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Asperger Syndrome: Tests of Right Hemisphere Functioning and Interhemispheric Communication

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The primary aim of this investigation was to assess to what extent Rourke's (1989, 1995) nonverbal learning disabilities syndrome (NLD) model resembles the pattern of assets and deficits seen in people with Asperger syndrome (AS). NLD can be characterized by a cluster of deficits primarily affecting nonverbal aspects of functioning, in the presence of proficiency in single word reading and a superior verbal memory. The neurological underpinnings of this syndrome may be dysfunction of white matter affecting right hemisphere functioning and interhemispheric communication. To explore this hypothesis, eight participants with AS (ages 10 to 41 years) were assessed in the following areas: the pragmatics of language and communication, verbal and visual memory, visual-spatial abilities, and bimanual motor skills. Results confirmed the close similarity in the neuropsychologic profiles of NLD and AS.

KEY WORDS: Asperger syndrome; nonverbal learning disabilities; right hemisphere dysfunction; interhemisphere communication; neuropsychological assessment.

INTRODUCTION

Asperger syndrome (AS) is a pervasive developmental disorder (PDD) characterized by reciprocal social deficits and rigid ritualistic interests, without cognitive or language delay (APA, 1994). The criteria for autism are not met. Despite its inclusion in the official systems of classification, it is unclear to what extent it overlaps with and differs from autism with normal intelligence, often referred to as high-functioning autism (HFA). Several other disorders have been described in the literature that bear a striking similarity to AS, such as social-emotional processing disorder (Manoach, Sandson, & Weintraub, 1995) and "developmental learning disability of the right hemisphere" (Weintraub & Mesulam, 1983; Voeller, 1986). Other studies by Ross and Mesulam (1979) and Ross (1981) have also described a profile exhibited by patients with right hemisphere dysfunction that is not unlike that seen in AS. In fact, many of these studies suggest the possibility that there may be a link between right-sided cortical dysfunction and AS simply because of the similarities between their clinical features (Ellis & Gunter, 1999).

Although this is a highly speculative idea, it corresponds in part to the construct of nonverbal learning disabilities syndrome (NLD), first suggested by Myklebust (1975) and later developed by Rourke (1989, 1995). This is defined on the basis of a cluster of deficits affecting the nonverbal aspects of a child's functioning, such as nonverbal problem solving, visual-spatial organization, psychomotor coordination, and tactile perception. Other deficits include understanding and expressing pragmatic and prosodic aspects of language and difficulty in adapting to novel and complex situations, often resulting in problems of social perception, social judgment, and social interaction. Also reported by Rourke are deficits in mechanical arithmetic in the presence of proficiency in single word reading, well-developed rote capacities, and a superior verbal memory.

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Rourke (1987, 1988) proposes that the NLD syndrome may develop from extensive damage to commissural fibers and/or right hemispheric associational white matter tracts, the effect being an understimulation or a dysfunction in communication to the right hemisphere. These tracts have very important and specific functions in that commissural fibers interconnect homologous regions in the two hemispheres (the corpus callosum representing the greatest band of these fibers), and associational tracts transmit impulses between cortical points within a single hemisphere (Rourke, 1987, 1988). He argued that the NLD syndrome affects the right hemisphere more than the left because it is made up of relatively more white matter and has longer communication links than the left hemisphere (Goldberg & Costa, 1981). Rourke (1995) proposes that damage or dysfunction to the right cerebral hemisphere may be "a *sufficient* condition for the production of the NLD syndrome," but he adds that a *necessary* condition for the manifestation of the syndrome is "damage or dysfunction of white matter . . . that interferes with "access" to right-hemisphere systems" (p. 21).

Rourke (1987) also stated that NLD may be triggered by damage to intrahemispheric (associational) white matter tracts before birth. This proposal can be linked to Goldberg and Costa's (1981) hypothesis that disruptions in perinatal and infant neurological development may have a significantly greater effect on right hemisphere processes. More recently, Tsatsanis and Rourke (1995) have postulated that there has been a paucity of evidence to support a white matter deficit in AS. However, because of its neuropsychological convergence with other NLD-related syndromes where white matter has been shown to be defective (e.g., de Lang syndrome, velocardiofacial syndrome), they suggested that neurological signs of white matter dysfunction will eventually be revealed in AS.

Although this hypothesis of white matter dysfunction in AS lacks neuropathological evidence, findings by McKelvey, Lambert, Mottron, and Shevell (1995) support the hypothesis that the neurobiologic basis of AS is a developmental abnormality of the right cerebral hemisphere. They reported on three patients with AS, each of whom was found to have abnormal right hemisphere functioning on single-photon emission computed tomography imaging. Other work by Volkmar *et al.* (1996) found evidence of cerebral abnormalities in Tom, an adolescent boy with AS, that were more prominent on the right side than the left. The authors proposed that this pattern of results corresponds to the nonverbal difficulties, such as in relationships and emotional or intuitive language, experienced by Tom. In addition a magnetic resonance imaging study of seven AS cases (with associated Tourette's syndrome) also revealed mostly right-sided abnormalities (Berthier, Bayes, & Tolosa, 1993). Neurological signs of right hemisphere impairments (i.e., left-sided difficulties) have been described in two participants with AS (Berthier, Starkstein, & Leiguarda, 1990). These studies thus provide evidence to suggest that patients with AS may have damage to, or dysfunction of, associational white matter tracts that are particularly deleterious to the functioning the right cerebral hemisphere. It must be noted, however, that the left temporal lobe has also been implicated in AS (Jones & Kerwin, 1990).

If AS results from dysfunctional white matter, then it follows that it should be associated with interhemispheric communication difficulties. Recent findings have also provided evidence of white matter damage in both cortical and callosal regions in individuals with AS. Using MR images taken from 19 patients, Berthier (1994) found structural cortical abnormalities in 10 patients (53%), and 3 of these patients were shown to have thinning of the posterior body in the corpus callosum. In addition, Lincoln, Courchesne, Allen, Hanson, and Ene (1998), in a quantitative MRI study, observed that compared with controls, individuals with AS have a larger anterior corpus callosum.

Rourke (1988) explained NLD in terms of different functions subserved by the right and left hemispheres: visuospatial analyses being largely subserved by the right hemisphere and primary language functions by the left. He further added that the right hemisphere is relatively more adept in processing novel material, whereas the left is suited to the kinds of processing that can use well-routinized sets of rules. It has been found that patients with NLD appear to show right hemisphere deficits (Rourke, 1989), whereas patients diagnosed with HFA display left hemisphere deficits (Rumsey, 1992; Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995). More specifically, Klin *et al.*, found that individuals with AS displayed a neuropsychological profile that overlapped closely with the impairments and abilities subsumed by NLD. This suggestion is consistent with the findings that individuals with AS typically show higher verbal than performance IQ scores (Gillberg, 1991; Klin *et al.,* 1995), whereas those with HFA have sometimes been shown to reveal the opposite pattern (Klin *et al.,* 1995). There has been an increasing number of studies that provide evidence for a convergence between NLD and AS syndromes (see Ellis & Gunter, 1999 for a review). For example, Ellis, Ellis, Fraser, and Deb (1994) found, in a group of children and young adults with AS, a pattern of results that was not unlike the NLD picture. This was shown by the inability to judge social situations, while maintaining a developed verbal memory and verbal IQ. More recent work by Ellis and Leafhead (1996) provides further support for the link between NLD and AS. They describe a 38-year-old man, Raymond, with AS. He was found to have problems in social judgment, ToM, facial processing, visuospatial analyses, and motor skills, while at the same time showing superior verbal abilities (verbal IQ 125, performance IQ 74). These findings have been replicated by similar work carried out by Volkmar *et al.* (1996) and Nass and Gutman (1997).

The purpose of the present investigation is primarily to explore to what extent Rourke's (1989, 1995) NLD model resembles the pattern of assets and deficits seen in AS. The discrepancy in left hemisphere/right hemisphere functioning (as proposed by this model) will be investigated by assessing language and communication, verbal and visual memory, and visuospatial abilities.

We are equally interested in the logically related issue of interhemispheric cooperation, hypothesized by us also to be dysfunctional by the NLD model. This will be assessed using tests of bimanual coordination in an attempt to investigate motor difficulties in AS. Similarly, transcallosal transfer of information will be assessed by briefly presenting words and faces bilaterally (left and right visual field simultaneously) to examine how efficiently information arriving initially in one cerebral hemisphere can be transferred to the other.

METHODS

Participants

From a list of consecutive referrals to the University of Michigan Division of Child Psychiatry, eight participants meeting the criteria for AS (APA, DSM-IV, 1994) were selected randomly. Diagnosis of AS was reached as follows. First, patients with PDDs (of which AS is one category) were identified. Diagnosis of PDD was made after a comprehensive multidisciplinary evaluation, which consisted of semistructured interviews with parents and patients, psychological testing, and behavioral assessment. The clinical information was supplemented by data based on the Autism Behavior Checklist (Krug, Arick, & Almond, 1980) and the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984). All available written records from educational agencies, social workers, and schools were also reviewed. Patients with AS consisted of those who met the criteria for that disorder as laid down by the ICD-10 (World Health Organization, 1993). These were patients with developmental disorders who failed to meet the criteria for autism according to ICD or autistic disorder (DSM-IV, American Psychiatric Association, 1994) but suffered from autistic social dysfunction and idiosyncratic interests, in the presence of a full-scale IQ of 70 or above on an individually administered test of intelligence (WISC-R, 1974; WAIS, 1981). None of them had a history of speech delay (as defined by the absence of three word sentences by 3 years of age). Deficits in the social use of language were not taken into account. It is important to note that none of the participants with AS had met the criteria for autism in the past or at the time of evaluation and that this group were distinguished from those with high functioning autism. Other details about the process of diagnosis have been given elsewhere (see Ghaziuddin & Gerstein, 1994).

Table 1 lists information taken from medical and educational records on developmental and family history, MRI data, medication, and current interests for eight participants with AS. Table 2 lists qualitative information obtained from participants with AS as a result of observations and informal questions made throughout the testing session. Table 3 reveals data relating to age, sex, and verbal and performance IQ for participants with AS.

Controls for the project were (a) five participants who were recruited from local schools and (b) three participants who were undergraduate volunteers. All groups reported normal or corrected to normal vision with no history of any neurological disease. Participants with AS and control participants were matched on the variables of age and verbal IQ. Verbal IQ was assessed in control participants using either the British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Pintilie, 1982) or the National Adult Reading Test (Nelson, 1991). Table 4 lists mean ages and age range and mean verbal IQ and verbal IQ range.

Two-tailed independent *t* tests revealed no significant differences between the two groups on either age [$t(14) = -.14, p > .05$] or verbal IQ [$t(14) = -.71, p > .05$].

Procedure

Participants were tested individually. Following an initial interview designed both to elicit information about their behavior, interests, etc. and at the same time

Table I. Information Relating to Developmental and Family History, MRI Data, Medication, and Current Interests for Michigan AS Subjects

Subject	Pregnancy	Milestones	Early speech	Difficulties	MRI data	Family history[a]	Medication	Current interests
LB	First born; full term, normal delivery	Normal	No speech delay	Problems first noted at the age of 4–5 years in preschool; Main complaints: “acting out” and “won’t get along with other children”	None	M: Possible history of depression. F: NI 2 Younger siblings: speech-therapy for artic ulation problems		Golf courses
RB	Full term; cardiac problems during the last trimester; cesarean section.	Started walking at 14 months	Speaking in three-word sentences at 19 months	Problems of social interaction noted in middle school	Normal	M: Depression F: Asperger-like traits	Zoloft	Animals
SB	Full term; labor failed to progress; cesarean section.	Walked without support at about 12 months	Speaking in three-word sentences at 19 months	Problems of social interaction noted at around 8 years of age	Normal	M: Depression F: Asperger-like traits	Zoloft	Mathematics
DS	Patient adopted	Few details recorded in chart suggest that there were gross delays in milestones	No speech delay	First professional help sought at 4 years of age; symptoms: “inviting his friends home and doing his own thing . . . chasing the cat . . . taking off without permission”	None	Adopted; family history not available	NI	Race/religion
MG	Cesarean section	NI	No formal speech delay but some articulation problems	Social difficulties in childhood and became more apparent between 5 and 7 years of age; saw a psychologist at 5 years; placed in therapy; suspicion of PDD raised at age 8–9 years	None	M: Depression F: NI	Lithium	Computers

MH	First born; full term; possible history of alcohol intake during pregnancy	NI	No speech delay	Problems first noted when the patient started school; these consisted of social difficulties, mainly, difficulty in relating to peers	Diffuse increased signal in the periventricular white matter of intermediate signal intensity in the right thalamus and in the right peritrigonal region; these findings are nonspecific and may represent gliosis, dysmy-lineation, or demylination	M: Depression F: Alcohol abuse	Prozac	Cars
MH1	Full term; normal delivery	Walked at 9 months	Spoke freely before 3 years	Problems with social interaction (difficulty in relating to others, difficulty in forming relationships) noted at 6 years of age	M: NI F: Schizoid personality disorder. 2 Younger siblings: AS	Anafranil	Mathematics	
FM	First born; full term, normal delivery	Normal	No speech delay (phrase speech by 3 years of age)	Some clumsiness, not in early years; first problems to be noted were hyperactivity and social difficulties when the patient started school	M: Depression F: NI	NI	Sports	

[a] NI, No information; M, mother; F, father.

Table II. Qualitative Information Relating to Eye Contact, Speech Evaluation, and Other Features for AS Subjects

Subject	Eye contact	Speech evaluation/conversation	Other
LB	Some avoidance of eye contact	Language very formalized: pedantic, little emotional tone	Socially odd but very aware; LB seemed very intelligent and knowledgeable, especially in the area of AS. She had read most of the books on this subject and was therefore well aware of what abilities the tests were tapping into. She disputed the fact that she had AS, but agreed to help with the project anyway.
RB	Eye contact mainly normal, although at times RB appeared to look "right through the examiner"	Good verbal skills, but at times very formalized; for example, when talking about his pet iguana, RB talked at length about the precautionary measures that should be taken when caring for such a pet. He reeled off these measures as if he was reading straight from an instruction manual in a very monotone manner.	Frequent lapses of concentration and attempts to interrupt the testing session; slightly aggressive at times
SB	Normal	Very pedantic and literal; for example, when asked if he was going back to school next week, he replied, "No, I'm going back to school in a couple of days, not in a week's time."	Very intelligent and quick to learn; at times he was very pedantic and condescending. He seemed to have no idea of the effect this may have on his conversational partner.
DS	Eye gaze behavior varied from avoidance at times to an intense gaze, as if he was searching for something	Conversation very tangential at times, and DS would often bring the conversation to religion and history, as he was clearly interested in these topics.	
MG	Significant lack of eye contact	Very formalized and pedantic at times; for example, when asked if he enjoyed doing the tests, MG replied, "Well, that is rather a futile question and I will reserve judgment until I see the results." Hyperverbal and tangential	No sense of formality. For example he did not say 'Hello' or 'Goodbye'. Good verbal memory—was able to recite lines word perfect from movies. Humor rather odd at times. When answering the empathy questionnaire he said that he was able to feel empathy for other people, but that he could only give so much to people as he had enough of his own personal tragedies.
MH	Avoided eye contact where possible	Speech very pedantic, polite, and formalized; MH's voice was very monotonic, almost sounded as if it was computer generated	Ignored social conventions. For example he broke wind without apologizing.
MH1	Total avoidance of eye contact	Lengthy and at times unnecessary; for example, when asked what courses he was currently taking, MH1 reeled off the full title of each course along with course code numbers	Very nervous disposition. Ignorance of social conventions. For example he continually wiped his nose on his sleeve.
FM	Avoided eye contact where possible	FM's behavior seemed hyperactive at times, and he often laughed out loud at inappropriate times.	

Table III. Personal Characteristics of Participants with AS

Subject	Age (years)	Sex	Verbal IQ	Performance IQ
LB	12	F	131	98[a]
RB	10	M	113	110[a]
SB	12	M	130	112[a]
DS	16	M	95	81[a]
MG	13	M	117	106[a]
MH	11	M	112	95[a]
MH1	15	M	105	91[a]
FM	41	M	88	76[a]
M	16.25		111.37	96.13

[a] From WISC or WAIS.

to put them at their ease, they were given a series of tests in a random order. Care was taken in many of the tests to ensure that all words and phrases could be understood and interpreted clearly.

Measures

The Right Hemisphere Language Battery

This battery (Bryan, 1989) consists of seven subtests. In this investigation, however, only four subtests where chosen: metaphor-picture matching, written metaphor choice, inferred meaning comprehension, and humor appreciation. The lexical-semantic subtest was not used because there is no evidence of a deficit in single-word comprehension in AS or NLD (Volkmar *et al.*, 1996; Rourke, 1989; Asperger, 1979; Tantam, 1988). The emphatic stress subtest, which assesses a person's ability correctly to place stress in a sentence, was not used because there is no validation or verification of the correct answer and more than one stress placement seems possible on a number of items (Tompkins, 1995). Owing to time limitations, the discourse analysis subtest was also not used.

Table IV. Summarized Subject Characteristics

		Age (years)		VIQ	
Subject	n	*M*	Range	*M*	Range
AS	8	16.25 (10.19)[a]	10–41	111.38 (15.22)	88–131
Control	8	16.88 (8.10)	10–35	115.75 (8.63)	103–124

[a] Values in parentheses are *SD*s.

Unusual Metaphors Test

The stimuli used for this task was taken from Bottini *et al.* (1994). They investigated the role of the right hemisphere in the interpretation of the figurative aspects of language in a positron emission activation study. In their study, the cerebral activity of normal volunteers was investigated using positron emission tomography, during both a metaphor sentence comprehension task and a literal sentence comprehension task. It was found that several regions of the left hemisphere were activated during the processing of literal sentences. Similar activations were also found during the processing of metaphors, and, in addition, a number of sites were activated in the right hemisphere.

In the metaphor comprehension task, 40 *novel* metaphors containing an equal number of plausible and implausible sentences were presented. In addition, 40 literal sentences were presented, again half of which were plausible and half of which were implausible. Participants were given four practice trials on the metaphorical and literal sentences. The experimental trials were then administered. Here participants rated the sentences as either plausible or implausible. The answers were then marked as either "correct" or "incorrect" using the consensus score derived from the study by Bottini *et al.* (1994). The maximum score possible for each condition was 40.

Warrington Recognition Memory Test

Recognition memory was tested separately for faces and words (Warrington, 1984). In the faces part of the test, 50 unknown faces were shown at the rate of one every 3 seconds for a "pleasant or unpleasant" decision (this procedure was designed to ensure attention is paid to every item). Recognition memory was then tested immediately afterward by presenting each of the faces paired with a distracter, with the participants having to choose which face has been seen before. A similar procedure was used with words. A perfect score is 50 and a chance score is 25.

Bead Threading

The subject was asked to thread 10 medium-sized beads onto a piece of string as quickly and as accurately as possible. The time taken to carry out this operation was recorded.

Etch-a-Sketch Test

A full sized Etch-a-Sketch (a children's toy allowing erasable drawings to be made using two knobs, one controlling vertical movements and the other horizontal movements) was used to assess bimanual performance. Bimanual skill was demonstrated by drawing diagonal lines (as this requires simultaneous input from both hands) along prescribed pathways. This was carried out by turning both the horizontal and the vertical dial in a clockwise direction. Before beginning the test trials, participants familiarized themselves with the equipment, thus enabling them to understand how to draw a diagonal line. A practice line was then given participants to copy: this began in the lower left corner of the Etch-a-Sketch rising to the upper right corner. This was only administered once to standardize practice effects. In the experimental trials, three diagonal lines were administered (Fig. 1): to draw, *line A:* the ratio of right hand input to left hand input is 2:1 (right hand has the greatest input); *line B:* the ratio of right hand input to left hand input is 1:1 (equal input from both hands); line C: the ratio of left hand input to right hand input is 2:1 (left hand has the greatest input).

Lines A, B, and C were 10 cm long. They were drawn separately on clear acetate sheets and placed on the Etch-a-Sketch window. Participants then had to follow these target lines by simultaneously turning the horizontal and vertical dials. Participants were asked to complete the lines as quickly and as accurately as possible. The order in which the lines was completed were chosen at random, to compensate for any practice effects. Once a line was selected, it was drawn three times. This procedure was repeated for the remaining diagonal lines. The time taken to complete each line was also recorded.

Scoring Procedure

After each line was drawn, a tracing was made. Deviations from the target line were measured at 5-mm intervals, and from this an average deviation was then calculated. For each target line (A, B, C), the average deviations from all three trials were added together, and from this, a further mean was then extrapolated.

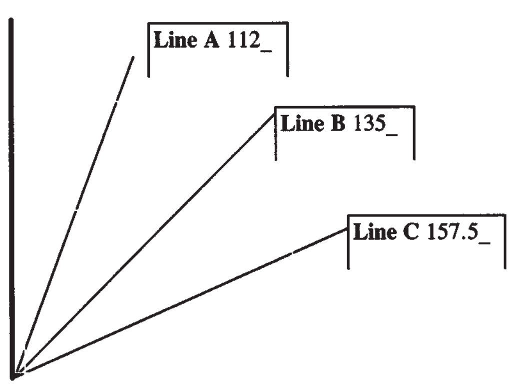

Fig. 1. Diagrammatic representation of the diagonal lines used in the Etch-a-Sketch test.

Luria's Reciprocal Coordination Test

Participants were required alternatively to move the positions of both hands, stretching the first and clenching the other. Performance was measured on how quickly and smoothly participants completed the task.

Rey-Osterrieth Complex Figure Test

This test is designed to investigate both perceptual organization and visual memory. The Rey-Osterrieth Complex Figure (Lezak, 1995) is a complex and meaningless geometric construction that is often used as a diagnostic test for right hemisphere dysfunction. The test required the subject to copy the figure. Then 40 minutes later, and after a series of intervening tasks, the subject was asked to draw the figure from memory. To score the test, the figure was subdivided into a series of 18 subcomponents, which were then assessed in terms of accuracy. For example, if a subcomponent was placed correctly in the figure, 2 points were given; if it was correct but placed incorrectly, 1 point was given; if the subcomponent was distorted or incomplete but recognizable and was placed properly, a score of 1 point was given; if it was distorted but placed incorrectly, a score of 0.5 point was given; and if the subcomponent was absent or not recognizable, 0 points were given. The maximum score possible was 36.

Global vs Local Processing

This is a recognition memory task based on the work of Delis, Robertson, and Efron (1986). A series of stimuli was presented, and participants were required to choose the correct stimulus from a set of four alternatives. For example, suppose the to-be-remembered stimuli was a large M made up of little z's. One alternative could be the correct stimulus. A second alternative could contain the correct global information but incorrect local detail (e.g., a large M made up of small t's). If this alternative was to be selected, then this would indicate the greater influence of global information over local information. A third alternative could contain incorrect global details but correct local details (e.g., a large O made up of small z's). If this alternative was to be selected, then this would indicate the greater influence of local information over global information. A fourth alternative would contain both incorrect global and local information (e.g., a large O made up of small t's). In this study, nine stimuli were presented: three linguistic symbols (M, J, and D), three meaningful symbols (arrow, triangle, and star), and three meaningless shapes. The to-be-remembered stimuli and four alternative stimuli were all presented in a randomized fashion. To carry out the task, participants were first shown the to-be-remembered stimulus, and then they performed a distracter task for 15 seconds. They were then shown the four alternatives (presented in a vertical array) and asked to point to the stimulus that they had previously seen. The maximum score possible was 9.

Face-Name Matching Task

This is a task that measures interhemispheric transmission duration using a choice reaction-time paradigm. Participants were presented with a bilateral display on a computer screen with one side displaying a name and the other a face. In half of the trials, the name and the face were of the same gender ("Same" condition), and in the other half, the name and the face were different genders ("Different" condition). Also in half of the trials, the name was presented in the left visual field and the face in the right visual field, and vice versa. From these items, eight conditions were formed. The subject's task was to decide whether the gender of the face and the name matched, regardless of the side of the screen they were presented. The participants made their decisions of either "match" or "mismatch" by pressing one of two designated keys with their preferred hand.

Participants were seated 57 cm from the screen. A viewing mask was used to help direct each subject's attention and to cut out any peripheral distractions. The stimuli was displayed on the center of the screen for 180 milliseconds, with a random interstimulus interval of 2.5 to 5 seconds. A warning tone was sounded after each response had been made. In the practice session, 16 trials were presented to familiarize the subject with the procedure. In the experimental session, 56 trials were then presented with 7 trials per condition. However, for the purpose of the present analysis, only two conditions were tested, with 28 trials in each. These were Crossed, same and different, and Uncrossed, same and different. The design was fully counterbalanced. Participants were asked to focus on the central fixation spot at all times and were told that their task was to decide whether the word and face presented matched in terms of gender. They were then asked to execute their response as quickly and as accurately as possible. Half of the pairs in each condition matched in terms of gender and, randomly, half mismatched. Also, within each condition, half of the names were female and the other half were male, and half of the faces were female and half were male. The dimensions of the faces were 4 × 4 cm, and the letters were presented in 14-point Geneva plain lowercase type. Reaction times (RTs) were measured in milliseconds.

Chimera Test

This is a task that again measures interhemispheric transmission time. Participants were presented with a face in the center of the computer screen. In half of the trials, the face was composed of one person (same condition), and in the remaining trials, the face was composed of two people (different condition). Within this task four conditions occurred: same female (both halves of the face are of the same female), same male (both halves of the face are of the same male), different female (the face is composed of two different females), and different male (the face is composed of two different males). For the data analysis, however, all the conditions were collapsed into one factor.

Participants were asked to decide whether the image was of one person or of two different people regardless of the gender. The subject made his or her decision of "same" or "different" by pressing designated keys on the keyboard. The order in which participants responded was counterbalanced, with half of the participants responding with their right hand on the first set of trials and their left hand on the second set of trials. The keys to which participants responded "same" and "different" were also counterbalanced.

Participants were seated 57 cm from the screen. A viewing mask was used to help direct the subject's attention and to cut out any peripheral distractions. The stimuli was displayed in the center of the screen for 135 milliseconds, with a random interstimulus interval of 2.5 to 5 seconds. Participants were asked initially to fixate on the central fixation spot before the stimulus and warning tone was presented. In the practice session, 12 trials were presented to familiarize the participants with the procedure. In the experimental session, 50 trials were then presented with 25 trials in the "Same" condition and 25 trials in the "Different" condition. The design was fully counterbalanced. Participants were asked to focus on the center of the screen at all times and were told that their task was to decide whether the face was composed of the same person or two different people. They were then asked to execute their responses as quickly and as accurately as possible. The dimensions of the faces were 4 × 4 cm.

RESULTS

IQ

A one-tailed related *t* test was carried out on the differences between verbal and performance IQ for AS participants (Table 4). This revealed a significant advantage of verbal over performance IQ [$t(7) = -5.07$, $df = 7$, $p < .001$].

Prediction of Results

Table 5 outlines the prediction of results that would be expected to occur based on the NLD syndrome (also see Table 17 for assessment of whether these predictions have been met).

The Right Hemisphere Language Battery

Correct responses to a Metaphor Picture Test, Written Metaphor Test, Inferred Meaning Test, and Humor Test were subjected to a 2 (Group) × 4 (Language) ANOVA. There was a significant main effect of Group [$F(1, 14) = 4.79$, $p < .05$] and Language [$F(3, 42) = 6.63$, $p < .001$]. These effects were modified by the presence of a significant Group × Language interaction [F (3, 42) = 2.90, $p < .05$]. An analysis of simple main effects revealed that the group with AS was significantly worse at choosing the correct punchline in the Humor Test compared with controls [$F(1, 30) = 11.77$, $p < .05$]. However, there were no significant differences between the groups on appreciation of metaphors or inferring meaning. Means and standard deviations are shown in Table 6.

Table V. Summary of Predictions Based on the NLD Model

Measures	Predictions based on the NLD model
Discrepancy between VIQ and PIQ	VIQ advantage over PIQ
Language	
The Right Hemisphere Language Battery	Impaired
Unusual Metaphor Test	Impaired on the Metaphorical sentences subtest No impairment on the Literal sentences subtest
Memory	
Warrington RMT	Impaired on the Faces subtest No impairment on the Words subtest
Bimanual coordination	
Bead Threading	Impaired
Etch-a-Sketch	Impaired
Luria Test	Impaired
Visuospatial skills	
Rey-Complex Figure Test	Impaired
Local Global Test	Impaired
IHTT experiments	
Face-Name Matching Test	Impaired
Chimera Test	Impaired

Unusual Metaphor Test

Correct responses to the Metaphor and Literal sentences subtests were subjected to a 2 (Group) × 2 (Sentence) ANOVA. There was a significant main effect of Group [$F(1, 14) = 16.75$, $p < .01$] and Sentence [$F(1, 14) = 56.99$, $p <.001$]. These effects were modified by the presence of a significant interaction [$F(1, 14) = 9{,}82$, $p < .05$]. An analysis of simple main effects revealed that the group with AS was significantly impaired in the ability to decide whether or not an unusual metaphor was plausible compared with controls [$F(1, 30) = 11.78$, $p < .01$]. There were no significant differences, however, between the groups on appreciation of literal language. Means and standard deviations are shown in Table 6.

Warrington RMT

Recognition memory for words and faces were subjected to a 2 (Group) × 2 (Memory) ANOVA. Signifi-

Table VI. Language Variables as a Function of Group

Variable	Group[a] Asperger syndrome ($n = 8$)	Control ($n = 8$)
Right hemisphere		
Language battery (max = 10)		
Metaphor Picture	8.37 (2.1)	9.38 (0.9)
Metaphor Written	9.38 (0.7)	9.88 (0.4)
Humor (max = 12)	7.13 (2.8)	9.75 (0.5)
Inference/12	10.25 (1.5)	11.37 (0.7)
Unusual metaphors (max = 40)		
Metaphors	24.75 (4.7)	32.13 (1.5)
Sentences	36.25 (2.6)	36.88 (1.7)

[a] Values given as *M* (*SD*).

cant main effects were found for both Group [$F(1, 14) = 9.18$, $p < .01$] and Memory [$F(1, 14) = 11.39$, $p < .01$]. These effects were modified by the presence of a significant interaction [$F(1, 14) = 6.00$, $p < .05$]. An analysis of simple main effects revealed that the group with AS was significantly impaired in the ability to recognize faces compared with the control group [$F(1, 28) = 15.12$, $p < .001$]. However, the groups did not differ in their word recognition scores. For means and standard deviations, see Table 7.

A one-sample Z-test was then carried out comparing the mean score for patients with right hemisphere brain damage reported by Warrington (1984) with mean scores of participants with AS. Warrington's mean scores for this patient group indicated a higher mean for words ($M = 44.6$, $SD = 5.2$) over faces ($M = 39.7$, $SD = 6.7$). It was found that, as with her right hemisphere–damaged patients, although the mean score of the group with AS on word recognition did not differ significantly from that reported by Warrington, their mean score for faces, in fact, was significantly lower ($Z = -3.51$, $p < .001$)

Bead Threading

The mean time taken to thread 10 beads onto a piece of string are shown in Table 8. The data were analyzed using a one-tailed independent t-test [$t(14) = 1.42$, $p > .05$]. This revealed no significant difference between the group with AS and the control group in the time taken to thread beads.

Etch-a-Sketch

Mean deviation from the three sets of target lines (112°, 135°, 157°) were subjected to a 2 (Group) × 3 (Target line) ANOVA. There was no main effect of Group [$F(1, 14) = 1.23$, $p < .05$] or Target Line [$F(2, 28) = 1.40$, $p > .05$]. These main effects were not modified by any significant interaction [$F(2, 28) = .72$, $p > .05$].

Mean time taken to complete the three target lines was also subjected to a 2 (Group) × 3 (Target Line) ANOVA. There was no main effect of Group [$F(1, 14) = .31$, $p > .05$], but a main effect of Target Line was found [$F(2, 28) = 4.23$, $p < .05$]. These results were not modified, however, by the presence of a significant interaction [$F(2, 28) = 1.02$, $p > .05$]. For means and standard deviations, see Table 9.

Table VII. Warrington RMT as a Function of Group

Variable	Group (max = 50)[a] Asperger syndrome ($n = 8$)	Control ($n = 8$)
Warrington RMT		
Words	44.75 (11.3)	46.75 (4.1)
Faces	31.38 (6.1)	44.63 (1.7)

[a] Values given as M (SD).

Table VIII. Time Taken to Thread Beads onto String as a Function of Group

Variable	Group[a] Asperger syndrome ($n = 8$)	Control ($n = 8$)
Bead Threading (seconds)	37.75 (6.1)	34.00 (4.3)

[a] Values given as M (SD).

Luria's Test of Reciprocal Inhibition

Participants were assessed on the ability rapidly to change the positions of both hands, simultaneously, stretching the first and clenching the other. Participants passed if they could perform this function and failed if they were unable to perform the movements quickly and smoothly or if they produced similar movements in both hands so that reciprocal coordination was

Table IX. Deviation from Target Lines and Time Taken to Complete Target Lines for Etch-a-Sketch Test as a Function of Group

Variable	Group[a] Asperger syndrome ($n = 8$)	Control ($n = 8$)
Average deviation		
Line A (112°)	1.70 (0.9)	1.23 (0.4)
Line B (135°)	1.2 (1.2)	1.11 (0.2)
Line C (157°)	2.07 (2.1)	1.25 (0.5)
Average time taken		
Line A (112°)	21.11 (9.3)	18.37 (5.6)
Line B (135°)	14.02 (5.1)	15.38 (4.9)
Line C (157°)	18.93 (8.9)	15.81 (4.9)

[a] Values given as M (SD).

replaced by equivalent coordination.[4] The results in Table 10 reveals that almost all participants were able to perform reciprocal coordination.

Table X. Participants Who Passed Luria's Reciprocal Inhibition Coordination Test

	Group[a]	
Variable	Asperger syndrome ($n = 8$)	Control ($n = 8$)
Reciprocal Inhibition	6 (75)	8 (100)

Values given as *n* (%); because of the small sample size, no statistical analysis (e.g., χ^2) is possible.

Rey-Osterrieth Complex Figure Test

Z-tests were carried out to explore whether any differences existed for visuospatial ability between norms for aged-matched controls reported by Spreen and Straus (1991) and individual scores for participants with AS. Table 11 gives details of these scores on copy and delayed recall conditions. The only significant difference found was for subject FM, whose delayed recall score was significantly below his aged-matched control group ($Z = 1.72$, $p < .05$). A further analysis was carried out on the data examining the difference between copy and delayed recall trials between participants with AS and control participants using a two-tailed independent t-test for unequal variance. These revealed no significant difference between the two groups [$t(9.25) = 1.87$, $p > .05$].

Local-Global Test

AS and control groups were compared for their recognition memory for hierarchical stimuli. Table 12 shows means and standard deviations. A two-tailed *t* test for unequal variance revealed no significant differences in performance between AS and control groups [$t(14) = -1.51$, $p > .05$]. An analysis of errors committed revealed that one subject with AS chose the hierarchical stimuli containing correct local information but incorrect global information (in three of nine cases), and another subject with AS chose hierarchical stimuli containing correct local information but incorrect global information (in two of nine cases) and stimuli containing correct global information but incorrect local information (in two of nine cases).

Face-Name Matching Task

Median RTs of correct responses were initially analyzed for each subject in each condition: crossed same, crossed different, uncrossed same, and uncrossed different. These conditions were then collapsed into crossed (same and different) and uncrossed (same and different). An RT criterion was established, a priori, eliminating any RTs that exceeded 5,000 milliseconds. The rationale for eliminating such extreme values was that many participants occasionally produced extremely long RTs, which apparently resulted from lapses of concentration. Elimination of such artifactual responses was thus more likely to represent the subject's true visual-motor processing capabilities. Interhemispheric transmission times (IHTTs) were then calculated for both participants with AS and control participants. The IHTTs were computed by subtracting the mean RTs of uncrossed combinations from the mean RT of crossed combinations (see Table 13 for means and standard deviations). An independent *t* test for unequal variance revealed no significant difference between AS and control participants [$t(9.27) = -1.15$, $p > .05$].

The number of correct responses made in each condition were subjected to a 2 (Group) × 2 (Cross) ANOVA. There was a significant main effect of Group [$F(1, 14) = 5.63$, $p < .05$] but no significant effect of Cross [$F(1, 14) = .17$, $p > .05$] was found. These results were not modified by the presence of a significant interaction [$F(1, 14) = .34$, $p > .05$]. Table 14 shows means and standard deviations for correct responses.

Chimera Test

Median RTs of correct responses were initially calculated for each subject in each condition: right hand same, right hand different, left hand same, and left hand different. These conditions were then collapsed into one

[4] The method of scoring was carried out in a qualitative, rather than a quantitative, manner.

[5] Because of the age difference between subject FM (41 years) and the remaining AS subjects (10 to 16 years), analysis of data was carried out to ensure that age was not a contributory factor in the pattern of results found. The data from FM and his aged-matched control subject were excluded from a number of neuropsychological test results (selected at random), and these were then reanalyzed. No significant differences were found in any of the *p* or *t* values, and thus it was concluded that age did not appear to influence the pattern of results found.

Table XI. Rey-Osterrieth Copy and Delayed Recall Scores for Participants with Asperger Syndrome and Norms for Aged Matched Controls. (max. = 36)

	Asperger syndrome[a]				Norms[a]		
Subjects	Copy	Delayed recall	Difference	Age group (years)	Copy	Delayed recall	Difference
LB	36	15	21	12	30.21 (6.7)	23.20 (6.4)	7.01
RB	36	30	6	10	27.20 (7.6)	19.73 (6.7)	7.47
SB	36	30	6	12	30.21 (6.7)	23.20 (6.4)	7.01
DS	34	25.5	8.5	16–30	35.10 (1.5)	22.70 (7.0)	12.4
MG	36	15	21	13	32.63 (4.4)	24.59 (6.3)	8.04
MH	34	25.5	8.5	11	28.61 (7.3)	22.59 (6.7)	6.02
MH1	36	16.5	19.5	15	33.60 (3.0)	26.00 (6.4)	7.6
FM	26	8[b]	18	31–44	33.20 (6.1)	19.50 (6.7)	13.7

[a] Values given as *M* (*SD*).
[b] $p \leq .05$.

condition which expressed the mean RT of all the correct median RTs. Table 15 shows means and standard deviations. A response time criteria was established, a priori, eliminating any RTs that exceeded 5,000 milliseconds. The data were analyzed using an independent *t*-test for unequal variance. This revealed that the RTs for the group with AS were significantly longer than those of the control group [$t(9.05) = 2.15$, $p < .05$].

The number of correct responses made were collapsed across all conditions. Table 16 shows means and standard deviations. The data were analyzed using an independent *t* test for equal variance. This revealed no significant difference in the number of correct responses between the group with AS and the control group [$t(14) = -0.35$, $p > .05$].

Assessment of Predictions

Table 17 summarizes whether the predictions made by the NLD model were supported by the results of this investigation. These findings are evaluated in the next section.

DISCUSSION

For this study, rigorous diagnostic criteria were applied before participants were classified as having AS. Only then were participants confidently diagnosed with AS using the ICD-10 criteria. Other characteristics such as idiosyncratic interests, odd prosody, visuospatial deficits, and difficulties in interpreting pragmatic language support the view that these participants are classifiable as having AS. These data also accord in general with the NLD model proposed by Rourke (1989, 1995); they indicate that there is a pattern of visuospatial and nonverbal deficits in the presence of intact verbal processing. This is further supported by the finding that all of the participants with AS had a significantly higher verbal IQ (VIQ) than performance IQ (PIQ). Work by Gillberg (1991), Klin *et al.* (1995), and Ellis *et al.* (1994) have described similar findings in individuals with AS. In terms of the validity of the syndrome, the VIQ-PIQ discrepancy, characteristic of AS, contrasts with the findings of Green, Fein, Joy, and Waterhouse (1995), who found

Table XII. Correct Responses to Local-Global Hierarchical Memory Recognition Test

	Group[a]	
Variable	Asperger syndrome ($n = 8$)	Control ($n = 8$)
Local-global test	8.13 (1.6)	9 (0.0)

[a] Values given as *M* (*SD*).

Table XIII. RTs to the Face-Name Matching Task and IHTTs

Group	Crossed same/difference[a]	Uncrossed same/difference[a]	IHTT[a]
Asperger syndrome ($n = 8$)	1401.44 (363.5)	1213 (246.8)	187.50 (195.1)
Control ($n = 8$)	1018.63 (197.5)	917.1 (173.5)	101.53 (79.70)

[a] Values given as *M* (*SD*).

Table XIV. Correct Responses to the Face-Name Matching Task

Variable (max = 28)	Group[a]	
	Asperger syndrome (n = 8)	Control (n = 8)
Crossed same/difference	20.13 (3.2)	23.25 (2.3)
Uncrossed same/difference	20.25 (4.8)	22.5 (3.9)

[a] Values given as *M* (*SD*).

Table XVI. Correct Responses for Chimera Test as a Function of Group

Variable (max = 100)	Group[a]	
	Asperger syndrome (n = 8)	Control (n = 8)
All Conditions	83.63 (9.1)	85.00 (6.37)

[a] Values given as *M* (*SD*).

an opposite pattern of intellectual deficits and assets in children with autism, presumably reflecting the relative strength in their visuospatial abilities. Additional findings from the Warrington RMT in this study further supports Rourke's notion of visuospatial deficits in the presence of normal language processing in NLD.

In a study assessing the validity of AS and its convergence with NLD, Klin *et al.* (1995) found that verbal output, vocabulary, articulation, and verbal memory were all normal in AS. In this study, participants were assessed on their understanding of literal language in the "Unusual Metaphors" test. Understanding of literal language is thought to be subserved by left hemisphere processing (Bottini *et al.*, 1994; Tompkins, 1995). The majority of participants with AS performed normally on this task, supporting the findings of Klin *et al.* In addition, verbal memory, as tested by Warrington RMT subtest for words, was found to be normal for the group with AS.

The intact verbal processing and verbal memory skills described above provide a stark contrast to the problems of nonverbal communication and pragmatic language comprehension seen in AS (e.g., Volkmar *et al.*, 1996; Frith, 1991; Kracke, 1994). This discrepancy in language processing has been captured by Rourke's (1989, 1995) NLD syndrome and has also shown to be a common feature in patients with right hemisphere damage (Tompkins, 1995; Cutting, 1990). Findings from the Right Hemisphere Language Battery suggest that the group with AS experienced difficulties only in appreciating humor; performance in the other subtests (written metaphors, pictorial metaphors, making inferences) was not impaired in comparison with controls. These data therefore provide some support for pragmatic difficulties in AS. An additional assessment, the Unusual Metaphors test, was also used to examine pragmatic language. The stimuli used in this subtest for metaphors were newly generated metaphorical sentences. Results revealed that the group with AS was severely impaired on this task, a finding that contrasts with the processing of well-known metaphors in the Right Hemisphere Language Battery.

Table XV. Correct RTs for Chimera Test as a Function of Group

Variable	Group[a]	
	Asperger syndrome (n = 8)	Control (n = 8)
All conditions	945.40 (231.5)	757.09 (89.6)

[a] Values given as *M* (*SD*).

A cluster of deficits affecting visuo-spatial abilities are characteristic of NLD (Rourke, 1989, 1995). These deficits have also been found in the neuropsychological profile in AS (Klin *et al.*, 1995) and are common in disorders affecting the right hemisphere (Ross & Mesulam, 1979; Weintraub & Mesulam, 1983; Voeller, 1986). In this study, memory for meaningful, complex patterns was shown to be severely impaired, as evidenced by the Warrington RMT subtest for faces, an assessment that is designed to tap into right hemisphere processing (Warrington, 1984). Identical results were found by Ellis *et al.*, (1994) in their assessment of young people with AS.

The Rey-Osterrieth Complex Figure Test was also administered to investigate both perceptual organization and visual memory. Superficially, the results revealed that all participants with AS performed no differently from controls in the copy condition, suggesting normal perceptual organization; only one subject (FM) was impaired on the delayed recall condition. Additional qualitative analysis, however, revealed that this subject copied the figure in a piecemeal fashion, without any noticeable degree of holistic organization. This finding suggests moderate right hemisphere dysfunction (Lezak, 1995). Other evidence has been cited, though, that provides more con-

Table XVII. Assessment of the Predictions of the NLD Model

Measures	Predictions based on the NLD model	Supported by results from AS Michigan Group?
Discrepancy between VIQ and PIQ	VIQ advantage over PIQ	Yes
Social awareness		
Interpersonal Reactivity Index	Impaired	No
Social Judgment Test	Impaired	Yes
Language		
Maxims Test	Impaired	No
The Right Hemisphere Language Battery	Impaired	Yes, but for the Humor subtest only
Unusual Metaphor Test	Impaired on the Metaphorical sentences subtest	Yes
	No impairment on the Literal sentences subtest	Yes
Memory		
Warrington RMT	Impaired on the Faces subtest	Yes
	No impairment on the Words subtest	Yes
Nonverbal		
Expression Matching Test	Impaired	No
Emotion Recognition	Impaired	Yes, but for the emotion of anger and disgust only
Eye Gaze	No prediction	NA
Free Vision Facial Processing	No prediction	NA
Theory of mind		
First-order	No prediction	NA
Second-order	No prediction	NA
Strange stories	No prediction	NA
Bimanual coordination		
Bead Threading	Impaired	No
Etch-a-Sketch	Impaired	No
Luria Test	Impaired	Two of eight subjects were impaired
Visuospatial skills		
Rey-Complex Figure Test	Impaired	Only for subject FM in the Delayed Recall condition
Local Global Test	Impaired	No
IHTT experiments		
Picture-Name Matching Test	Impaired	No
Chimera Test	Impaired	Yes, but only for response times and not for number of correct responses

clusive support for impaired visual-spatial processing in AS. Mottron and Belleville (1993) present a case study of EC, an adult diagnosed with either HFA or AS (the diagnostic evaluation was not very rigorous), who was shown to have exceptional graphic abilities. Even though his finished artwork was of a very high standard, the authors comment that EC adopted a piecemeal approach in his drawing, where outlines did not occupy a primary position. They further demonstrated that EC's performance on the Rey Osterreith Complex Figure Test was lacking in hierarchical organization. Additional findings by Ellis and Gunter (1999) and Ellis and Leafhead (1996) support this observation.

A further investigation was carried out testing visuospatial abilities, this time looking at hierarchical local-global organization. There is evidence to suggest that the right hemisphere is adapted for analyzing the global aspects of the visual world, whereas the left hemisphere is well suited for the processing of local features (Hellige, 1993). No significant overall differences were found, however, between the group with AS and the control group, and analysis of the errors made by the group with AS revealed that these participants were only slightly more likely to make errors involving global processing than errors involving local processing. A possibly more sensitive test of local-global processing was carried out by Mottron and Belleville (1993), again with EC. The task involved EC naming the local and global elements of the stimuli that were each tachistoscopically presented for 10 to 25 milliseconds. The results showed that even though EC demonstrated a normal global advantage (indeed he attended to the outline faster), he did not show any global precedence (he attended to the local details more than the global details). The latter finding, therefore, provides some slight evidence for a different style of visuospatial processing in participants with AS.

Related work by Jolliffe and Baron-Cohen (1997) has shown that on the Embedded Figures Test (EFT), individuals with autism and AS perform better than controls, a finding they have shown that cannot be attributed to Frith's (1989) concept of weak central coherence. Rather, Baron-Cohen and Hammer (1997) suggest the superior ability on the EFT represents an extreme "male cognitive style" or an extreme "male brain" (spatial skills better than social skills). They further speculate that an explanation for superior performance on the EFT may have neurological underpinnings. They cite the work of Lamb and Robertson (1990), who have shown that patients with right-sided lesions are more likely to report local features in the Navon Task (local-global task), whereas patients with left-sided temporal lesions are more likely to report the global features. They conclude then that the right temporal-parietal junction may be abnormal in autism. The work by Baron-Cohen and Hammer (1997), therefore, is not inconsistent with Rourke's notion of sufficiency that proposes white matter dysfunction in the right cerebral hemisphere. Further, Baron-Cohen and Hammer's work demonstrates that damage to the right hemisphere, in selective areas, can manifest itself as a visuospatial asset.

In his description of the NLD syndrome, Rourke (1995) proposed deficits in both fine and gross psychomotor coordination. Motor problems have also been widely documented in AS (Wing, 1981; Frith, 1991; Ellis & Leafhead, 1996; Volkmar *et al.*, 1996; Tantam, 1991), and indeed Asperger (1944) believed that motor clumsiness was a key feature of the disorder. One of the fundamental problems of diagnosing clumsiness, however, is the lack of an operationalized definition of "motor clumsiness" (Ghaziuddin *et al.*, 1992). In the present investigation, it was informally observed that some of the participants showed signs of motor difficulty in their ability to write (FM, MH, MH1); however, only bimanual coordination was formally assessed in an attempt to elucidate "clumsiness." The rationale for such a narrow assessment of clumsiness was to test Rourke's (1988) proposal that some children with NLD may do so because of congenital absence of the corpus callosum, which, according to Bogen (1993), is often only detected from slowed motor coordination, particularly on bimanual tasks. In the group with AS, a heterogeneous pattern in results was seen. Three participants (FM, MH, MH1) experienced problems in the bead threading test, although, overall, no significant differences in time taken to complete the task were found. In addition, FM and MH1 found it difficult to carry out Luria's Reciprocal Coordination task in the manner required (i.e., quickly and smoothly). This pattern of results, as specified by the ICD-10 diagnostic criteria, does suggest that motor problems are a characteristic, but not an essential, feature of AS. Whether these results are a manifestation, in whole or in part of a dysfunctional corpus callosum, remains to be seen. What is needed are more sensitive measures of bimanual coordination, together with appropriate imaging studies (e.g., Berthier, 1994) to resolve the issue of the role that the corpus callosum plays in the presentation of clumsiness in AS.

The second aim of this investigation was to examine transcallosal transfer of visual information. If there was damage or dysfunction to the white matter tracts within the corpus callosum (as proposed by Rourke's 1995, NLD model), then longer IHTT's reflected in increased response times would be expected in AS. Two experiments were designed to test this hypothesis: the Face-Name Matching Task and the Chimera Test. The results of these tests revealed a variable pattern in performance. In the group with AS, accuracy in each test (number of correct responses) was not impaired compared with controls. This group was also found to be similar to controls in the Face-Name Matching Task on their IHTT. Significant differences were revealed, however, in the Chimera Test, where the AS group was found to be significantly slower to react to the chimeric stimuli to arrive at a same or different decision, a result that gives some support for Rourke's NLD model. At this juncture it should also be mentioned that, in both tests, performance in the group with AS was more variable than in the control group, as shown by the higher standard deviations. In a study relating IHTT to age, Brizzolara, Ferretti, Brovedani, Casalini, and Sbrana (1994) found that RTs from young children (7-year-olds) were much less made stable than those from adults. They also found evidence of an age-related decrease of RTs, a finding that they interpreted as reflecting the maturation of the corpus callosum. Given that the participants with AS were performing in a way characteristic of younger children, could the instability in the RTs and IHTT in the group with AS represent an immature corpus callosum, or were there other factors affecting their performance? Focused research, using a variety of task paradigms is needed to answer these questions.

Throughout this discussion, it has been shown that Rourke's (1989, 1995) NLD model provides a theoretical framework that can embrace many of the major signs of AS. For example, it is able to account for apparently unconnected deficits in functioning, such as psychomotor coordination, visual-spatial organization, and pragmatic language, by proposing damage or dysfunction to white matter structures in the brain. This model is also able to account for the assets and deficits, which are manifested to a greater or lesser degree in AS, by virtue of the fact that dysfunction of these white matter tracts can be differentially affected. The advantages conferred by this model are thus its ability to provide a comprehensive causal mechanism in AS. The NLD model, however, cannot account for the inability to infer intentions in others, and thus the ToM approach (Baron-Cohen, 1995; Baron-Cohen *et al.*, 1997) must be considered as an interesting theoretical position but not necessarily an explanation of the syndrome. Recent findings have been reported, however, that link deficits in theory of mind with right hemisphere damage (Winner, Brownell, Happé, Blum, & Pincus, 1998; Siegal, Carrington, & Radel, 1996), thus providing a tentative neurological link with our approach to AS. In addition, the suggestion by Baron-Cohen *et al.* (1999) and Brothers (1990, 1997), regarding the connection between the cognitive deficits and emotion seen in autism (including ToM) and the neural circuitry of the limbic system and orbitofrontal cortex, also has merit. It could also be argued that the more universal an explanation, the less precise it is. More research is needed to secure Rourke's theoretical position, not least to relate it to ToM findings.

It must be noted, however, that in the present study, more emphasis was placed on exploring deficient right hemisphere systems (notion of *sufficiency*) rather than insufficient access to right hemisphere systems (notion of *necessity*) in AS. To this end, future work will extend the current study, examining in more depth the impact of deleterious intermodal integration on neuropsychological functioning. In addition, a group of individuals with NLD will be included to directly compare their profile against individuals with AS.

In light of this discussion, some attempt should also be made to examine the relationship between AS and HFA. There has been much debate relating to the extent to which the two disorders are similar. Some researchers, such as Ehlers *et al.* (1997), believe that, owing to the clear overlap of behavioral symptoms, there is clear evidence that the two disorders lie on a continuum. Others (e.g., Asperger, 1979), however, believe that the two disorders are distinct. It is only now that a clearer picture is beginning to emerge, with the advent of more stringent diagnostic criteria designed to discriminate disorders within, or adjacent to, the autistic spectrum. The data presented here are consistent with the findings by Klin *et al.* (1995) that AS can be captured by the NLD syndrome. In their study comparing AS and HFA, they proposed that AS could be accounted for by right hemisphere deficits and HFA by left hemisphere deficits. They speculate that these disorders can be distinguished from each other in terms of their neuropsychological characterization. However, they ere on the side of caution by explaining that AS and HFA could share the same etiology while having phenotypic differences solely accounted for by neuropsychological differences. Although their data provided a clear distinction between the two disorders in terms of neuropsychological presentation, only the most prototypical cases were used. In the present study, however, many differences in presentation were shown among the participants with AS. Could it be that there are more subtypes with respect to very able autistic individuals? Or is it the case that the diagnostic systems currently available fail to capture the true nature of these syndromes? Only with more validation studies and additional research on behavioral genetics and neuroanatomy can the relationship between AS and HFA be resolved.

Finally, it can be seen that, owing to its many and varied manifestations, the complex nature of AS is still a puzzle. Although no account has yet been put forward that can completely encapsulate both etiology and symptomology, or indeed explain the validation of AS vis-à-vis HFA, the fact that a wide range of neuropsychological explanations are being applied can only advance the understanding of such an enigmatic disorder. The present findings may be seen as a contribution to the eventual understanding of AS.

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