The severity and nature of motor impairment in Asperger's syndrome: a comparison with Specific Developmental Disorder of Motor Function

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Background: The aims of this study were to measure objectively the extent and severity of motor impairment in children with Asperger's syndrome and to determine whether the motor difficulties experienced by such children differed in any way from those classified as having a Specific Developmental Disorder of Motor Function (SDD-MF). Criteria derived from ICD 10-R were used to identify 11 children with Asperger's syndrome and a matched group of 9 children with a Specific Developmental Disorder of Motor Function. Children in both groups were required to have a verbal IQ of 80 or greater on the WISC IIIR. **Method:** The Autism Diagnostic Interview (Revised; Lord, Rutter, & LeCouteur, 1994) was used to identify features of AS in the first group and to exclude them in the latter. The Movement Assessment Battery for Children (Henderson & Sugden, 1992) provided a standardised test of motor impairment. A Gesture Test based on that by Cermak, Coster, and Drake (1980) was used to assess the child's ability to mime the use of familiar tools and to imitate meaningless sequences of movements. **Results:** All the children with Asperger's syndrome turned out to meet our criterion for a diagnosis of motor impairment, five of the six most severely motor impaired children in the whole study being from this group. Performance of the Asperger group was also slightly poorer on the Gesture Test. The profile of performance on each test was examined in detail but no evidence of group differences in the pattern of impairment was found. **Conclusions:** This study is consistent with others suggesting a high prevalence of clumsiness in Asperger's syndrome. Our findings also attest to the widespread prevalence of motor impairment in developmental disorders and the problems such co-morbidity poses for attempts to posit discrete and functionally coherent impairments underlying distinct syndromes. **Keywords:** Asperger's syndrome, specific developmental disorder of motor function, developmental coordination disorder, motor coordination, gesture, classification.

Although there is still considerable debate about its nosological status (Frith, 1991; Howlin, 2000; Volkmar & Klin, 2000), Asperger's syndrome gained formal recognition as a distinct clinical entity, through entries in the diagnostic manuals of the World Health Organisation in 1992/1993 (ICD-10, 1992; ICD-10R, 1993) and the American Psychiatric Association in 1994 (DSM IV, 1994).[1] Both ICD-10 and DSM IV describe similar sets of diagnostic features encompassing the obsessional pursuit of repetitive or idiosyncratic interests as well as impaired social interaction, alongside normal cognitive and language development. Also, both manuals mention 'clumsiness' of movement as a common feature but fail to accord it the status of an essential or defining feature. More generally, clumsiness is not specified as a major feature of the other pervasive developmental disorders such as autism, but the defining features include many with a substantial motor component (e.g., 'stereotyped and repetitive motor mannerisms that involve either hand or finger flapping or twisting, or complex whole-body movements', ICD-10R, 1993, p. 149).

Since Asperger did not set out to compile a formal specification of the procedure for diagnosis of the syndrome that was subsequently to bear his name, the question of whether clumsiness was a defining feature did not arise. However, he certainly attached considerable weight to clumsiness in his clinical descriptions of the syndrome. In the classic paper on the syndrome (Asperger, 1944 translated in Frith, 1991), we find four case histories each describing the child as poorly coordinated. The difficulties mentioned include absence of facial expression, poor fine motor coordination and a lack of fluency in locomotion. Of Harro L, Asperger notes: 'His movements never unfolded naturally and spontaneously ... from the proper coordination of the motor system as a whole. Instead, it seemed he could only manage to move those muscular parts to which he directed a conscious effort of will' (p. 57). Of another child, Asperger notes: 'this motorically clumsy child had atrocious handwriting.... The pen did not obey him ... he

corrected without concern for appearance and would simply write new letters on top of old ones' (p. 63).

Wing's (1981) seminal paper, introducing Asperger's ideas to the English-speaking world, presented additional case studies that underlined the importance of motor aspects. In a previous paper, she had reported that at least a third of autistic children were clumsy (Wing, 1969). Now, in this paper, she remarked on ill-coordinated movements and odd posture as 'major features' of AS, a view taken up by many subsequent investigators (e.g., Burgoyne & Wing, 1983; Ghadziudden, Tsai, & Ghadziudden, 1992; Gillberg, 1989; Manjiviona & Prior, 1995; Miyahara et al., 1997; Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995; Szatmari, Bremner, & Nagy, 1989b; Smith, 2000; Tantam, 1988, 1991). Unfortunately, however, comparison between existing studies of clumsiness in AS is difficult, particularly because agreed criteria for the diagnosis of the condition do not exist (Howlin, 2000) and no two studies use the same criteria (Ghazuiddin et al., 1992; Smith, 2000).

Setting aside studies which offer purely descriptive data on movement difficulties in children with AS, only four provide sufficient information on individual children to allow a rough estimate of the prevalence of motor impairment. Of these, the studies by Gillberg (1989), by Ghaziuddin et al. (1994) and by Miyahara et al. (1997) report broadly concurring results, whereas that by Manjiviona and Prior (1995) apparently differs in outcome. Since the description of the diagnostic procedures in these studies is not sufficiently explicit to allow us to decide whether differences in outcome might be ascribed to systematic differences in diagnostic criteria, it might be useful to consider three other variables: the nature of the motor assessments, the age of the subjects and their IQs.

Gillberg (1989) reported that 83% of his AS group obtained scores on the gross motor component of the Griffiths test which were more than 15 points below their overall IQ. An unfortunate aspect of this study was the exclusion of data from the hand–eye coordination section of the Griffiths test which contains items sensitive to fine motor coordination. Since others (e.g., Szatmari, Bartolucci, & Bremner, 1989a; Szatmari, Tuff, Finlayson, & Bartolucci, 1990) have shown that young children with AS have difficulties with both gross and fine motor activities, it seems likely that this narrowing of focus would result in an underestimate of the already high prevalence of clumsiness in Gillberg's sample.

In their study of 11 AS and 9 HFA children between the ages of 9 and 20, Ghaziuddin, Butler, Tsai, and Ghaziuddin (1994) used the Bruininks–Oseretsky test (Bruininks, 1978), which provides three separate measures of performance: a gross motor score, a fine motor score and an 'upper limb coordination' score (largely comprising ball skills). While they drew attention to the apparent lack of a difference between AS and HFA children, of more concern, here, is the performance of the AS group relative to the test norms. Using one standard deviation below the mean as their criterion of abnormality, it transpired that eight of their AS children (73%) exhibited abnormally poor performance on all three sections of the test, and the remaining three were abnormal on at least one. Furthermore, of the three children who failed to exhibit abnormality on all three parts, two were at least four years beyond the maximum age (14 years) covered by the test norms. Obviously, to the extent that motor performance may be expected to improve beyond an age of twelve, the test is likely to be insensitive to abnormality in older individuals.

In a study of 26 Japanese children aged 6–15 with AS, Miyahara et al. report that 85% of their sample obtained scores at least 2 SDs below the mean on the Movement ABC (Henderson & Sugden, 1992), the test used in the present study. However, this same group of researchers have suggested that the norms for the Movement ABC will need adjustment for use with Japanese children so this figure has to be treated with some caution (Miyahara et al., 1998).

Finally, the study by Manjiviona and Prior (1995) involved children aged 7 to 17. On the Test of Motor Impairment, the precursor of the Movement ABC, only 7 out of 12 children with AS obtained scores below the 15th percentile (i.e., 58%). Of the five children who scored above the 15th percentile, however, one was 14, another 17, both well above the age norms for the test. The remaining three, aged 9 to 12, fell within the compass of the norms.

Since there is debate in the literature concerning the use of low IQ as an exclusion criterion for AS, more generalised learning difficulties could also be a confounding factor in studies of motor competence. However, in the studies considered so far, it seems unlikely that IQ could account for differences in the prevalence of motor impairment in the Asperger group. Although Ghaziuddin et al. used a full-scale IQ criterion of 70, only two of his AS group had a VIQ below 80. Similarly, in Manjiviona and Prior's study, only two children in the AS group had full-scale or verbal IQs below 80. However, it is noteworthy that in both of these investigations almost all those children, whether AS or HFA, with verbal IQ below 80 seemed to be particularly impaired in movement.

Most of the studies investigating 'clumsiness' as a feature of AS compared an AS group to an HFA group. While, in general, these studies failed to reveal a difference between the two groups, reinforcing the conclusion that clumsiness is not useful as a differential diagnostic feature, notable exceptions are the study already mentioned by Gillberg (1989) and that of Klin et al. (1995). The latter found deficits in fine motor skills in 90% of their AS group but only 32% of their HFA group, and deficits in gross motor skills which were universal in their AS group only occurred in 63% of their HFA group. However, Klin

et al. had included delayed motor milestones and clumsiness amongst the defining diagnostic features of AS. Consequently it is possible, as they remarked, that their sample represented 'a specific group of AS individuals whose neuropsychological profile includes motor symptoms' (Klin et al., 1995, p. 1137).

In sum, while the literature on this topic supports the view that the prevalence of motor impairment in AS is substantial, the conflicts that exist between studies suggest that the question of extent and severity is worth reopening. To this end, we employed the Movement Assessment Battery for Children (Movement ABC: Henderson & Sugden, 1992), which is now used worldwide (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001) and currently offers the most recent normative data available for tests of motor competence.

Clinicians sometimes speculate about whether the motor deficits exhibited by children with AS can be distinguished from those exhibited by children with other 'specific' developmental disorders. Were this to be the case, the inclusion of more detailed 'syndrome-specific' descriptions of the motor deficits into existing classification schemes would add considerably to the ease of differential diagnosis. To address this issue, we elected to compare our AS group with a group of children whose primary problem was motor, whose cognitive abilities were similar to those of our AS sample, but who showed no signs of autistic behaviour and had no language problems. ICD-10 and DSM IIIR were the first editions to possess a separate entry for such a disorder. Defined as *a marked (ICD-10) or serious (DSM IV) impairment in the development of motor coordination that is not solely explicable in terms of general intellectual retardation or of any specific congenital or neurological disease,* the condition is labelled Specific Developmental Disorder of Motor Function (SDD-MF) in ICD 10 and Developmental Coordination Disorder (DCD) in DSM IV.

Two sources of information were used to explore the possibility that the pattern of motor impairment might differ in these two groups of children. The Movement ABC covers a fairly wide range of motor activities, organised into three components, one of which focuses on manual dexterity, another on ball skills and the third on balance. It was, therefore, possible to examine differences in profile across these domains for the two groups.

Another area of performance we felt might differentiate the motor difficulties of AS from those found in SDD-MF was the use of 'gesture'. In ordinary usage the term gesture refers to non-verbal communicative actions (e.g., waving good-bye; pounding one's fist in anger). Somehow in the world of neuropsychology, however, the term has come to be used to cover a much wider range of actions, extending from the imitation of meaningless sequences of movements to the demonstration of how a familiar object should be used (show me how you brush your teeth). While the clinical literature on deficiencies in the use of gesture in autistic children generally refers to communicative gesture, many of the more empirical studies employ tasks involving imitation of tool use, etc. (e.g., Bartak, Rutter, & Cox, 1975; De Myer et al. 1972; Ohta, 1987; Smith & Bryson, 1994). In our search of the literature on children with AS, we could find no empirical studies of the use of 'gesture' in the strict sense but found a number of interesting verbal descriptions. For example, 'gestures' are described as 'limited' by Gillberg (1991), 'large and clumsy' by Szatmari et al. (1989a) and 'conspicuously artificial' by Attwood (1998). In contrast, a review of case studies of children with SDD-MF revealed no equivalent clinical observations and no empirical evidence of *special* problems in this area – although children with SDD-MF have been shown to perform less well than controls on a number of tasks involving imitation, mime etc. (e.g., Ayres, 1991; Smyth & Mason, 1997; Dewey, 1993; Hill, 1998).

In the present study, we decided to avoid the use of actions which had a 'social' context, such as waving good-bye, in order to preclude any role for differences in the appreciation of the symbolic content of the act. We therefore decided to use a test derived directly from the neuropsychological literature on 'gesture', which was designed for use with children and which had been employed in a number of recent developmental studies (Cermak, Coster, & Drake, 1980). The test involves the ability to mime the use of familiar objects from memory and to imitate meaningless movements.

In sum, the aims of this study were twofold. Our first objective was to quantify the extent and severity of the motor difficulties commonly reported among children with AS. Our second objective was to explore the possibility that the motor difficulties experienced by children with AS were distinctive and thus 'syndrome-specific'. To address this question, we compared the motor difficulties found in children with AS with those found in children with SDD-MF, where the motor features have undoubted primacy. Since the majority of children diagnosed as suffering from AS are boys and rather little is known about gender differences, as a simplification, we decided to include only boys in this study.

Method

Participants

Two groups of children aged between 6 years 5 months and 10 years 6 months participated in this study: eleven with AS, and nine with SDD-MF. At the time of referral to clinical services, all children were attending mainstream schools within the South East Thames Health Region of the United Kingdom. Details of the characteristics of the two groups are presented in Table 1.

Prior to referral, potential candidates were screened by a Clinical Medical Officer who excluded any child

Table 1 Individual data, with group means and standard deviations, for Age, Verbal IQ, Performance IQ, Full-scale IQ, ADI scores and Movement ABC total scores

| Subject Number | Age (months) | WISC-R | | | Autistic Diagnostic Inventory | | | Movement ABC Total score |
		VIQ	PIQ	Full-scale IQ	Social reciprocity	Communication	Restricted interests	
(AS)								
1	79	102	99	101	10	8	3	35.0
2	84	93	77	81	8	7	3	32.5
3	95	93	80	86	21	15	7	30.0
4	98	144	104	131	9	10	4	13.0
5	112	82	77	77	24	10	7	32.0
6	120	126	91	111	13	10	6	30.0
7	123	129	131	133	12	6	3	10.0
8	124	96	88	92	11	13	3	25.5
9	125	87	92	88	11	11	2	17.5
10	126	121	91	107	10	7	4	27.0
11	129	104	77	91	9	13	3	14.0
Mean	**110.45**	**107.00**	**91.55**	**99.81**	**12.55**	**10.00**	**4.09**	**24.23**
SD	**18.21**	**19.95**	**15.97**	**18.96**	**5.17**	**2.86**	**1.76**	**8.94**
(SDD-MF)								
1	82	89	76	81	2	7	0	18.5
2	84	137	107	127	4	0	0	15.5
3	94	84	81	81	6	5	0	14.5
4	107	113	103	109	1	2	2	15.5
5	108	121	103	114	3	1	0	18.5
6	112	103	96	101	6	0	0	17.0
7	115	115	113	116	3	2	1	15.0
8	116	95	65	77	3	2	0	37.5
9	117	117	94	107	4	3	2	16.0
Mean	**103.89**	**108.22**	**93.11**	**101.44**	**3.56**	**2.44**	**0.56**	**18.67**
SD	**13.72**	**16.94**	**15.90**	**17.83**	**1.67**	**2.30**	**0.88**	**7.21**

with a clearly diagnosable medical condition that could account for their difficulties. Also excluded were children with severe abnormalities of vision or hearing, and any child with a severe learning difficulty (i.e., severe mental retardation). Children who were considered eligible for inclusion in the study were then assessed on a battery of tests which allowed us to apply inclusion and exclusion criteria consistent with ICD-10R guidelines. Since ICD-10 does not provide precise criteria for the diagnosis of either AS (Howlin, 2000) or SDD-MF (Henderson & Barnett, 1998), it was necessary to decide on operational definitions for both conditions prior to the selection of subjects.

For both groups, we employed the same stringent **exclusion** criterion of below 80 on the verbal component of the Weschler Intelligence Test for Children (WISC IIIR). Our reason for not incorporating the nonverbal section of the WISC into our IQ criterion was that these sub-tests make demands on the perceptual and motor systems which are likely to put some children with movement difficulties at a disadvantage. However, we did adminster all sub-scales of the WISC and have reported full-scale IQs for consistency with ICD-10R which specifies an IQ of below 70 as the criterion for excluding children with 'mental retardation'.

AS group. Members of the AS group were selected from children referred to the Newcomen Centre at Guy's Hospital over a three-year period. To be included in this group, all children were required to meet the diagnostic criteria for AS presented in ICD-10R (i.e., qualitative deficiencies in reciprocal social interaction, and restricted, repetitive stereotyped patterns of behaviour,

interests and activities, but no clinically signficant general delay in language or cognitive development). The diagnosis was made by a consultant paediatrician and child psychiatrist, both of whom had considerable experience of diagnosing autistic spectrum disorders. Extensive data on each child was gathered using the Autism Diagnostic Interview-Revised (Lord, Rutter, & LeCouteur, 1994), a standardised instrument, generally regarded as one of the most reliable and valid measures of the social, communicative, and other impairments characteristic of autistic children in general. At present, this instrument only specifies validated cut-off points for a diagnosis of autism. Consequently, scores derived from it can only be used to provide objective evidence of the pattern of impairment across domains in a child with AS. In addition, however, it does help the clinician to differentiate between children who do exhibit very early language and/or cognitive delays and children who do not. In the present study, children with an early cognitive or language delay evident below the age of 36 months were excluded. Eight children with verbal IQs greater than 80 met these criteria and were then tested on the Movement ABC. Three children, initially referred for examination of their movement difficulties, subsequently turned out to meet our admission criteria for the AS group. They were included in this group, making a total of 11.

SDD-MF group. Candidates for membership of the SDD-MF group were recruited from the waiting lists of the Paediatric Occupational Therapy departments of the West Lambeth NHS Trust and the South East Thames Regional NHS Service. In all cases, parents

and/or teachers had expressed concern about the child's difficulties in the motor domain and had requested a more detailed professional examination. For the diagnosis of SDD-MF, we used the Movement ABC (Henderson & Sugden, 1992), setting a criterion of below the 15th percentile. A total of 15 children met this criterion and were then assessed on the WISC-III and the ADI. Two children had to be excluded because they had verbal IQs below 80, and a third because a diagnosis of Pervasive Developmental Delay could not be ruled out. Another three children met ADI criteria for Asperger's syndrome and were assigned to the AS group, leaving a total of nine in the SDD-MF group.

It was beyond the bounds of this study to formally assess all participants for other co-morbid conditions. However, we were able to determine that no child had been given any diagnostic label other than the one assigned in this study. Two children were known to have some additional attentional difficulties, one child from each group had some behavioural difficulties, and one child with SDD-MF had had some language delay but none of these were substantial enough to warrant another diagnosis.

Procedures

Ethical approval for the project was obtained from the Guy's Hospital Research Ethics Committee, the Roehampton Institute Committee on Ethics and the local NHS Trusts involved in subject selection. All tests were administered by the appropriate professionals, two consultant paediatricians, a clinical psychologist, two occupational and one physiotherapist. Most tests were administered in a quiet room at the Newcomen Centre, Guy's Hospital, London. However, one child in the AS group only agreed to participate in the study if he could perform the tests in school with his classmates. All children were tested individually and videos were made of performance in the Gesture Test.

Materials and measures

The Autism Diagnostic Interview-Revised (Lord et al., 1994) is a standardised semi-structured interview conducted with a parent or other informant. The battery includes 111 questions relevant to the past and current functioning of children referred for possible autism. The interviewer enquires about general background, family, medical and educational history, then obtains a detailed account of impairments in three domains: reciprocal social interaction, verbal and non-verbal communication, and repetitive and stereotyped patterns of behaviour. The behavioural descriptions obtained are coded as 0 – no abnormality, 1 – possible abnormality, 2 – definite autistic-type abnormality or 3 – severe autistic-type abnormality. Codings for relevant items are added to produce a total for each area of impairment. A diagnostic algorithm, which was originally created to correspond to the symptoms of autism specified in ICD 10, is then applied and a diagnosis of childhood autism given if a threshold is met on all three areas. The cut-off points for the three classes of behaviour are reciprocal social interaction 10, communication 8, and stereotyped behaviours 3 respectively.

Reliability and validity data for the inventory is reported in Lord et al. (1994) and more recently in Gilchrist et al. (2001).

Wechsler Intelligence Scale for Children – IIIR (Wechsler, 1992). Both groups of children were tested on all sub-scales of the test, although only Verbal IQ was used for inclusion purposes.

Movement Assessment Battery for Children (Movement ABC: Henderson & Sugden, 1992) contains two assessment components, a teacher checklist and a standardised test, both designed to measure impairment of motor function in children aged 4 to 12 years. In the present study we used only the standardised test, which is divided into four age bands covering 4–6-year-olds, 7 and 8, 9 and 10, and 11 years upwards. In the present study, boys aged 7 and 8 were tested on Age Band 2, and those between 9 and 10 on Age Band 3. Within each Band, the structure is identical, with three areas of function being assessed: manual dexterity, ball skills, and static and dynamic balance. Since the focus of the test is exclusively on motor acts, there are no specified verbal instructions and the tester is free to employ any strategy which he/she considers will lead to proper understanding of the task demands. This makes the instrument particularly suitable for assessment of children with communication, intellectual, attentional and/or behaviour problems.

Raw scores for each item of the test are converted to scaled scores, which can then be summed to produce three sub-scale totals and/or an overall total. Item scores range from 0 to 5 with high scores representing greater impairment. Total scores above 13.5 fall below the 5th percentile and are considered indicative of a definite motor problem. Scores between 10 and 13.5 span the 5th to 15th percentile range and suggest a degree of difficulty that is borderline. Reliability and validity information is presented in the manual (Henderson & Sugden, 1992), and more recently in Croce, Horvat, and McCarthy (2001).

The Gesture Test (Cermak, Coster, & Drake, 1980) contains two components, each comprising 10 items. The first includes tasks that require the subject to mime the use of specified tools (representational actions). The second requires the imitation of non-meaningful actions (non-representational actions). In the representational section, the 10 tasks are performed to verbal command, e.g., 'Show me how you brush your teeth with a toothbrush'. Before the command is given, each tool is presented for the subject to identify. It is then removed from sight during the response, to eliminate the opportunity to use the item itself. In the non-representational section, the subject is required to imitate hand and arm positions demonstrated by the examiner. The stimulus posture is sustained by the examiner until the child has achieved a posture. The specific items for each section are shown in Figure 1.

On both components of the test, actions/gestures are scored on a four-point scale as follows: a score of 1 is given when the sequence of movement is unrecognisable, scores of 2 or 3 are awarded when the action/gesture is recognisable but spatial and/or temporal accuracy is imperfect, and a score of 4 is given for a 'correct' representation. In addition, a change from one level of response to another during an action results in a
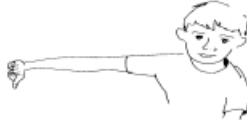
Representational Items

ITEMS TO SELF "Show me how you would:	ITEMS AWAY FROM SELF "Show me how you would:
1. …brush your teeth with a toothbrush."	1. …hit a nail with a hammer."
2. …comb your hair with a comb."	2. …turn a screw with a screwdriver."
3. …eat with a spoon."	3. …cut wood with a saw."
4. …shave with a razor."	4. …cut paper with scissors."
5. …drink with a straw."	5. …dig a hole with a trowel."

Non Representational Items

ITEMS TO SELF   ITEMS AWAY FROM SELF

Figure 1 The 10 items contained in each section of the Gesture Test

half point being either added to or subtracted from the response score depending on whether the change was to a higher or lower level. Scores for each component range from 10–40 with higher scores representing better performance. In addition, two other 'error' scores are derived, one relating to the spatial and temporal accuracy of the movements involved in the action, the other concerned with the spontaneous use of the second hand in bilateral tasks (see Green, 1997, for further details).

Scoring was undertaken by the first author from video-cassettes. In order to check the reliability of these scores, a random selection of videos of 14 children were scored by another occupational therapist who was ignorant of the diagnostic categories of the children. Using Spearman rank correlation, inter-rater agreement for the total scores was .95, and for the two components, .85 and .93, respectively.

Other tests. In addition to the tests described in this paper, the children were assessed on a number of experimental motor tasks designed to examine the effect of social pressure on motor performance, on the Autistic Diagnostic Observation Schedule (ADOS: Lord et al., 1989), and Harter's Self-Perception Scale for Children (Harter, 1985). Data from these tests are not included here and will be reported separately.

Results

Characteristics of the groups

Table 1 shows the age, Verbal IQ, Performance IQ, Full-scale IQ, ADI and Movement ABC scores for each child in the study, along with the group means and standard deviations. By design, all children had verbal IQs above 80, with a number in each group in the superior range. Although it was not a requirement in this study, all children also had full-scale IQs above 70. The differences between the groups in age, VIQ, PIQ and Full-scale IQ did not approach significance ($t < 1.0$ in all cases).

There was virtually no overlap between the groups on any of the three components of the ADI. A single member of the SDD-MF group approached the criterion score for autism in one component (communication) but showed no evidence of any impairment in the other two components, scoring 2 and 0 respectively on the social reciprocity and restricted interests sections. In contrast, three members of the AS group reached the criterion on all three components and all but one child did so on two. The remaining child with AS who only reached criterion on the restricted interests component nevertheless attained a total ADI score of 18, whereas no members of the SDD-MF group attained a total score above 11. Given this lack of overlap, statistical analysis of the ADI scores was unnecessary.

We had set our inclusion criterion for the SDD-MF group at a score of 10 or more on the Movement ABC. This corresponds to the 15th percentile. All nine children in this group met this criterion, had verbal IQs above 80 and had full-scale IQs above 70. In fact, three children in the group had full-scale IQs more than 1SD **above** the population mean (>115) and had Movement ABC scores below the 3rd percentile (i.e., more than 2 SDs **below** the mean) and five children had full-scale IQs in the range ±1 SD and Movement ABC scores below the 5th percentile. The remaining two children had verbal IQs of 84 and 95 with Movement ABC scores of 14.5 and 37.5, the latter being well below the 1st percentile.

All members of the AS group turned out to meet our SDD-MF criterion, as well, with eight children scoring below the 2nd percentile and one below the 5th percentile. All children in this group had full-scale IQs above 70, with four in the superior range. In fact, as Table 1 shows, the mean motor impairment score for the AS group was actually slightly higher than for the SDD-MF group (24.2 vs. 18.7).

Further analysis of performance on the Movement ABC test

Since the Movement ABC is a standardised test we had no reason to believe that chronological age would be a predictor of performance, and it was not ($r = -.16$). Performance IQ was predictive of Movement ABC score ($r = -.58$, $p < .01$), as we have

Table 2 Mean category scores for individual subjects on the three components of the Movement ABC test, with group means and standard deviations

Subject number	Movement ABC (mean category scores)		
	Manual dexterity	Ball skills	Balance
(AS)			
1	5.0	5.0	3.33
2	4.67	5.0	2.83
3	4.33	4.0	3.00
4	3.17	0.5	0.83
5	3.33	4.0	4.67
6	4.55	5.0	2.16
7	1.67	1.0	1.00
8	1.0	4.0	4.33
9	2.33	4.0	0.83
10	3.67	3.0	3.33
11	2.5	1.5	1.16
Mean	**3.36**	**3.36**	**2.47**
SD	**1.17**	**1.64**	**1.36**
(SDD-MF)			
1	2.67	1.25	2.67
2	1.33	2.00	2.5
3	1.83	0.75	2.5
4	3.0	2.5	0.5
5	3.17	0.0	3.0
6	3.67	0.0	2.0
7	3.0	0.0	2.0
8	4.67	5.00	4.5
9	3.33	1.0	1.33
Mean	**2.96**	**1.39**	**2.33**
SD	**0.97**	**1.62**	**1.11**

found in other studies. In contrast, Verbal IQ was not predictive of impairment score, although in this study the correlation approached significance ($r = -.41$, $p > .05 < .10$).

Table 2 shows, for each child, a breakdown of the Movement ABC scores into its three components, manual dexterity, ball skills and balance. The correlation between performance on ball skills and on manual dexterity was significant ($r = .46$, $p < .05$), as was that between ball skills and balance ($r = 0.48$, $p < .05$), whereas, not surprisingly, that of manual dexterity (involving a securely seated subject) with static and dynamic balance ($r = .23$) was non-significant. On each component, the AS group obtained higher mean impairment scores than the SDD-MF group. An ANOVA[2] conducted on these data revealed that the overall tendency towards greater impairment in the AS group approached significance ($F(1,18) = 3.03$; $p = .09$). The main effect of component was significant ($F(2,36) = 3.96$, $p < .05$), performance being worst, overall, on the manual dexterity tasks. In addition, the interaction between group and component was significant ($F(2, 36) = 4.91$, $p < .01$). Post hoc analysis revealed that the difference between the groups was only significant ($p < .05$) on Ball Skills (see Figure 2). This appears to

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[2]All parametric analyses were repeated using non-parametric techniques. There were no differences in outcome.
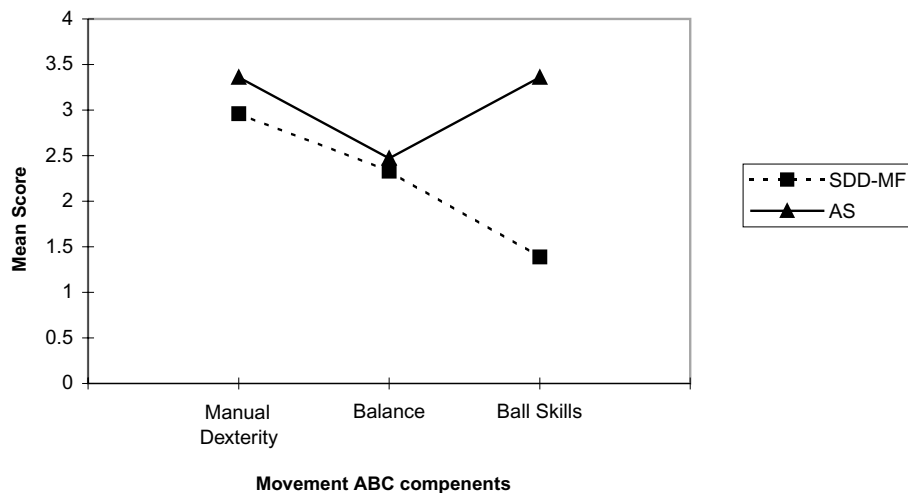
Figure 2 Differing patterns of impairment for the AS and SDD-MF groups on the three components of the Movement ABC

have been due to a relative sparing of performance on Ball Skills in the SDD-MF group. For example, the percentage of the AS group scoring below the 5th percentile ranged from 82% on manual dexterity to 55% on balance, whereas in the SDD-MF group it ranged from 78% for manual dexterity down to only 22% for ball skills.

Four children with AS approached the Movement ABC in ways which might have led to an underestimate of their motor competence. One flatly refused to perform one of the ball skills tasks during the testing session, but later showed that he found the task very difficult. Another incorporated his performance on the throwing and catching task into a fantasy of skating around the room. On the pegboard item within the manual dexterity component of the test, two more children concentrated their attention on the creation of patterns with the pegs with apparent neglect of the speed requirement. However, when these children's scores were removed from the analyses, the pattern of significance was unaffected.

The Gesture Test

Table 3 shows the score for each child on the representational and non-representational components of the Gesture Test. Since the correlation between chronological age and performance on the Gesture Test was too substantial to ignore ($r = .41$, $p < .07$), an ANCOVA was conducted on these data with age as a covariate. This revealed a significant main effect of group ($F(1,17) = 5.28$, $p < .05$), with the AS group performing worse. Although there was a slight overall tendency for children to find the representational task more difficult than the non-representational, this effect was not significant ($F(1, 18) = 2.3$). The interaction between group and type of gesture did not approach significance ($F < 1.0$).

Most tests of gesture, including the one used in this study, have not been standardised and therefore do not yield norms. For reference purposes, therefore, Green (1997) included a small group of children of similar age and intelligence but with normal development. Using the mean and standard deviation of this group for reference, we found that only one child in the SDD-MF group obtained a score above the mean of the 'normal' sample and only two in the AS group. As with the Movement ABC, the scores of the AS children were more variable, with more children performing very poorly. In the SDD-MF group, 63% of the children obtained scores more than 1 SD

Table 3 Individual scores for the representational and non-representational components of the Gesture Test, with group means and standard deviations

	Gesture Test Scores		
Subject no.	Representational	Non representational	Total
AS GROUP			
1	27.00	25.00	52.00
2	21.50	29.50	51.00
3	19.00	24.00	33.00
4	31.50	31.00	62.50
5	15.50	22.00	37.50
6	32.50	30.00	62.50
7	36.50	35.50	72.00
8	30.50	33.50	63.50
9	36.50	33.50	69.50
10	28.00	24.50	52.50
11	29.00	29.00	58.00
Mean	**27.95**	**28.86**	**55.82**
SD	**6.82**	**4.45**	**12.28**
SDD-MF GROUP			
1	27.00	31.00	58.00
2	19.50	31.50	51.00
3	25.00	32.00	57.00
4	38.00	37.00	75.00
5	36.00	32.00	68.00
6	28.00	32.00	60.00
7	36.00	35.00	71.00
8	32.00	31.00	63.00
9	34.50	34.00	68.50
Mean	**30.67**	**32.83**	**63.50**
SD	**6.17**	**2.06**	**7.71**

below the mean, whereas in the AS group, 82% did. A supplementary analysis of the spatio-temporal 'errors' made on the gesture test revealed that the AS group made marginally more errors than the SDD-MF group, but this difference was not statistically significant. Nor did there appear to be any evidence of a difference between the groups in the profile of performance over error type.

Overall, impairment scores on the Movement ABC were negatively related to the quality of performance on the Gesture Test, i.e., 'poor' scores on the Movement ABC were associated with 'poor' scores on the gesture test. When the groups were examined separately, however, it transpired that this relationship was entirely confined to the AS group ($r = -.68$, $p < .05$). In contrast, the correlation for the SDD-MF group was negligible ($r = -.03$). This might have been due to the distribution of Movement ABC scores for the SDD-MF group, with rather little variance across eight subjects and one outlier. Within the AS group, the correlations between performance on the Gesture Test and the three components of the Movement ABC were similar (Manual dexterity, $r = -.56$; Ball skills, $r = -.37$; and Balance, $r = -.63$ respectively).

Discussion

Before considering the results of this study, it might be useful to examine the constitution of our samples and the extent to which our results might be generalisable. As diagnostic entities, both AS and SDD-MF are relative newcomers to the manuals of the WHO and APA. Consequently, the criteria for diagnosis are under-specified in each case and there is considerable debate about how the definition of each might be improved. Of the two sets of criteria, those proposed for SDD-MF, however, seem less concise and more open to interpretation. In part, this seems likely to be due to the fact that until recently, 'clumsiness' was only treated as a global concomitant of other disorders, with little attempt made to decompose it into functional constituents. This was broadly consistent with a clinical tradition in which motor impairment was merely regarded as a 'soft sign' of neurological damage, with little conception of its inverse, *motor competence*, as a measurable dimension (*vide* earlier editions of ICD and DSM). In addition, the lack of specificity is a reflection of our present ignorance of motor development and its abnormalities. For instance, in developmental coordination disorders there is no equivalent of the 'triad of impairments' found in autism which might have suggested dimensions of impaired function underlying the apparently diverse tasks in which failure occurs. ICD-10 simply specifies that a diagnosis of SDD-MF be given if a child falls more that 2 SDs below the mean on a test of gross **OR** fine motor performance. No further advice is given about which kinds of task

come into these two categories and how they might be differentiated (Henderson & Henderson, 2002).

The two groups of boys in this study were well matched on age, IQ and school experience, with every individual in each group meeting ICD-10R criteria for their respective diagnostic category. The fact that all diagnoses of AS were made by two experienced clinicians working collaboratively guaranteed consistency of classification. Our use of standardised tests allowed us to be much more precise about the characteristics of two groups than if we had relied solely on clinical interpretation of the criteria. Not only did our use of the ADI (R) allow us to provide detailed information on individual children, it also allowed us to compare the scores obtained by our sample with those of the cohort described in Gilchrist et al. (2001). Specifically, the means (SD) for reciprocal social interaction in the present AS group and in Gilchrist's were very similar – 12.55 (5.17) and 12.6 (4.0) respectively. For communication, the values were 10.0 (2.86) and 12.0 (4.1) respectively, and for stereotyped behaviour 4.09 (1.76) and 6.8 (2.6) respectively. None of these differences reached statistical significance. The SDD-MF group were also assessed on the ADI (R) and were shown to be **free** of any of the social, communicative, or obsessional problems characteristic of AS.

It might be useful to note that all of the children in this study classified as SDD-MF also met the criteria for Developmental Coordination (DCD) specified in DSM. Whereas ICD uses IQ > 70 as an absolute definition of 'normal' intelligence, the current edition of DSM takes the view that it is the difference between the child's position on the IQ scale and their position on a measure of motor performance that is crucial. For instance, the 'brightest' child in this group had an IQ more than 1SD **above** the mean and an ABC score more than 3 SDs **below** the mean. The child with the lowest IQ, 84, had a score on the Movement ABC more than 2 SDs below the mean.[3] In sum, we believe that the two groups of primary school-aged children in this study represent their diagnostic categories as well as possible, at this point in time.

We compared our AS group only with an SDD-MF group, on a restricted range of tests. It is possible that a comparison with children with other developmental disorders or employing other dimensions of motor performance might have produced different results. However, in the light of accumulating evidence on the high prevalence of motor impairment in all of the so-called 'Specific' learning difficulties, we consider this unlikely (see below for further discussion).

[3]There is much debate about the use of the discrepancy notion in relation to many of the so-called specific learning difficulties. However, in the motor domain, no attempts have yet been made to test it and even the conceptual basis has been called into question (Henderson & Barnett, 1998).

Extent and severity of motor impairment in AS

As noted above, reliable estimates of the prevalence of motor impairment in children with AS are hard to come by (for comprehensive reviews, see Ozonoff & Griffith, 2000; Smith, 2000). Although studies by Gillberg (1989), Ghaziuddin et al. (1994), and Miyahara et al. (1997) have suggested that that the prevalence of motor impairment in AS exceeds 80%, we have argued that this figure is likely to be an underestimate. In our small sample, motor impairment was universal in the group with AS, with the scores of all 11 children falling below the 15th percentile point and 9 falling below the 5th. In these particular groups, the most severe cases were, with a single exception, to be found in the Asperger group. Although the overall severity of impairment within the AS group was substantial, there was also considerable variability. Whereas a child with a score of, say, 14 on the Movement ABC might manage several tasks quite well (but perhaps too slowly), a child with a score of 35 is unlikely to perform any task competently.

Profile of performance on the Movement ABC

Asperger in his case study of Hellmuth, L., remarked 'he stood in the middle of a group of playing children like a frozen giant. He could not possibly catch a ball, however, easy one tried to make it' (see Frith, 1991, p. 61).

On the Movement ABC, we found that the tasks involving the aiming and catching of a ball best distinguished the AS from the SDD-MF group. Whereas the disadvantage of the AS group was slight on manual dexterity and balance tasks, it attained statistical significance on the ball skill tasks. We therefore re-examined the literature on ball skills in AS. There is certainly no shortage of mention of impaired ball skills in AS (e.g., Asperger, 1944; Attwood, 1998; Manjiviona & Prior, 1995), with Tantam (1991) taking the view that ball skills are particularly affected. However, of the components of standardised tests, ball skills seem likely to be the most affected by social pressures. Consequently, a number of explanations suggest themselves other than the strictly motoric, perhaps the most obvious being that lack of participation in social games involving ball skills leads to lack of practice and lower competence (e.g., Attwood, 1998). Furthermore, it is not difficult to conceive of reasons why ball skills might obtain an exaggeratedly poor anecdotal repute. In everyday life, failures to catch or to aim successfully advertise themselves in a much more categorical and public fashion that poor pegboard performance or poor copying ability.

On the other hand, the idea of a special difficulty with ball skills has invited some interesting speculations. For example, Tantam (1991) constructs an explanation around the premise that children with autistic tendencies have special difficulty copying movements that another is making and are peculiarly unable to benefit from demonstration as a teaching method. From this, he ingeniously concludes that children with AS might appear even more clumsy than those with classic autism, *because only the former make the effort to interact.* Consequently, their behaviour contains a higher proportion of unsuccessful but noticeable attempts to imitate actions.

Another line of speculation might start from the incontrovertible observation that catching skills are set apart from the rather more encapsulated skills involving balance, for example by their dependence on a mental model of the spatio-temporal attributes of the environment as well a sensory-motor map of one's own body schema. This is required if the trajectory, arrival time and size of the ball are to elicit appropriately calibrated and synchronised locomotor, reaching and grasping actions.

An equally valid, and arguably more parsimonious, interpretation of these data is one that holds the difference between the groups to have arisen not from a peculiar difficulty of the AS group with ball skills, but from an anomalous sparing of ball skills in this particular sample of children with SDD-MF. Notable here is the motivational incentive surrounding the perceived importance of 'ball games' whereby a number of children with SDD-MF (but not AS) arrived for clinical assessment dressed in the football strips of their favourite teams.

Performance on the Gesture Test

Although definitions of the term gesture vary considerably, it is generally acknowledged that the use of gesture forms an integral part of social interaction and seems likely, at least in part, to be learned through imitation (but see Iverson & Goldin-Meadows, 1997, for an alternative explanation). Since gesture is often described as abnormal in autistic individuals, it is surprising how few systematic studies exist. In fact, we could find none focusing on children with AS so decided to include a comparison of the use of 'gesture' in the two groups. In view of the fact that our primary interest in this study lay in motor deficits, we chose a test that contained no 'social' items but instead tapped the ability to mime the use of familiar objects and to imitate meaningless sequences of movement. Whilst regretting the loss of ecological validity entailed by eschewal of social content, we preferred this to the difficulties involved in studying movements with symbolic content. In evaluating the performance of any complex action, there is always a difficulty in distinguishing a failure to appreciate and retain in working memory what action is required, from a failure to plan and execute the required action. This difficulty seems likely to be more severe in movements that conform to a social convention or that have symbolic content.

The AS group did less well than the SDD-MF group on the two types of gesture, with both groups performing less well than normal controls (Green, 1997). Consistent with other studies (e.g., Dewey, 1993; Dewey, Roy, Square-Storer, & Hayden, 1988; Hill, 1998), there was a non-significant tendency for all the children to be less successful at miming the use of a familiar object than imitating meaningless sequences of movement. Sometimes the items in gesture tests are subdivided according to whether the movements involved are made away from the self or towards the self. Although in the present test, this distinction did not seem to us persuasive, we performed the recommended analysis – to no effect. Hitting a nail with a hammer (classed as away from the self) involves reciprocating movements towards and away from the body, as does eating with a spoon (classed as towards the self). However, the goal of hammering lies in extra-personal space whereas the goal of eating is self-referential. In addition, our failure to find systematic differences in the types of spatio-temporal error made by the two groups of children echoes that of Hill, Bishop, and Nimmo-Smith (1998) whose error analysis also failed to reveal any differences between the type of error made by children with SDD-MF (there labelled DCD) and children with specific language impairment.

For possible explanations of why our AS group might have more difficulty with mime and imitation than the SDD-MF group, it might be useful to turn to the literature on autism. Deficits in gesture are well documented in autistic children (for reviews see Smith & Bryson, 1994; Smith, 2000), with the study by Rogers, Bennetto, McEvoy, and Pennington (1996) showing them to be almost universal. One of the most common explanations for the deficit sees it as an integral component of a general communication difficulty. An alternative proposed by DeMyer et al. (1972), however, was that a deficit of motor planning might have a role to play. Pursuant to this, Jones and Prior (1985) showed that autistic children were not only less accurate than controls on the imitation of static postures and dynamic sequences of movement, but they also showed many more 'soft' neurological signs than the controls, which Jones and Prior took to be an indication of 'dyspraxia', supportive of De Myer et al.'s position.

In a series of studies of gesture imitation in autistic children, Smith and colleagues (e.g., Smith & Bryson, 1994, 1998) took a narrower approach to the question of whether motor impairment contributes to poor performance on gesture tests, employing the pegboard, manual-dexterity test used by Szatmari et al. (1989a), rather than a multi-component test of motor competence. Using gesture tests similar to those used in the present study, requiring the imitation of arbitrary manual movements and pantomimed use of objects, Smith and colleagues showed that autistic children were significantly poorer than matched, language-impaired children on both the gesture and manual dexterity test, with dexterity accounting for 37% of the variance on posture imitation in the AS group. In our group of AS children, we obtained a correlation of .67 between Movement ABC total score and Gesture Test score, indicating that motor impairment accounted for 45% of the variance of gestural performance. However, manual dexterity was not a better predictor of gestural ability than any other component of the Movement ABC.

Rogers and Pennington (1991) suggested that motor-imitation might actually be a core deficit in autism, resulting in, rather than being caused by, other deficits in social cognition. In Rogers et al. (1996), they changed their position slightly, proposing that the underlying deficit was better conceptualised as a defect in executive functioning. The deficit in imitation was held to stem from an inability to form a plan of the required sequence of movements and hold it in working memory, pending execution. Rogers et al. (1996) tested this hypothesis against the view that impaired imitation springs from an underlying symbolic or meta-representational deficit. The latter hypothesis would predict differences in performance according to whether imitation was of representational or non-representational sequences, whereas the executive hypothesis should lead to a difference between sequential and non-sequential tasks. In a comparison between HFA adolescents and a mixed 'clinical' group, matched for age and IQ, no support for the symbolic deficit was found. In contrast, various aspects of the results converged on support for the executive hypothesis. Unfortunately, the assessment of motor function was not adequate in the Rogers et al. (1996) study, leading the authors to conclude that a more general type of motor deficit might have played a role in their results. Our study concurred with the above on the lack of difference between representational and non-representational gestures (in either group) while at the same time revealing substantial, generalised motor difficulties. The executive function hypothesis therefore appears to provide a better fit to our results than the symbolic deficit hypothesis.

In sum, we have argued in this paper that motor impairment may be almost universal in AS, although the severity of the impairment seems to be quite variable. We could find no persuasive evidence from the profile of performance across the components of Movement ABC or from consideration of the type of task required by our gesture test that clumsiness took a systematically different form when it was accompanied by the features of AS than when it was unaccompanied by such features (SDD-MF).

Discrete syndromes or co-morbidity?

In 1989, Gillberg and Gillberg reported that some of the children he originally diagnosed as DAMP (having attention, motor and perceptual problems)

turned out to meet his criteria for AS, while others showed some autistic tendencies. In the present study, three children who were eventually admitted to our AS group had originally been referred for assessment of movement difficulties, alone. Although their social difficulties were acknowledged by their parents and teachers, it was not until the families had been interviewed that it became evident that they met, in full, the criteria for admission into the AS group. Findings such as these add to the accumulation of evidence supporting the idea that co-occurrence of impairments within the spectrum of developmental disorders is so common (e.g., Kaplan, Wilson, Dewey, & Crawford, 1998; Gillberg, 2000; Kadesjo & Gillberg, 2001) that it has led some to suggest that pure cases may be the exception rather than the rule (Powell & Bishop, 1992).

One reason for pursuing the co-morbidity issue is the pressure to form a theoretically coherent view of the diverse impairments commonly found in children with AS. In the present study, some performance tasks proved slightly more sensitive to AS than others. However, there was rather little encouragement for the view that the motor impairment was in any way distinctive and might therefore serve as a key feature in differential diagnosis. Moreover, if we stand back to examine the wider perspective of co-morbidities that involve motor impairment, it might seem that this ambition was always doomed. Clumsiness is a relatively common accompaniment of many developmental disorders (Kaplan et al., 1998; Powell & Bishop, 1992; Kadesjo & Gillberg, 2001). As Hill et al. (1998) have observed, children who attract attention initially for some other impairment are often found to have concomitant difficulties on tasks involving motor control. Motor impairment seems to sit no more comfortably with one of these than another. The prevalence of such conjunctions may mean that the attempt to assign children by rule to membership of a single, discrete diagnostic category is misguided. Rather, co-occurrence might become increasingly prevalent as developmental disorders become more profound (admittedly, it could always be that deeper, better motivated, analyses might still reveal distinct and coherent sub-types of motor impairment which, taken in the mass, merely contribute to a global impression of clumsiness).

Many experts in the field view AS as part of a spectrum of autistic disorders, suggesting that family and genetic studies have made it clear that the autistic phenotype extends beyond autism as traditionally diagnosed (see e.g., Wing, 2000; Cox, 1991; Green, 1990). Even if one takes this perspective, one must still face the problem identified by Bishop (1989) who noted that the difficulties in recognizing the boundaries of autism are not solely the consequence of the subjective and elusive nature of the symptoms. Instead, it seems that we are dealing with a disorder that has no clear boundaries. This fuzzi-

ness, which could equally well apply to all of the developmental disorders, will, as Rutter points out, be viewed by some 'as a reflection of the supposed woolliness of psychology … or as an indication that developmental disorders cannot be proper diseases'. However, such assumptions are entirely misguided, according to Rutter, since 'even single gene Mendelian disorders show amazing variability' (Rutter, 1998, p. xii).

An inevitable implication of these conceptions of co-morbidity is that syndrome coherence should not be sought at the functional level but should, instead, be looked for in biological factors which might determine patterns of co-morbidity in terms of the shared vulnerability of particular faculties to genetic and environmental insult, at a particular period of development. The participation of motor capacities in so many of these compounds may merely attest to the amount of brain dedicated to the various levels at which action can be planned and its execution controlled, rather than to a peculiar vulnerability of motor skills.

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