

HANDEDNESS IN CHILDHOOD AUTISM SHOWS A DISSOCIATION OF SKILL AND PREFERENCE

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INTRODUCTION

About 90% of the adult population are right-handed in the dual senses that given a choice they *prefer* to use the right hand for carrying out actions, and that they are more *skilled* at using the right hand for complex tasks. The causal relation between preference and skill is far from obvious (Morgan and McManus, 1988); preference may be the consequence of the greater skill of the right hand, or the greater skill of the right hand may reflect greater usage due to preference. In this paper we describe hand preference and skill in children with autism, in which abnormalities of lateralisation have previously been reported (Satz, Soper and Orsini, 1988; Bryson, Porac and Smith, 1990), and confirm that there is a reduced degree of handedness and a diminished consistency of hand usage within particular tasks. Additionally we demonstrate that children with autism are significantly more likely to demonstrate a dissociation of skill and preference, showing a clear preference for right hand usage but demonstrating no overall differences in skilled performance between the hands at the population level. We conclude that hand preference develops prior to skill asymmetry, rather than vice-versa, and that children with autism show a specific abnormality in the development of skill asymmetry.

MATERIALS AND METHOD

Children with autism were diagnosed according to the criteria of Rutter (1978); all were receiving special education in a school for children with autism, but none had sufficient neurological or other problems to preclude this education. Control children were in two groups: normal controls, matched for sex and mental age (and therefore younger than the children with autism), and children with mental retardation, of similar age and mental age to the children with autism. Mental age was measured, where possible, using the British Picture Vocabulary Scale (Dunn, Whetton and Pintilie, 1982). Since verbal MA usually lags behind non-verbal MA in children with autism (De Meyer, 1976) this measure was, if anything, a conservative estimate of developmental level in the subjects with autism.

Hand preference was assessed by a battery of 13 symmetrically presented unimanual tasks (such as throwing a ball, threading a cotton reel, hammering, and using a spoon), each repeated on three occasions during a half hour interval. The tasks were similar to those used in a previous study (McManus, Sik, Cole et al., 1988). Responses were scored as Right (R), Left (L) or Bimanual/mixed (B). A conventional laterality index (LI) (McManus, Sik, Cole, Mellon, Wong and Kloss, 1988) was calculated across all the items attempted as $100 \cdot [n(R) - n(L)] / [n(R) + n(L) + n(B)]$. Direction of handedness was classified as left-hand-

ed if $LI \leq 0$, and degree of lateralisation was calculated as $|LI|$. Consistency within tasks was calculated across all pairs of replications of each task (1st with 2nd, 2nd with 3rd, 1st with 3rd), expressing the number of pairs in which a response of R was given on both occasions or a response of L was given on both occasions as a percentage of the total number of pairs; this index is necessarily in the range 100% to 33%, complete inconsistency within tasks not being logically possible.

Hand skill asymmetry was assessed using the Annett pegboard task (Annett, 1970a), in which 10 wooden dowels arranged in a row are moved as quickly as possible from one row of holes to another. The time is measured with a stopwatch to the nearest tenth of a second. Each child carried out the task twice with each hand either in the order RLLR or LRRL, the order being randomised between children. A Skill Asymmetry Index (SAI) was calculated as $100 \cdot (L - R) / (L + R)$. This index differs slightly from Annett's standard method of calculating the difference between hands ($L - R$), but was adopted in the present case to ensure that absolute differences in performance were not confounded with relative differences. In fact taken across all subjects the correlation between the two indices is 0.9641, and within the groups of normal controls, children with autism and retarded controls the correlations were .9573, .9634 and .9876, indicating that the two indices are almost completely equivalent in their overall effect.

RESULTS

Twenty children with autism (15 male; 5 female; mean chronological age = 11.1 years; S.D. 3.2), were compared with 20 sex and mental age matched normal controls (mean chronological age = 4.9 years; S.D. 0.8), and 12 children with mental retardation (6 male; 6 female; mean chronological age = 12.2; S.D. 1.5). Age differed significantly between groups ($F = 56.93$; d.f. = 2, 49; $p < .001$), with normal controls being younger than both other groups. Mental age (MA), in those cases in which it could be measured, differed only slightly between groups ($F = 3.85$; d.f. = 2, 39; $p = .03$; Table I), the normal controls being of slightly higher mental age than the mentally retarded controls.

Three (15%) children with autism showed a left-handed preference, compared with 1 (5%) normal control, and 4 (33%) retarded controls (differences not significant); the marginally raised incidence in left-handers is compatible with that reported elsewhere (Fein, Humes, Lucci et al., 1984). Degree of handedness differed between the groups ($F = 3.97$; d.f. = 2, 49; $p = .025$), being lower in the children with autism than in the normal controls, and the consistency of handedness also differed between groups ($F = 10.66$; d.f. = 2, 49; $p = 0.0001$), both control groups being more consistent than the children with autism. Although consistency of handedness will necessarily be related to degree of handedness through a base-rate effect (weakly lateralised tasks showing more possibility for variation), Figure 1 shows that the children with autism had a lower consistency of handedness than both control groups. Analysis of covariance shows that the consistency of the three groups differs ($F = 10.66$; d.f. = 2, 49; $p < .001$), even after degree of handedness has been taken into account ($F = 8.89$; d.f. = 2, 48; $p = .001$). Normal and mentally retarded controls do not differ in consistency ($F = .445$; d.f. = 1, 30; NS) even when degree of handedness is taken into account ($F = .263$; d.f. = 1, 29; NS). The difference between subjects with autism and all controls is significant when degree of handedness is taken into account ($F = 16.78$; d.f. = 1, 49; $p < .001$) and when degree of handedness, age

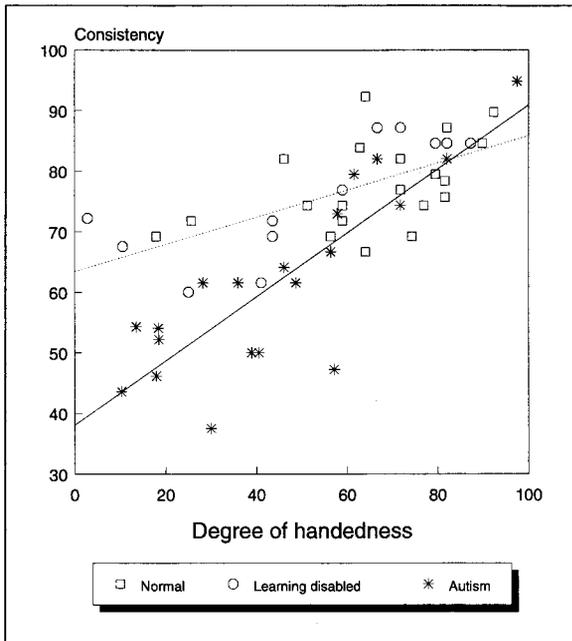


Fig. 1 - The degree of handedness of subjects is shown in relation to the consistency of handedness within tasks. Regression lines are fitted separately for children with autism (solid line) and for all controls (dotted line).

TABLE I

Comparison of Subjects with Autism (A), Normal Controls (N) and Mentally Retarded Controls (MR)

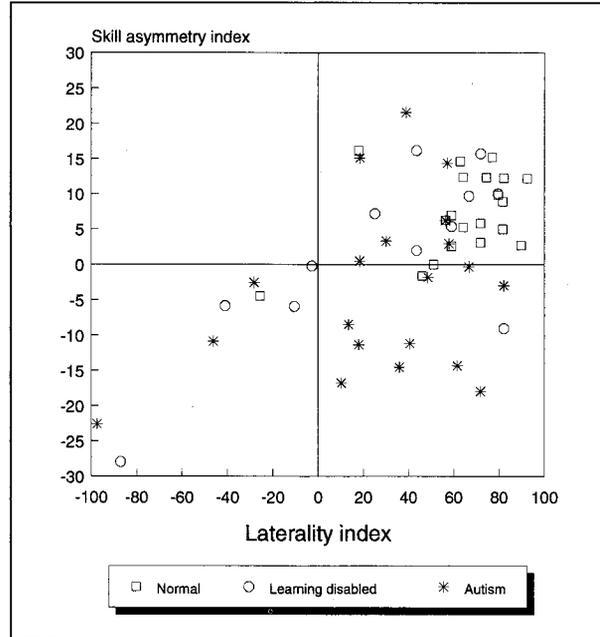
		Normal (N = 20)	Mentally retarded (N = 12)	Autism (N = 20)	Scheffé's test
Age (years)	Mean	4.9	12.2	11.1	A > N MR > N
	S.D.	(0.8)	(1.5)	(3.2)	
Mental age (years)	Mean	4.3	2.7	3.7	N > MR
	S.D.	(1.4)	(0.7)	(1.8)	
	n ¹	20	9	13	
Degree of handedness	Mean	65.4	51.1	44.9	N > A
	S.D.	(19.4)	(28.1)	(24.1)	
Consistency of handedness	Mean	77.7	75.6	61.8	N > A MR > A
	S.D.	(7.3)	(9.9)	(15.2)	
Right hand	Mean	20.1	27.2	22.6	MR > N
	S.D.	(3.8)	(8.0)	(7.2)	
Left hand	Mean	23.3	27.4	21.3	
	S.D.	(5.1)	(4.0)	(8.9)	
Average time on pegboard ² (secs)	Mean	21.7	27.3	21.9	A > MR N > MR
	S.D.	(4.3)	(4.8)	(4.3)	
Better hand	Mean	19.9	24.5	19.6	MR > N; MR > A
	S.D.	(3.7)	(3.4)	(6.4)	
Worse hand	Mean	23.4	30.1	24.3	MR > N
	S.D.	(5.1)	(7.1)	(8.9)	
Better hand vs. Worse hand ³	Mean	7.8	9.9	9.6	
	S.D.	(4.9)	(7.5)	(7.1)	

¹ Not all children could be tested using the British Picture Vocabulary Scale.

² Mean time for all four trials, two using the left hand and two the right hand.

³ Expressed as 100 · (Worse - Better) / (Worse + Better).

Fig. 2 - Relationship between the laterality index assessed from preference and the skill asymmetry index assessed from the peg-board task. Positive scores indicate superior right hand performance or right hand preference, and hence individuals in the upper right and the lower left quadrants are concordant for skill and preference.



and verbal mental age are taken into account ($F = 6.34$; $d.f. = 1, 37$; $p = .016$).

Skill on the Annett pegboard overall, expressed as average time on the pegboard, differed between groups ($F = 4.13$; $d.f. = 2, 49$; $p = .022$) but due only to the mentally retarded controls being significantly slower than the normal controls and than the children with autism. Similar conclusions apply to the differences between groups in the performance on right and left hands (and on better and worse hands also). 3/20 (15%) normal controls, 5/12 (42%) mentally retarded controls and 13/20 (65%) children with autism were more proficient with the left hand than the right ($\chi^2 = 10.4$, $d.f. = 2$, $p = .0055$). The extent of difference between the better and the worse hand was the same in all

TABLE II
Comparison of Reliability of Skill Asymmetry Measures in Subjects with Autism (A), Normal Controls (N) and Mentally Retarded Controls (MR)

	Normal (N = 20)	Mentally retarded (N = 12)	Autism (N = 20)	Normal and retarded controls (N = 32)
Right hand	.7695	.7985	.8783	.8329
Left hand	.8929	.3615	.9146	.7362
SAI	.3063	.9350	.5247	.7473
Better hand	.7279	.2310	.9200	.6142
Worse hand	.9164	.7430	.8525	.8545
Better hand vs. worse hand	.0966	.7750	.1530	.4136

three groups ($F = 0.58$; $d.f. = 2, 49$; NS), indicating that the extent of lateralisation on the task is similar in all the groups. The relationship between LI and SAI (Figure 2) showed that whereas only 2/20 (10%) normal controls and 1/12 (8%) mentally retarded controls were discordant for skill asymmetry and preference [defined as $\text{sign}(\text{LI}) \neq \text{sign}(\text{SAI})$], 10/20 (50%) of the children with autism were discordant ($\text{chi-square} = 10.84$, $d.f. = 2$, $p = .0044$). Comparison of concordant and discordant children with autism showed no significant differences in degree of lateralisation, consistency of lateralisation, age or verbal mental age, implying that differences in discordance are unlikely to be due to confounding with these variables.

Reliability of Pegboard Measures

Since each child carried out the pegboard twice with the left hand and twice with the right hand it is possible to compute the reliability of the measures for each hand, and for the standardised skill asymmetry scores. Reliabilities for each hand were computed from the correlation of the first and second occasion on which that hand was used, and reliabilities for the skill asymmetry scores were calculated from the correlation of the index calculated from the first time of performance by the right and left hands with the index calculated from the second time of performance by the right and left hands. The reliability of right hand performance is uniformly high; comparison using Fisher's Z-transform (Cohen and Cohen, 1975) shows no significant differences between groups ($\text{chi-square} = 1.11$, $d.f. = 2$, NS). Left hand performance shows an overall significant difference in reliability between the groups ($\text{chi-square} = 8.99$, $d.f. = 2$, $p < 0.05$), which detailed comparisons show to be due to the retarded group being less reliable than either the normal controls ($\text{chi-square} = 6.58$, $d.f. = 1$, $p < 0.05$) or the children with autism ($\text{chi-square} = 8.14$, $d.f. = 1$, $p < 0.005$), with there being no difference between normal controls and children with autism ($\text{chi-square} = 0.12$, $d.f. = 1$, NS). A similar pattern was found for the SAI scores, the overall differences being significant ($\text{chi-square} = 11.67$, $d.f. = 2$, $p < 0.005$), with the retarded children being more reliable than the normal controls ($\text{chi-square} = 11.21$, $d.f. = 1$, $p < 0.001$) or the children with autism ($\text{chi-square} = 7.30$, $d.f. = 1$, $p < 0.01$), but the children with autism not differing from the normal controls ($\text{chi-square} = 0.60$, $d.f. = 1$, NS). Thus although there are differences in reliability between the groups on the various measures these are entirely due to the difference between retarded controls and the other two groups, there being no differences between children with autism and normal controls. Calculations of reliabilities for better and worse hands show that the reliability for the better hand is significantly different between groups ($\text{chi-square} = 11.18$, $d.f. = 2$, $p < .005$), and this is entirely due to the difference between children with autism and retarded children ($\text{chi-square} = 10.78$, $d.f. = 1$, $p < .005$), there being no significant difference between normal controls and children with autism ($\text{chi-square} = 3.75$, $d.f. = 1$, NS) or retarded children ($\text{chi-square} = 2.79$, $d.f. = 1$, NS). Comparisons of the reliability of the assessment of the worse hand revealed no significant differences between groups ($\text{chi-$

square = 2.26, d.f. = 2, NS), as neither did the performance of the better hand relative to the worse hand (chi-square = 5.88, d.f. = 2, NS), although in the latter case there was a strong trend towards the retarded group being separate from the other two groups.

DISCUSSION

In almost all adults and, as shown in our control groups, in most children, handedness expressed as a preference is highly concordant with handedness expressed as an asymmetry of skill between the hands. This study finds that in children with autism there is a highly significant increase in the proportion of children who show discordance between the preferred hand and the more skilled hand, half preferring to use the hand with which they are apparently less skilful. This dissociation, between handedness as preference and handedness as skill asymmetry, is not one which we have seen reported before and confirms the suggestions made elsewhere that the handedness of children with autism is different from that in controls. Our study also confirms and replicates previous findings that children with autism have a reduced degree of laterality (Bryson, Porac and Smith, 1990) and a reduced consistency of handedness (Satz, Soper and Orsini, 1988), the two effects being independent of each other, and of the discordance of preference and skill.

It might be worried that the differences we have found between children with autism and controls in skill asymmetry perhaps reflect a cognitive or linguistic misunderstanding of the nature of the task, or of the motivational demands and the need for maximal speed in the task. This seems unlikely given that the reliability of the measures is similar in children with autism and normal controls (although the retarded controls undoubtedly differ in their reliability on these measures), and that the children with autism do not differ from the normal controls on measures of overall performance or in performance with the right, left, better or worse hand (although once again the retarded controls do show differences from both of the other groups). Taken overall it seems unlikely that our results can be explained away in terms of the poor performance or otherwise of the children with autism, since overall they are equivalent to the normal controls in their pegboard performance except that they show high levels of discordance with preference.

It might also be of concern that matching on mental age or linguistic ability may have been insufficient and thereby biassed the results. This is unlikely though since it must be remembered that on all of the measures of simple performance the children with autism and the normal controls are indistinguishable: it is only the retarded children who differ from the other groups. Likewise it is unlikely that the discordant group are discordant *because* of linguistic or other difficulties, since the analysis shows that the discordant children with autism do not differ from the concordant children with autism on measures of mental age, chronological age, degree of handedness or consistency of handedness.

Although the sample sizes used in this study are small, they are clearly sufficient to confirm adequately the results previously reported by Satz and his colleagues (Satz, Soper and Orsini, 1988). The additional differences that have been reported, in particular of the discordance between skill and preference in children with autism, are highly significant by conventional statistical testing (and it should of course be remembered that significance testing was designed precisely for comparing *small* samples — with increasingly large samples there is less and less need for the use of inferential as opposed to descriptive statistics). Nevertheless, as with all unusual and surprising findings, the results reported in this study can only be regarded as secure when replicated by independent workers.

Direction of hand preference in normal children becomes consistent after the age of about eighteen months, having passed through what might be called a chaotic phase (Harris and Carlson, 1988; Liederman, 1983), whereas degree of hand preference continues to develop until at least age 9 (McManus, Sik, Cole et al., 1988). Skill asymmetry is maintained throughout the same age range (Annett, 1970a). Transverse studies of normal children cannot untangle the causal relations between the development of skill and the development of preference, although skill asymmetry has nevertheless been argued on other grounds to be the primary process (Annett, 1985b). We refer to this as the skill primacy hypothesis.

The preference asymmetry shown by the children with autism is not significantly different in incidence in our study from that shown in control children, although in other studies there is a minor increase in the overall rate of left-handedness (Fein, Humes, Lucci et al., 1984). The implication is that the development of preference asymmetry is relatively normal in children with autism. In contrast with the control children, in whom the vast majority show skill asymmetry favouring the right hand, half of the children with autism show an asymmetry favouring the left hand, thereby resulting in half of the children with autism showing discordance between preference and skill asymmetry. It should be emphasised that the children with autism do *individually* show evidence of skill asymmetry (the better hand being better than the worse hand on the skill task by a similar amount to control groups); they differ principally from the controls in that the better, more skilled, hand shows no relationship to the preferred hand. They have therefore become lateralised for skill in the sense that one hand performs proportionately better than the other, but the direction of lateralisation bears no relation to their preference, and as a population half of them are more skilled with the right hand and half with the left.

Since children with autism as a population develop hand preference almost normally but do not show evidence of population-level skill asymmetry, our data suggest that hand preference probably develops prior to skill asymmetry (and thus the developmental lesion occurring in autism occurs between the establishment of preference and the establishment of skill asymmetry). We therefore suggest that the skill primacy hypothesis is wrong, that preference must develop prior to skill asymmetry, and that our data are best construed in terms of a preference primacy hypothesis.

Fig. 3 - A proposed model of the development of handedness and other lateralities in normal right-handed children. Solid arrows with heads indicate postulated causal relationships, whereas solid lines without arrow heads indicate events which are developmentally sequential but not necessarily causally related. The site of the proposed developmental block in children with autism is indicated by the horizontal open arrows.

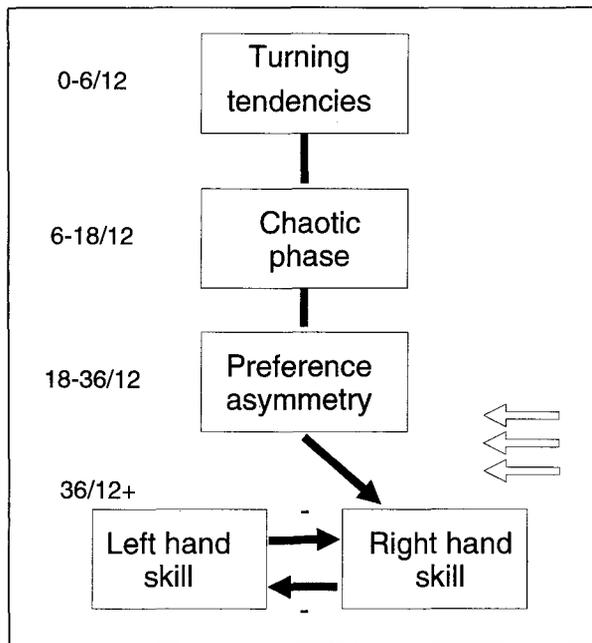


Figure 3 summarises a tentative developmental model of the normal sequence of laterality development: an initial stage of simple turning tendencies (Harris and Carlson, 1988; Michel, 1983) is followed by (but is not necessarily the cause of) a period of 'chaotic lateralisation' (Harris and Carlson, 1988; Liederman, 1983). The period of chaotic lateralisation is then followed by (but again may well not be the cause of) the formation of hand preference. Practice in the use of either hand for skilled unimanual tasks will result in improved performance relative to the other hand (the reciprocal negative causal arrows between right hand skill and left hand skill in Figure 3), and pre-existing hand preferences will be the cause of a bias in that skill asymmetry towards the preferred hand, indicated in Figure 3 by preference asymmetry causing the skill of one hand to be enhanced relative to the other. Disruption of this developmental sequence at the age of 24 to 36 months in autism will result in a reduced consistency of handedness due to incomplete passage through the stage of preference formation, probably due to neurobiological factors (Schopler and Mesibov, 1989), leaving some residue of the chaotic phase of development, which manifests as inconsistency. Disruption of development at that stage will also block the normal influence of preference asymmetry upon skill asymmetry, leaving a symmetric, unstable positive feedback system in which, for any individual child, chance alone means that either hand is equally likely to become more skilled, so that 50% of the population with autism show a left hand superiority on skilled tasks.

ABSTRACT

Hand preference and hand skill were assessed in 20 children with autism, 20 normal controls and 12 children with mental retardation. 90% of the normal controls and 92% of the children with mental retardation showed concordance for hand preference and hand skill (i.e. the preferred hand was also the more skilful), whereas only 50% of the children with autism showed concordance of preference and skill, the remaining 50% preferring to use the hand which was less skilful. Children with autism also showed a lesser degree of handedness and a lesser degree of consistency than the other groups, although this was unrelated to the discordance of skill and asymmetry. A developmental model of handedness is proposed in which the development of handedness as preference is ontogenetically prior to the development of handedness as skill asymmetry, such that in normal children the development of skill asymmetry occurs as a secondary consequence of the establishment of preference. The causal sequence is disrupted in autism, so that although preference is established, it does not subsequently result in concordant skill asymmetry.

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