mean. The analysis revealed that the autism and Asperger groups differed significantly from the normal control group [Yates Continuity Correction to correct for expected frequencies < 5, $\chi^2 (1) = 6.48$, $p < .05$ for both].

Response Time

Since it was possible that the clinical groups could fail the fragments (and part) set due to being impulsive, response times for correct and incorrect responses were examined (see Table 3). Examining first the fragmented set: the data was approximately normally distributed for each group and the variances were approximately equal, so two one-factor ANOVA's were performed, one on each type of response. These ANOVAs revealed that the groups did not differ in response time on the number of correct or incorrect responses [$F_{correct} (2, 48) = 0.96$, $p = 0.39$; $F_{incorrect} (2, 48) = 0.06$, $p = 0.95$]. Examining the Part set: the data again was approximately normally distributed for each group and the variances were roughly equal, so two one-factor ANOVA's were performed, one on each type of response. These ANOVAs again revealed that the groups did not differ in

response time on the number of correct or incorrect responses [Fcorrect(2, 48) = 0.69, p = .51; Fincorrect (2, 48) = 1.38, p = 0.26]. Whether one looks at the mean response time on the correct or incorrect responses, the analysis yielded the same results. The clinical groups did not differ in their response times.

insert Table 3

Object naming, Omissions and Disengagement Errors

Since it is the Fragments condition which is so difficult for the clinical groups the remaining analysis focuses on this condition. Because the clinical groups' relative difficulty with the Fragments condition could simply be because they had difficulty naming some of the objects portrayed, the naming errors were examined. The number of naming errors on the Fragment Naming Control set (FNC) were calculated for each group and contrasted with each groups total number of errors. A 3 x 2 Pearson chi-square test was then conducted to see whether the groups differed in the proportion of their errors which could be considered to be due to an inability to name (and hence know) the objects portrayed. Chi-squared analysis revealed no significant difference between the three groups [$\chi^2(2) = .03$, $p = .98$].

It was also possible that the clinical groups' relative difficulty with the Fragments condition was simply because they were less willing to give a response or make a guess in comparison to their normal control group, i.e. they were tending to make more omissions for whatever reason, rather than there really being a problem in integrating fragments. This was thought possible given these individuals' known communication difficulties, lack of spontaneity and problems with generating ideas, so the number of omissions were examined. The number of omissions made by each group for the Fragments set were calculated and contrasted as a proportion of their total number of errors. A 3 x 2 Pearson chi-square test was again conducted to see whether the groups differed in the proportion of their errors which could be considered to be due to omissions. Chi-squared analysis revealed no significant difference between the 3 participant groups [$\chi^2(2) = 0.04$, $p = .98$].

Finally, it is possible that the clinical groups' relative difficulty with the Fragments condition might be due to a problem in mentally disengaging from a fragment. A quarter of the stimuli had an element which itself was meaningful, so a tendency to be captured by the visual salience of an element would be expected to show up most on these items. Thus the row of keys of

the accordion could be described as a piano, the head of the unicorn (minus his horn) as a horse, the bottom of the rake as a comb, the body of the jug as a vase and the base of the frying pan as a bowl. The actual number of disengagement errors were quite small and did seem to occur only with these stimuli. Nevertheless these errors were calculated for each group and contrasted as a proportion of their total number of errors. A final 3 x 2 Pearson chi-square test was conducted to see whether the groups differed in the proportion of their errors which could be considered to be due to a problem with mental disengagement. Chi-squared analysis revealed no significant difference between the 3 participant groups [$\chi^2(2) = 0.09$, $p = .96$].

Discussion

As predicted by central coherence theory (Frith, 1989), both groups of clinical participants (with either autism or Asperger syndrome) were significantly impaired in their ability to integrate fragments holistically to identify an object. However, they were unimpaired in their ability to recognise an object from a single part. The impairment in integration replicates the finding of Stevens and Moffit (1988) who found an adult with Asperger syndrome to have a borderline impairment. This is at odds with the study of Mottron and Belleville (1993) who found no such impairment in an adult with high-functioning autism. The differences between these earlier studies and the modified version of the HVOT probably lies in the methodological differences between the two tasks employed.

The modified Hooper test sought to directly test central coherence theory, whilst the earlier studies did not. This led to the adoption of two conditions, one of which required the integration of multiple fragments (Fragments condition), and the other of which required only a consideration of a single element or part (Part condition). Individuals with either autism or Asperger syndrome showed evidence of relatively impaired processing on the Fragments condition, but normal processing on the Part condition. This suggests that the failure of the Mottron and Belleville study to detect a difference, and the mild impairment found in the Stevens and Moffit study, was confounded by the fact that half of the stimuli they used could be recognised from a single part, and therefore resembled our Part condition.

The visuo-conceptual deficit observed in the clinical groups raises the question as to how this task differs from that of the Object Assembly task (in the Wechsler (1974; 1981) IQ tests), since they both have puzzle-like pieces, and in both a whole needs to be constructed from parts. Individuals with autism are not usually found to have deficits on Object Assembly (Happé, 1994),

and are known to be proficient at jigsaws (Baron-Cohen & Bolton, 1993). One reason may be that it is possible to construct the design in the Object Assembly task in a 'bottom-up' way. This is on the basis of local connections (contours) between the puzzle pieces, since it is not until the object is nearly completed that the identity of the most difficult items necessarily becomes apparent (Lezak, 1995). Thus individuals who are unable to conceptualise what the Object Assembly constructions should be, could put them together in a piecemeal fashion, by matching lines and edges in a serial manner. The Hooper test does not afford this opportunity. Indeed, for many of the items it is not possible to see where the pieces would join if one were to try to use such a serial approach. The Hooper test requires the fragments to be integrated in parallel (since the lines do not facilitate an obvious local matching procedure), a process which is essentially 'top-down' rather than bottom-up. It is for this reason that the original Hooper test was described as providing a quantitative measure of *visuo-conceptual* functioning.

Further evidence for the top-down (and hence parallel processing) nature of the task comes from response times. Participants from all groups tended to identify many of the items very rapidly and inspection of the data for the 3 groups combined did not reveal any increase in response time as the number of elements increased. This suggests processing was in parallel and hence top-down. However, inspection of the clinical groups' data revealed they had a tendency to take longer as the number of elements to be integrated increased. This might suggest that where they failed to employ a top-down or parallel processing strategy they tried to use a serial matching approach, as one would use when physically matching puzzle pieces. The interesting finding was that despite their difficulty integrating elements they were not observed to be less accurate as the number of elements to be integrated increased. This is quite hard to explain, since weak central coherence might suggest that their performance should be less accurate as the number of elements to be integrated increased. This is an area for future study.

When looking at the performance within groups it was found that the clinical participants performed significantly worse on the Fragments relative to their own performance on the Part condition. On the other hand the normal control group performed similarly on both conditions. It could be interpreted that differences in central coherence ability underlies the performance of the clinical and normal control groups. Thus the normal group's strong coherence enabled them to cope with the demands of conceptually integrating fragments, whereas the clinical groups' weak central coherence prevented them from performing as well on the Fragments condition as they did on the Part condition. In this regard it is interesting that the autism group is significantly less able to integrate elements than the Asperger group. This would be consistent with the anecdotal reports of individuals with autism.

In the second half of this discussion we turn to consider other factors which might be influencing the clinical groups' ability to integrate elements. The first of these pertains to motivational problems. It is unlikely that the clinical groups' poor performance is a secondary consequence of motivational factors. Three separate results argue against this hypothesis. First, they were not impaired on the control or Part task and one would expect motivational differences to be evident on this task also. Second, participants with autism or Asperger syndrome were able to integrate elements together so as to identify some of the more difficult to identify objects, thus displaying motivated behaviour. Third, the finding most pertinent to a motivational hypothesis is that (despite their poor overall performance) the clinical groups were observed to respond to the varying degrees of difficulty of the stimulus materials employed in much the same way as their control group. In fact, even the items which they failed demonstrated their highly motivated behaviour as reflected in the good (albeit incorrect) responses they made. For example, some of the items that were incorrect but good guesses were as follows: a paper bag for the sweet, an axe for the broom, a chair or slide for the athletics jumping hurdle, and a rod or musical instrument for the walking stick. Such evidence leads one to conclude that the clinical groups' difficulty in mentally synthesizing fragments in the Fragments condition cannot be due to motivation problems. Such findings also rule out inattention and particularly fatigue playing a role since the control or part task was always presented after the critical or fragments task, so fatigue effects would be expected to be more evident on this task.

A second factor which could be suggested as playing a contributory role in their deficit in integrating elements is impulsiveness. However, it is unlikely that clinical groups perform poorly simply because they give the first response which comes into their head, as like the control group, they tended to respond rapidly on the objects they could identify easily, but tended to respond more slowly on the items they could not identify easily. Furthermore, like the control group they took longer to make their response on the Fragments condition than they did on the Part condition. This was presumably because of the increase in the number of elements which needed to be considered and because of their difficulty with this condition. The clinical groups' response times on the Fragments condition does not support impulsive responding.

A third factor which might have given rise to a problem in integrating multiple elements stems from the anecdotal reports which suggest that children with autism fixate on small morphological details (Rimland, 1971) together with the experimental evidence that suggests they have problems with mental disengagement (Hughes & Russell, 1993; Russell, Mauthner, Sharpe & Tidswell, 1991). However, there are number of studies which demonstrate that children with autism

can mentally disengage. These include visual perspective taking tasks, where the child has to infer what someone else can see from his/her spatial position, even if this is different to what the child currently sees (Baron-Cohen, 1989b; Hobson, 1984; Tan & Harris, 1991). Similarly, they seem to perform at a level appropriate to their mental age on judging the content of 'false' photographs, maps, drawings and models, all of which require the child to put aside their knowledge of current reality in order to answer a question about an out-of-date situation (Charman & Baron-Cohen, 1992, 1995; Leekam & Perner, 1991; Leslie & Thaiss, 1992). The modified Hooper task itself also contains a quarter of the fragmented stimuli with an element which in itself was meaningful, so a tendency to be captured by the visual salience of an element (in this case a meaningful element), or to make an isolate response, would be expected to show up most on these items. However, the number of disengagement or isolate errors did not differ between groups[2]. The individual with Asperger syndrome in the Stevens and Moffit study gave 5 isolate errors (out of a total of 30 stimuli). This may have something to do with the fact that about half of their items could be identified from a single part, which would encourage such a response bias. This did not occur in the study presented here, possibly because the fragments and single part responses were kept separate and the Part condition always followed the Fragments condition. Furthermore, the clinical groups' attempts to identify the item portrayed, amidst their difficulties with integration, led them to occasionally (albeit rarely) give a meaningful, but incorrect interpretation for each element rather than tending to focus on a single element. For example, the frying pan became a knife and bowl. On the face of such evidence one is left to conclude that a problem with mental disengagement or fragmentation *per se* cannot be at the heart of the clinical groups' difficulty in mentally integrating fragments.

A fourth factor which could account for the problem in identifying the objects in the Fragments condition, is that the clinical participants could have been unfamiliar with the objects employed, or have a problem with object recognition in general. Neither of these factors seem likely for two reasons. Firstly, the participants did not differ in their ability to correctly identify the fragmented objects in their whole form when presented in the Fragments naming control task. Secondly, their ability to correctly identify the whole objects employed in the Part condition suggests that they do not have a problem with object recognition in general, which is consistent with the evidence for unimpaired object recognition demonstrated in a high-functioning adult with autism (Mottron & Belleville, 1993).

[2] In this experiment, "isolate errors" as a result of fragmentation problems are assumed to be synonymous with "mental disengagement errors". The test does not distinguish between the two and it is not entirely clear what the relationship between the two is, since a difficulty with mental disengagement might be made worse by problems with fragmentation. This in no way creates a problem for this task, since the analysis sought only to demonstrate that "integration errors" did not occur because of a tendency to concentrate on a single element or detail.

The results strongly suggest that it is the need to integrate the fragments that accounts for the clinical groups' difficulties. Future work will need to investigate the neural basis for this problem. Recent evidence suggests that patients with right hemisphere lesions are impaired at integrating fragments on the traditional HVOT (Fitz, Conrad, Hom, Sarff & Majovski, 1992; Nadler, Grace, White, Butters & Malloy, 1996), and it is possible that right hemisphere lesions not only cause the integration deficits but also the social and pragmatic deficits characteristic of autism (Brownell, Potter, Bihrle & Gardner, 1986; Brownell, Potter & Michelow, 1984; Brownell, Simpson, Bihrle, Potter & Gardner, 1990; Happé & Frith, 1996).

One of the problems with both this modified and the traditional HVOT is that the stimuli are line drawings, and therefore are not 3D objects in the real world. It is possible that the integration of fragmented 'real' objects might be different. A further consideration for future research, will be to test and contrast the ability to conceptualise the fragments of a real object, with the ability to physically put the object together. Also future research should correlate performance on the modified HVOT with symptom severity in an attempt to explain in a more direct fashion how the symptoms of autism and Asperger syndrome might be linked to weak central coherence.

Although both groups demonstrated an impairment, the individuals with autism were significantly more impaired than those with Asperger syndrome. Also, there was wide variability within as well as between clinical groups, which suggests that integration (central coherence) ability may vary widely. Although the ability to integrate elements also varied quite widely in the normal group (though less than in the clinical groups), the findings reported here do not suggest that those with an autism spectrum disorder are at one end of the normal continuum on this test of visual synthesis. The clinical participants seemed to possess a real impairment, as only a minority of their scores overlapped with control individuals. However, despite this impairment, the performance of our high-functioning adults with autism or Asperger syndrome was one of inefficiency rather than inability. They were not unable to integrate visual elements, just significantly less proficient at doing so. Therefore our clinical subjects differ from patients with apperceptive visual agnosia, who cannot synthesize what they see. Such patients indicate awareness of discrete parts of a word or a phrase, or recognise elements of an object without organising the discrete percepts into a perceptual whole.

The results of the majority analysis suggest that this lack of proficiency in integrating elements applied to the majority of our subjects with autism or Asperger syndrome. Therefore it seems that difficulties in visual synthesis characterise at least some individuals on the autism

spectrum. The performance of the clinical groups supports Frith's (1989) proposal that central coherence or the ability to integrate information is impaired in autism and Asperger syndrome. Moreover, the findings are in line with evidence from other studies demonstrating that individuals with autism or Asperger syndrome have difficulty in integrating multiple objects (Carpentieri & Morgan, 1994; Jolliffe & Baron-Cohen, 1998; Rumsey & Hamburger, 1988; 1990). The evidence from these papers and the findings reported in this paper suggest that a problem in integrating information characterises individuals on the autism spectrum. Given that the impairment characterised the majority of individuals with autism, the findings support Frith's suggestion that a problem in integrating information might be a core deficit in autism.

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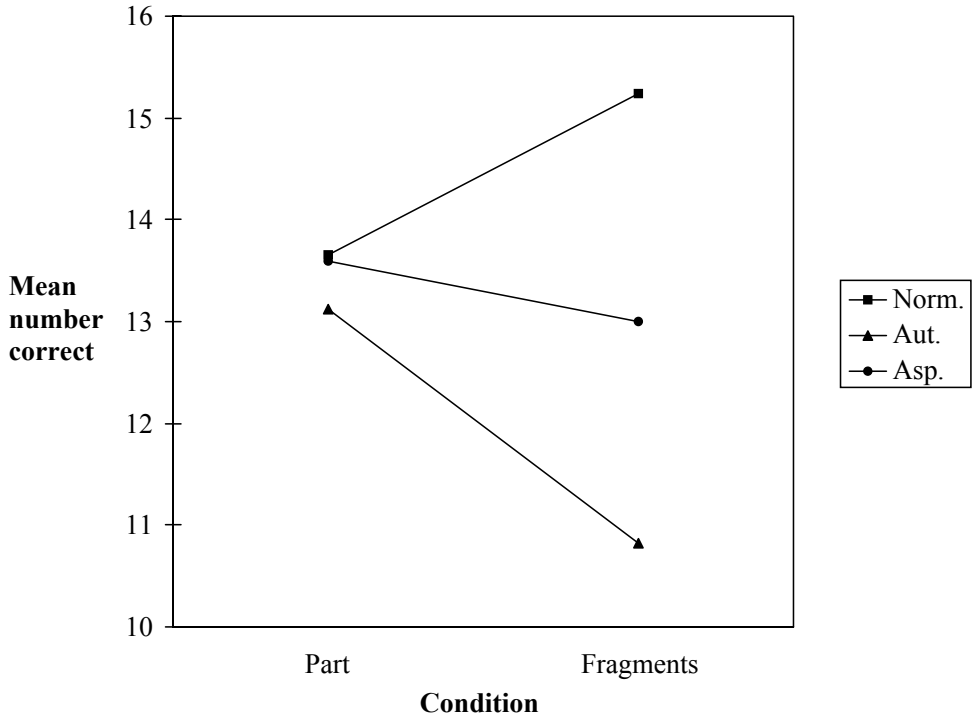
Table 1 Participant characteristics showing chronological age (CA), verbal (VIQ), performance (PIQ) and full-scale IQ (FSIQ).

Participant Group		CA	VIQ	PIQ	FSIQ
Normal	Mean	30.00	106.47	105.24	106.35
(n = 17)	sd	9.12	10.94	14.00	12.72
	Range	(18 - 49)	(87 - 127)	(85 - 134)	(88 - 133)
Autism	Mean	30.71	107.59	101.77	105.12
(n = 17)	sd	7.84	14.37	13.06	13.47
	Range	(19 - 46)	(88 - 135)	(85 - 132)	(90 - 133)
Asperger	Mean	27.77	110.82	100.29	107.12
(n = 17)	sd	7.81	13.51	14.23	14.34
	Range	(18 - 49)	(89 - 130)	(85 - 133)	(86 - 132)

Table 2 Mean accuracy scores and response times, by condition.

Participant Group (n = 17)		Accuracy		Response Time	
		Fragments	Part	Fragments	Part
Normal	Mean	15.24	13.65	6.49	5.42
	sd	1.60	2.15	1.59	1.56
	Range	(12 - 18)	(10 - 17)	(3.98 - 12.59)	(2.00 - 10.00)
Autism	Mean	10.82	13.12	8.45	4.91
	sd	2.90	1.87	1.60	1.79
	Range	(7 - 15)	(10 - 16)	(3.98 - 25.12)	(2.00 - 19.95)
Asperger	Mean	13.00	13.59	8.53	5.53
	sd	2.21	2.29	1.58	1.67
	Range	(9 - 16)	(9 - 17)	(3.16 - 15.85)	(2.51 - 15.85)

Figure 1 Effect of Condition on mean accuracy scores



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A test of central coherence theory: I. Can adults with high-functioning autism or Asperger syndrome integrate fragments of an object?

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Figure Legend

Fig. 1: Effect of Condition on mean accuracy scores

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