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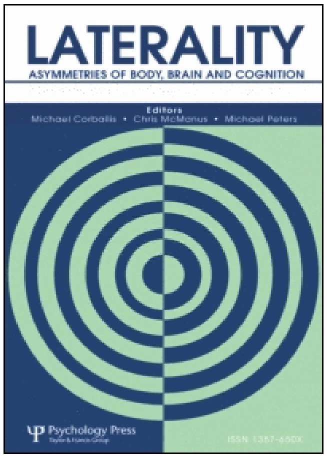

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A Reaching Test Reveals Weak Hand Preference in Specific Language Impairment and Developmental Co-ordination Disorder

Elisabeth L. Hill & Dorothy V.M. Bishop
MRC Applied Psychology Unit, Cambridge, UK

A reaching test for quantifying hand preference (QHP task) was given to 7- to 11-year-old children with specific language impairment (SLI) or developmental co-ordination disorder (DCD). The performance of these clinical children was compared to both an age-matched and younger control group. The four groups did not differ in terms of preferred writing hand or preference on a handedness questionnaire. The QHP measure discriminated the clinical and younger control groups from the age-matched controls, but not from each other. Right-handed children with SLI, DCD, and the younger controls reached predominantly with the right hand to spatial positions located to the right of their body's midline and with the left hand to positions situated to its left. Right-handers in the age-matched control group showed a significantly greater tendency to use their right hand to reach to all spatial positions. The increased tendency of the children with SLI to use the non-preferred hand was particularly striking because it was seen both in those with and without recognised motor difficulties. The QHP task appears to be a sensitive, but non-specific, indicator of developmental disorders.

INTRODUCTION

Since Orton (1925) first proposed that specific impairments of language and literacy were caused by confused cerebral dominance there has been continuing interest in investigating laterality in children with developmental disorders (e.g. Annett & Kilshaw, 1984; Geschwind & Galaburda, 1987; Tallal & Katz, 1989). However, there is little agreement about the nature of the postulated association. Whereas Orton regarded *lack* of lateralisation as a cause of developmental speech, language, and reading problems, Geschwind and Galaburda regarded non-right-handedness as a pathological sign, regardless of strength of

Requests for reprints should be sent to Elisabeth Hill, Dept of Experimental Psychology, Downing Street, Cambridge, CB2 3EB, UK. Email: eh215@cus.cam.ac.uk

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preference. More recently, Annett (1993) proposed that moderately strong right-handedness is the most common form of handedness, being the optimal phenotype, with both left-handedness and very strong right-handedness as correlates of developmental problems. Although brain imaging studies provide some evidence of atypical morphological asymmetries in language- and reading-impaired children (e.g. Jernigan, Hesselink, Sowell, & Tallal, 1991; Plante, Swisher, Vance, & Rapcsak, 1991; Rosenberger & Hier, 1980; Tallal & Katz, 1989), studies of manual asymmetry have been much more inconsistent in their findings. In a meta-analysis of research on handedness and developmental reading disorders, Bishop (1990a) concluded that the data were consistent with the null hypothesis of no difference in hand preference between reading-impaired and normally developing children. Furthermore, when attention is turned to children with more severe developmental disorders affecting spoken language, the evidence for a link with atypical handedness is even less compelling (Bishop, 1990a,b). However, other researchers have argued that it is premature to dismiss the notion of a link between laterality and reading or language disorders, because the measures that have been used to assess handedness may have been insensitive and/or inappropriate. Annett and Kilshaw (1984) argued that when handedness is quantified in terms of relative skill of the two hands on a peg-moving task, then one can find a link with reading disability, with poor readers being either extremely right-handed or left-handed. However, this pattern was not observed for language-impaired children studied by Bishop (1990b), and was not replicated by Palmer and Corballis (1996) in a study of reading ability in a large sample of New Zealand schoolchildren.

In the current study, we considered whether a new measure of handedness, the Quantification of Hand Preference (QHP) task developed by Bishop, Ross, Daniels, and Bright (1996), in which hand preference is quantified in terms of the child's readiness to use the right hand to reach across the body's midline and into contralateral space to pick up an object, might be a more sensitive indicator of atypical lateralisation in developmental disorders. We compared two developmental disorders: specific language impairment (SLI) and developmental co-ordination disorder (DCD). SLI (also known as developmental language disorder) is diagnosed when a child fails to develop language at a normal rate, for no apparent reason. Language functioning is significantly below age level and out of proportion with the rest of the child's development. The impairment cannot be accounted for in terms of physical impairments or identifiable neurological disease (American Psychiatric Association, 1994). All theories that argue for a link between atypical lateralisation and disorder have emphasised the importance of cerebral lateralisation for *language* learning, and so would predict that SLI is exactly the kind of disorder where one would expect to find abnormalities.

There is, however, a very different reason why one might predict there should be atypical motor lateralisation in children with SLI, and that is because many of these children are impaired on motor tasks (Dewey, Roy, Square-Storer, & Hayden, 1988; Johnston, Stark, Mellits, & Tallal, 1981; Powell & Bishop, 1992; Robinson, 1991; Vargha-Khadem et al., 1995). Bishop (1990a) suggested that development of a consistent hand preference might depend on maturation of skilled motor performance, in which case we would expect to find less well established laterality in children with motor immaturity or dysfunction. Bishop specifically suggested that a test of hand preference involving midline crossing might be a more sensitive indicator of such undeveloped lateralisation than more conventional handedness assessments. According to this hypothesis, a procedure such as the QHP task should reveal less well established lateralisation not only in children with SLI, but also in other children with movement difficulties. For this reason, we included in our study a sample of children diagnosed as having a ''developmental co-ordination disorder'' (DCD). This is defined as a developmental disorder where the child experiences movement difficulties out of proportion with general development and in the absence of any medical condition (e.g. cerebral palsy) or identifiable neurological disease (American Psychiatric Association, 1994). In the past such children have been given a variety of labels including ''clumsy'' (Gubbay, 1975) and ''developmentally dyspraxic'' (Denckla, 1984). Although SLI and DCD can co-occur, most children with DCD have normal language functioning, and, indeed, the typical pattern is to find that Verbal IQ is higher than Performance IQ in this disorder (e.g. Barnett & Henderson, 1992; Lord & Hulme, 1987). Handedness has not been investigated directly in the DCD population, although crossed lower limb preference has been reported (Armitage & Larkin, 1993). Little, if anything, is known about the possible mechanisms underlying DCD.

If extent of lateralisation on the QHP task is largely a function of motor skill, we should expect children with SLI and DCD to show less lateralisation than age-matched control children. However, we would also predict that we would see less lateralisation in younger normally developing children with more immature motor skills, and indeed spontaneous midline crossing has been reported to emerge with age (Atwood & Cermak, 1986; Cermak, Quintero, & Cohen, 1980). The development of hand preference for reaching has not been systematically studied over a wide age range, although Harris and Carlson (1993) showed that the likelihood of reaching across the midline to grasp an object with the preferred hand was stronger in adults than in infants. We might therefore expect this task to reveal a more long-term developmental trend, with the likelihood of midline crossing with the preferred hand being stronger in older than younger children. In this study, we therefore contrasted the performance of four groups of children: (i) children with SLI; (ii) children with DCD; (iii) age-matched normally developing control children; (iv) normally developing children who were three years younger than children in the other three groups.

Predictions

If lack of lateralisation reflects underlying atypical language lateralisation in children with SLI, then group (i) should be less lateralised on the QHP task than the other three groups, If, however, lateralisation on the QHP task depends on level of skilled motor performance, we would expect groups (i), (ii), and (iv) to show less lateralisation compared to group (iii).

METHOD

Selection Tests

Raven's Progressive Matrices. (Raven, Court, & Raven, 1986.) This is a test of non-verbal ability measuring a child's reasoning capacity. It is a multiple choice task, uninfluenced by manual dexterity. Test–retest reliability is reported as .88. Scores were converted to scaled scores using a mean of 100 and SD of 15.

CELF–R Repeating Sentences. (Semel, Wiig, & Secord, 1980.) This is a subtest of the Clinical Evaluation of Language Fundamentals–Revised and was selected because Bishop, North, and Donlan (1995) found it to be sensitive to SLI. The test assesses auditory–verbal memory for sentences of increasing grammatical complexity. The experimenter reads out a sentence, which the child must then repeat. Although CELF–R has not been standardised officially in the UK, Bishop et al. reported that British children scored similarly to the US standardisation sample on this test. No data on reliability are reported on the test manual. However, a retest of 37 twin pairs with SLI seen in a study by Bishop et al. (1995), 44 months after original test, gave a test–retest correlation of .79. Scores were converted to scaled scores with a mean of 100 and SD of 15.

WPPSI Subtests. (Wechsler, 1990.) The Picture Completion and Repeating Sentences subtests of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) were used to assess the non-verbal and language abilities of the younger control children. Non-verbal ability was assessed through Picture Completion, a test in which children must identify what is missing from a series of pictures. Repeating Sentences measures language ability and is administered in the same way as CELF–R Repeating Sentences. Test–retest reliability is reported as .82 for Picture Completion and .79 for Repeating Sentences. Scores were converted to scaled scores using a mean of 10 and a SD of 3.

Movement ABC. (Henderson & Sugden, 1992.) This is a test battery designed to identify children with impaired motor development. A total of eight tasks measuring manual dexterity, ball skills, and balance are completed (e.g. timed peg-moving, bouncing a ball, walking along a line). The tasks vary according to the child's age. Each test is scored on a scale of 0–5 with a high score indicating a greater degree of movement difficulty. The Movement ABC has been standardised in the US with overall test reliability ranging from 97% in 5-year-old children to 73% in 9-year-olds.

Participants

A total of 75 children participated in the study, falling into one of four groups: (i) children with specific language impairment (SLI), (ii) children with developmental co-ordination disorder (DCD), (iii) age-matched normally developing control children, and (iv) younger control children. Hand preference was not a selection criterion for inclusion in the study. Ethical approval had been obtained from the relevant Health Authorities.

SLI Group. A total of 20 children with SLI (13 male; 7 female) were selected from residential schools for children with SLI in Cambridge and the south-east of England. All pupils at these schools have comprehensive psychological and medical evaluations prior to school entry, and only those with severe and selective language difficulties are enrolled. Only children who had language impairments for no known neurological reasons, no permanent hearing loss, and with English as the first language spoken at home were included in the sample. Children were aged between 7 and 11 years. To be included in this study, children had to achieve a non-verbal IQ above 80 on Raven's Progressive Matrices and a standardised score of 80 or below on CELF–R Repeating Sentences. Although motor ability was not a selection criterion for those in the SLI group, children also completed the Movement ABC, allowing questions concerning the prevalence and effect of motor difficulty in SLI to be addressed.

DCD Group. A total of 12 children with DCD (9 male; 3 female) were recruited through Child Development Centres in East Anglia and West Sussex (UK). Children were aged between 7 and 11 years. To be included in the sample, the children had to meet the following criteria: a non-verbal IQ score above 80 on Raven's Progressive Matrices, a standardised score above 80 on the CELF–R Repeating Sentences, and a Movement ABC score falling at or below the 15th centile. No child showed evidence of neurological impairment.

Age-matched Controls. Control children (25 male; 11 female) were selected from primary schools in Cambridge to be matched to the SLI and DCD groups in terms of age, sex ratio, and non-verbal ability. Children were aged 7 to 11 years. All had a non-verbal IQ score above 80 on Raven's Progressive Matrices, a standardised score above 80 on the CELF–R Repeating Sentences, and a score above the 15th centile on the Movement ABC.

Younger Controls. A second group of control children (9 male; 8 female), aged 5–6 years, was selected from local primary schools in the same way as the children in the age-matched control group. The Picture Completion and Repeating Sentences subtests of the WPPSI were used for this purpose so that in terms of standard scores, these children were matched non-verbally to the DCD and SLI groups and verbally to the DCD groups. All children scored above the 15th centile on the Movement ABC.

The purpose of including a younger control group, who were at least three years younger than the other children, was to consider how far impaired performance by the clinical groups might resemble that of normally developing children at an earlier stage of development. To get an impression of how the younger control children performed on a standard timed motor task in comparison to the children in the two clinical groups, they were given the version of the Movement ABC peg-moving subtest that is designed for 7-to 8-year-olds. The raw times taken by the younger children could be compared to those of 7-to 8-year-old children in the clinical groups (see Table 1), to whom they were closely comparable.

Group means for age and the selection tests appear in Table 1. There were no gender differences between the groups, $\chi^2(3) = 1.71$, $P > .1$, or between age in the DCD, SLI, and age-matched control groups, $F(2,55) = 0.06$, $P > .1$. Children in the younger control group were developing normally according to the age-appropriate version of the Movement ABC, but performed the ''motor match'' (peg-moving) subtest at least as slowly as the children aged 7–8 years in the two clinical groups.

Handedness Assessment

Writing Hand. The hand used to hold a pencil was recorded in the course of administering the Movement ABC.

Handedness Questionnaire. Parents were asked to complete a handedness questionnaire, based on the Edinburgh Handedness Questionnaire (Oldfield, 1971), for their children. This involved indicating whether a child used the left or right hand ''always'', ''usually'', or ''both equally'' for each of nine tasks; including writing, throwing, using a spoon, and opening the lid of a box. One item from Oldfield's original questionnaire, striking a match, was excluded because it was unsuitable for children. Data were converted to laterality quotients using the formula provided by Oldfield; $LQ = 100(R - L)/(R + L)$. Data on the hand preference questionnaire were not available for two of the children in the SLI group, one child in the DCD group, two control children, and four younger controls, because parents did not return the questionnaire.

TABLE 1
Group Means

	Group			
	SLI (*n* = 20)	*DCD* (*n* = 12)	*Control* (*n* = 26)	*Young Control* (*n* = 17)
Age (year)	8.61_a (1.53)	8.72_a (1.36)	8.74_a (1.11)	5.41_b (.48)
Non-verbal IQ*	0.05_a (1.05)	0.02_a (.7)	0.45_a (.74)	0.39_a (.11)
Language ability**	-2.71_a (.39)	-0.01_b (.95)	0.34_b (.62)	0.38_b (.11)
Movement ABC***	13.28_a (8.73)	19.08_b (5.33)	1.62_c (1.87)	2.44_c (2.91)
ABC range	2–30.5	12.5–29.5	0–4	0–9.5
Pegmoving time†	24.89_{ab} (5.06)	28.8_a (3.71)	23.14_b (3.21)	29.3_a (5.44)

Group means (SD) for age, the Movement ABC, Z-scores of non-verbal IQ and language ability, and for Timed Peg-Moving (sec).

Means with different subscripts differ significantly at $P < .05$ by the Fisher Least Significant Difference Test.

* Group matching test: All scored within the normal range, $F(3,71) = 1.8$, $P > .1$

** Group selection test: SLI scored below the normal range, $F(3,71) = 137.9$, $P < .001$

*** Group selection test: A high score indicates impairment. DCD scored at or below 15th centile (raw score of 10 or above); controls scored above 15th centile; SLI free to vary: 12 out of 20 children (60%) scored at or above 15th centile, $F(3,71) = 43.09$, $P < .001$

† Peg-moving time (sec) for all younger controls on the peg-moving subtest for 7–8 year olds on the Movement ABC and for the children in the clinical and age-matched control groups aged 7–8 years (SLI $n = 10$; DCD $n = 7$; Control $n = 12$). Data are collapsed across the preferred and non-preferred hands

Quantification of Hand Preference (QHP) Task. This test was designed by Bishop et al. (1996) to provide a behavioural measure of degree of hand preference. Seven positions, each placed 30 degrees apart from one another and within the child's reach (this varied according to the length of the arms of each child) were marked on a cardboard template (see Fig. 1). The template was placed on a table and three picture cards showing easily nameable items were placed at each position. Children stood in front of the template in the centre of the baseline. They were asked by the experimenter to pick up a specific, named card and to place it in a box located directly in front of them. The experimenter recorded the hand used to pick up each card. No time constraints were imposed. The card order was random but the sequence of positions was the same for all participants. The child was not informed of the experimental interest in hand preference.

Procedure

Children were seen individually in a quiet room either at the Applied Psychology Unit, Cambridge, or in their school. The testing session lasted

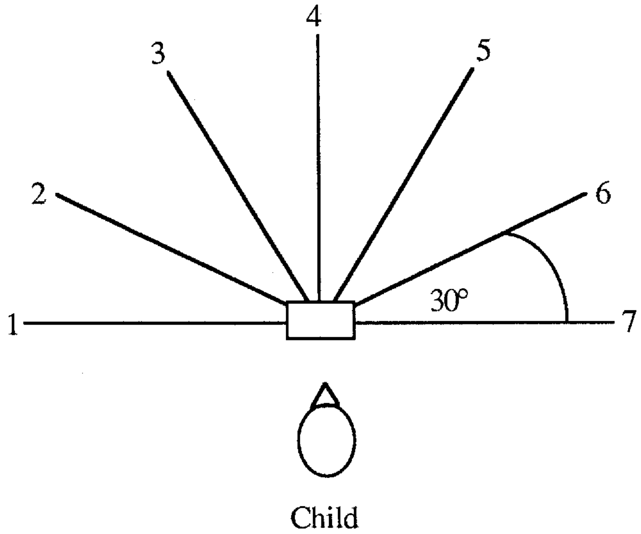

FIG. 1. Set-up for the task of hand preference (taken from Bishop et al., 1996). The participant reaches for three cards at each of the numbered locations and places them in the central box. The distance of cards from the central box was adjusted for each child to be within comfortable reach of the contralateral arm.

approximately 30 minutes. The QHP task was completed first, followed by Raven's Progressive Matrices, CELF–R Repeating Sentences, and finally the Movement ABC.

RESULTS

In terms of writing hand, the four groups did not differ significantly. In the SLI group, 2 of the 20 children were left-handed; in the DCD group, 2 of 12 children were left-handed; in the control group, 5 out of 26 children were left handed; and in the younger control group, 2 of the 17 children were left-handed [$\chi^2(3) = .93$, $P < .1$].

The mean laterality quotient (LQ) for each group is shown in Table 2 along with the distribution of LQs. A high positive score indicates that a child predominantly uses the right hand, a high negative score that the child predominantly uses the left hand. A Kruskal-Wallis non-parametric analysis of variance revealed no main effect of group [$H(3) = 3.16$, $P > .1$]. One can see from inspection of Table 2 that when attention is restricted to right-handers (in the lower half of the table), the LQs for the DCD group do appear to be lower than for the other three groups. A Kruskal-Wallis test on right-handers only showed that this trend was not statistically significant [$H(3) = 3.68$, $P > .1$], indicating that left-handedness was not over-represented in either of the clinical groups.

TABLE 2
Distribution of Laterality Quotients for each Group, with Means and SDs

	Group			
LQ range	*SLI (n = 18)*	*DCD (n = 11)*	*Control (n = 24)*	*Young Control (n = 13)*
–100 to –81	–	2	3	1
–80 to –61	1	–	–	–
–60 to –41	–	–	1	–
–40 to –21	–	–	1	–
–20 to 0	–	–	–	–
1 to 20	–	–	–	–
21 to 40	–	–	–	–
41 to 60	–	1	–	–
61 to 80	4	3	1	3
81 to 100	13	5	18	9
Mean LQ	81.2	51.32	59.46	78.87
(SD)	(38.94)	(70.35)	(70.63)	(52.3)

QHP task. Analysis of this task was restricted to right-handers, because left-handers typically show weaker laterality effects than right-handers (see Harris & Carlson, 1993) and the numbers of left-handers in the current study were too small for meaningful analysis. The frequency of right hand reaches was plotted for the seven different spatial positions for each group (see Fig. 2).

A repeated measures ANOVA with one between factor (group) and one within factor (spatial position) was applied to the data. There were significant effects of group, $F(3,60) = 6.27$, $P < .001$, and spatial position, $F(6,360) = 48.2$, $P < .001$. The group $\times$ spatial position interaction was also significant, $F(18,360) = 3.34$, $P < .001$. The group effect was explored further by pairwise planned comparisons: the main effect of group remained significant for the contrast between SLI and age-matched controls, $F(1,37) = 22.83$, $P < .001$; between DCD and age-matched controls, $F(1,29) = 5.84$, $P < .05$; and between younger and age-matched controls, $F(1,34) = 9.61$, $P < .01$. Repetition of the ANOVA with the age-matched controls excluded gave a non-significant main effect of group, $F(2,40) = 1.25$, $P > .1$, indicating that the SLI, DCD, and younger control groups did not differ significantly overall in terms of right hand reaches.

The data from Table 1 indicate that the children with SLI showed more evidence of motor impairment than those in the control groups. In order to test whether the weak lateralisation of the SLI group was due to the performance of those with associated motor impairments, right-handers in the SLI group were subdivided into those who fell within the control range on the Movement ABC (SLI–Pure, $n = 7$) and those who fell within the DCD range (SLI–Clumsy,

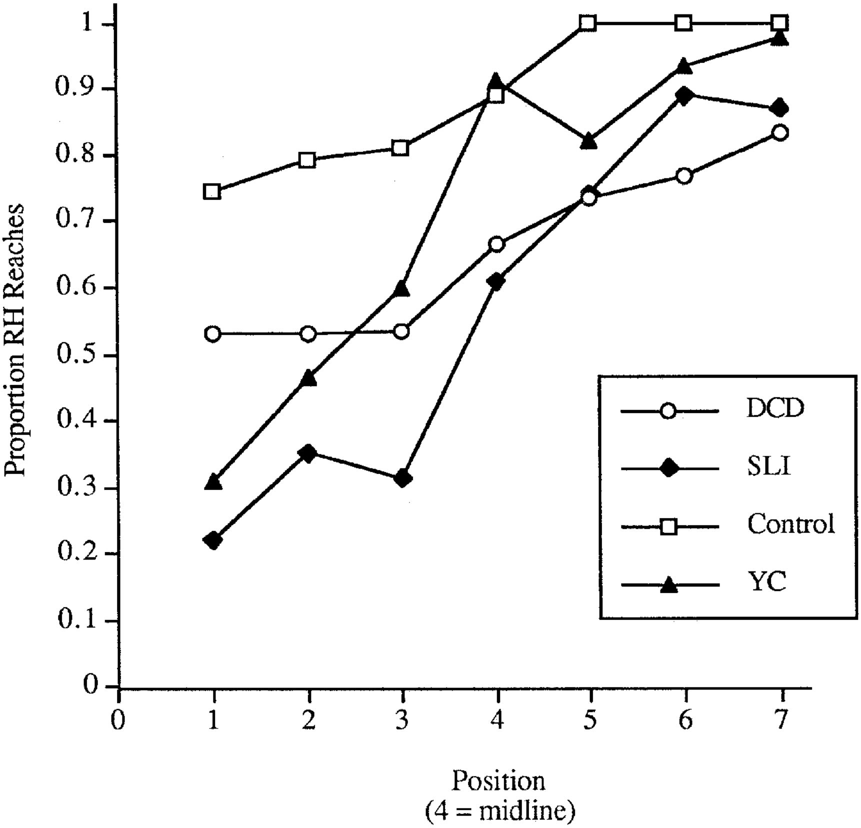

FIG. 2. Proportion of right hand reaches to each spatial position for right-handed children. The average standard error was .19 (range = .06 to .94) for the SLI group, .13 (range = .11 to .15) for the DCD group, .04 (range = 0 to .83) for the age-matched controls, and .06 (range = .02 to .1) for the younger control group.

$n = 11$). The performance of these two SLI subgroups was compared to that of the age-matched control group using a repeated measures ANOVA, as described earlier. Once again, significant effects of group, $F(2,36) = 12.32$, $P < .001$, and spatial position, $F(6,216) = 27.03$, $P < .001$, were found, along with a significant interaction between group and spatial position, $F(12,216) = 3.24$, $P < .001$. This indicates that the weak lateralisation of the SLI group as a whole was not due to the performance of the children in the SLI–Clumsy group alone.

The significant interaction between group and position that was observed is difficult to interpret, given the restriction of range of scores in ipsilateral space, which is particularly striking for the older control children. Rather than doing further quantitative parametric comparisons, we therefore investigated this interaction with a categorical analysis. Overall, the results from the QHP task differ strikingly from those of the questionnaire, on which each group appeared strongly right-handed. On the QHP task, children in the clinical groups, as well as the younger controls, appeared less right-handed than the age-matched control children. There are two possible ways in which this result could be obtained. It could be that there is a general trend for children with developmental disorders, and younger controls, to be more influenced by extrinsic spatial position than by intrinsic biases when selecting which hand to use, so that they show less midline crossing. Alternatively, children in these groups may be more random in their hand choice overall, and so be inclined to use the non-preferred hand, even when reaching into ipsilateral space. To address this issue, we did a further analysis in which right-handed children were classified in terms of whether the left or right hand was used more often when reaching into contra-vs ipsilateral space. This yielded three groups: LL (left hand preferred for contra-and ipsilateral reaches), LR (left hand for contralateral, right hand for ipsilateral reaches) and RR (right hand used more often for both contra-and ipsilateral reaches). Although the group sizes are very small for such categorical analyses, the findings were suggestive: the LL pattern was seen only in clinical children—one (6%) of those with SLI and two (20%) of those with DCD. The LR pattern was seen in 13 (72%) children with SLI, 2 (20%) children with DCD, 5 (24%) age-matched controls, and 9 (60%) younger controls. Finally, the RR pattern was seen in 4 (22%) of the SLI group, 6 (60%) of the DCD group, 16 (76%) of the age-matched controls, and 6 (40%) of the younger controls.

Given the recent development of the QHP task, we felt it was important to replicate this result. Approximately 10 months after the initial test session it was possible to retest 26 of the right-handed children: 10 with SLI, 4 with DCD and 12 from age-matched control group. As the performances of the children with SLI and DCD had not differed in the earlier test, the data for these two clinical groups were combined, and were compared with the age-matched control group in terms of total proportion of right hand reaches. An unpaired *t*-test revealed a significant difference between the clinical and age-matched control groups, $t(180) = -3.56$, $P < .001$; mean for SLI + DCD = .60 (SD = .41); mean for controls = .81 (SD = .36), indicating that the clinical children were again more prone to use the non-preferred hand than were their normally developing peers. The test–retest correlation for total proportion of right hand reaches for this subset of children was moderately strong ($r = .58$, df = 24, $P < .01$).

DISCUSSION

In the present study, behavioural differences of hand preference were found when reaching for cards located in different spatial positions. The children with SLI, DCD, and younger controls differed significantly from the children in the age-matched control group, showing a tendency to use the non-preferred hand in a task that involved reaching across the body's midline. The reaching task revealed differences between groups in degree of hand preference that were not detected by a conventional handedness inventory. It should be noted that the inventory was administered as a questionnaire to parents, rather than by direct observation of the child performing specific activities. This method had the advantage that the parent could report on strength of preference as well as direction, based on long familiarity with the child rather than a brief period of observation; however, accuracy of parental report is likely to be less than perfect, so it would be advisable in future studies to cross-check this result with an observational measure. However, unreliability of parent report is unlikely to be the whole explanation for lack of agreement between methods: other studies with adults using self-report have also found discrepancies between behavioural tests and questionnaires (e.g. Bishop et al., 1996; Bryden, Singh, Steenhuis, & Clarkson, 1994).

How should the weak lateralisation on the QHP be interpreted? Ever since Orton's (1925) early writings, there has been interest in atypical cerebral lateralisation as a basis for causing disorders of language and literacy. Language is usually lateralised to the left hemisphere, and it has been argued that failure to establish a clearly dominant hemisphere is associated with non-optimal language development. If we accept that hand preference provides an indirect index of underlying cerebral lateralisation for language, our finding of reduced strength of hand preference in children with SLI seems to support Orton's original views. However, there is a problem for this interpretation, which is that closely parallel findings were obtained for another developmental disorder, DCD, in which language skills are unimpaired.

We know that there is substantial comorbidity between SLI and poor motor skills (Bishop, 1990b), raising the question of whether weak hand preference on the reaching task might be more an indicator of motor impairment than of language lateralisation. It could be argued, for instance, that reaching across the body midline requires more complex motor programming than an ipsilateral reach, and when confronted with the option of making a difficult movement with the preferred hand vs an easy movement with the non-preferred hand, children with poor motor skills will adopt the latter course. The main evidence against an explanation in terms of poor motor skills comes from the comparison between the two subgroups of children with SLI, i.e. those who were impaired on the Movement ABC and those who were not. We found that both these groups were significantly less lateralised on the QHP task than age-matched control children. However, caution needs to be adopted in interpreting this result, because we have evidence that the Movement ABC may underestimate the extent of motor impairments in children with SLI. Hill, Bishop, and Nimmo-Smith (in press) found that children with SLI were impaired on a praxis task that involved producing meaningful gestures, regardless of whether they did poorly on the

Movement ABC, and Hill (1997) found similar results on timed tasks such as finger opposition and visually guided pointing.

The difference in manual lateralisation on the QHP task between the two clinical groups and the age-matched control group might seem to suggest that weak lateralisation is indicative of neurodevelopmental abnormality. However, the comparison with the younger control group casts a different light on this result, and suggests that lack of motor skill, rather than any pathological process, is implicated. In sum, the QHP test detects a difference in the hand preference of children with DCD and SLI that is suggestive of immature motor development, rather than neurological impairment.

As well as quantitative analysis of the QHP task, we used it to categorise right-handed children according to whether they were more likely to use the right or left hand when reaching into ipsi- and contralateral space. The results from the SLI and younger control groups were generally compatible with an account in terms of extrinsic factors being stronger than intrinsic factors in determining hand choice: put simply, these children are less likely to use the preferred hand to cross the midline compared with older control children. The data from the DCD group are based on such a tiny sample that they can only be interpreted cautiously, but they suggest that at least a subset of these children prefer to use the left hand to reach into the right side of space, even though they are right-handed on questionnaire. One possibility is that these children may have such motor difficulties that they are more likely than other children to receive explicit instruction in carrying out skilled actions, and so their right hand preference is more a consequence of training than natural bias. The fact that crossed hand–foot laterality is seen in children with DCD (Armitage & Larkin, 1993) is consistent with this explanation. Another possibility is that children with DCD may be particularly likely to persist in using the same hand across a series of actions, because programming movements is difficult for them, and so it is simpler for them to repeat a movement on the same side rather than switch to the other limb. This possibility could be assessed by a study that considered sequential effects in the QHP task. It would be worth investigating both possibilities further with a larger sample of children.

There are many other ways in which this line of work needs to be taken forward. In particular, we need to put the ‘‘immaturity’’ hypothesis to stronger test by carrying out longitudinal studies to establish whether the differing hand preference of children with SLI and DCD in comparison to their normally developing peers indicates a delay in the development of a reliable hand preference (in which case they may develop a more mature response profile over time) or whether we are observing a more persistent and deviant form of hand preference. In addition, it will be of interest to compare the findings of the current study with those from other developmentally disordered groups, e.g. children with specific reading disability, autistic disorder, or stuttering. It would also be of interest to contrast reaching with other motor tasks, such as using a pincer grip to place items, or pointing (cf. Butterworth & Morissette, 1996; Calvert & Bishop, 1998). Finally, structural and functional brain imaging studies would enable one to confirm whether this task does indeed provide an index of underlying cerebral lateralisation for speech, or whether it is a more non-specific marker of neurodevelopmental delay.

It is clear that the QHP measure is a more sensitive indicator of developmental disorder than the traditional handedness inventory, in which extent of preference is assessed in relation to a number of different tasks. The behavioural reaching task measures hand preference on an internally consistent continuum, allowing particular attention to be paid to the issue of midline crossing, and pitting an intrinsic preference to use one side against an environmental situation that gives an advantage to the other. However, although this measure seems more sensitive to developmental disorder than other handedness tests, further work is needed to develop an instrument that gives adequately reliable scores for individual children. The test–retest study indicated significant stability of the QHP measure in a small group of right-handed children, but it should be noted that the correlation is low in relation to the test–retest reliability that is usually required for a test to be used for clinical assessment. It is possible that a longer test, with more trials per position, would be more reliable. The QHP procedure is quick and easy to administer, and places fewer demands on the child than performance tests such as peg-moving, so a longer series of trials could be administered without inducing fatigue or poor co-operation.

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