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Shelley E. Parlow [a], Marcel Kinsbourne [b] & Jackie Spencer [b]

[a] Department of Psychology, Carleton University, 1125 Colonel By Drive, Ottawa, K1S 5B6, Canada

[b] Tufts University,

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Cerebral Laterality in Adults With Severe Mental Retardation

Shelley E. Parlow
Carleton University

Marcel Kinsbourne and Jackie Spencer
Tufts University

Language lateralization was investigated in 16 adults with severe mental retardation, half of whom had Down syndrome and half other conditions. Down syndrome and non-Down syndrome participants were matched for language ability using a brief test of general communication, naming, recitation and repetition abilities. Both perceptual (dichotic) and executive (dual-task) laterality tests were administered on two separate occasions following a practice day, and the scores averaged across test days. The expected overall dichotic right-ear advantage and dual-task interaction between verbal and musical interference conditions were found. It appears that individuals with severe retardation, with or without Down syndrome, are not lateralized in any grossly deviant fashion.

Laterality testing is a noninvasive means of assessing cerebral lateralization of function (Bryden, 1982). Although widely used with normally functioning populations, it has rarely been applied to populations with severe mental retardation. This is presumably because of the technical difficulties involved in ensuring adequate motivation and compliance. Some information is, however, available on individuals with Down syndrome (DS). This population is unusual for several reasons. First, the retardation associated with DS is genetically mediated, and is not generally associated with brain damage. Second, when compared with other populations suffering from retardation, DS individuals show a syndrome-specific pattern of poor language ability with relatively good "quasi-spatial" abilities

Requests for reprints should be sent to Shelley Parlow, Department of Psychology, Carleton University, 1125 Colonel By Drive, Ottawa, Canada K1S 5B6.

(Elliott, Weeks, & Elliott, 1987). Third, it has been argued (Hartley, 1981; Pipe, 1983) that the poor language skills associated with DS are the result not of a deficient left hemisphere, but of reversed cerebral specialization. The presence of a large group of individuals with right-hemisphere language lateralization of genetic origin would have important implications for our understanding of the relationship between embryological pathogenesis, cortical organization, and mental development.

Evidence in support of the latter hypothesis comes largely from dichotic listening experiments. Some studies have reported conflicting results; for example, Tannock, Kershner, and Oliver (1984) found a right-ear advantage in DS individuals; and Bowler, Cufflin, and Kiernan (1985) reported heterogeneity with respect to asymmetry in DS. However, a recent metanalysis of nine published papers found that "persons with Down syndrome tend to exhibit a left-ear/right-hemisphere advantage for speech sounds, whereas the majority of other mentally handicapped people exhibit a typical right-ear/left-hemisphere advantage" (Elliott, Weeks, & Chua, 1994, p. 192).

In contrast, tests of executive (output) laterality using dual-task interference and other motor tests have shown the expected left-hemisphere lateralization for control of speech (Elliott et al., 1987; Piccirilli, D'Alessandro, Mazzi, Sciarma, & Testa, 1991). Elliott et al. (1994) concluded that speech perception and speech production are dissociated in DS, though not in the non-DS population suffering from retardation.

Most of these studies did not report IQ; for example, Tannock, et al. (1984) selected participants "on judged ability to complete the task requirements." This omission must weaken any attempt to explain the relationship between laterality and cognitive ability. We have estimated IQ in these studies using the formula, IQ = 100 × (MA/CA), where MA = Mental Age and CA = Chronological Age. MA was not available in one study (Piccirilli et al., 1991), and IQ was extrapolated in that case from the mean score on Raven's Colored Progressive Matrices (Raven, 1977). Our review revealed that DS laterality has been studied at three stages of the life span: (a) preschool, ages 3 to 5 years (Hartley, 1981; no IQ estimate); (b) adolescent, ages 12 to 15 years, with mean IQ estimated at 35 to 39 (e.g., Bowler et al., 1985; Hartley, 1982); and (c) young adult, ages 23 to 29 years, with mean IQ estimated at 65 (Elliott et al., 1987; Piccirilli et al., 1991). Most of the studies that have examined perceptual laterality have studied the second group, while those few that have examined executive laterality have focused on the third. There have been no studies of older adults. Differences in either age or IQ may therefore have led to the discrepant results for perceptual and executive laterality.

Only one study in this literature has included a test of language ability. Piccirilli et al. (1991) assessed naming of 20 common objects, comprehension of 10 simple commands, and the number of animals and fruits generated in 1 min (i.e., verbal fluency). As all participants had to follow all 10 simple commands and obtain at least 15 points in the naming tests and 10 points in the verbal fluency test, the resulting sample was relatively high functioning verbally. The investigators did not correlate verbal ability with laterality in their sample. Thus, as with age and IQ, the role played by language ability is also unknown.

An additional factor to consider is peripheral laterality. Tests have shown a higher incidence of non-right-handedness in mentally retarded samples, in proportion to the degree of the retardation (Bradshaw-McAnulty, Hicks, & Kinsbourne, 1984). This appears to be true for both DS and non-DS individuals with mental retardation (Batheja & McManus, 1985; Murphy, 1962; Pickersgill & Pank, 1970). What bearing this might have on central laterality in this population is unknown, although it has been speculated that ambiguous handedness and poor language lateralization go together in the mentally handicapped population in general (see Bryden, McManus, & Bulman-Fleming, 1994). As DS participants and non-DS controls have typically been matched on handedness, however, this variable cannot account for the group differences described in the dichotic studies.

In the present study, we investigated both perceptual (dichotic) and executive (dual-task interference) measures of central laterality in a sample of institutionalized older adults with severe mental retardation. All DS participants had verified full trisomy 21. They and the matched group of non-DS mentally handicapped controls had spent most of their lives in the same institution. This sample is the oldest and probably the most impaired to be described in this literature.

The study evaluated the following hypotheses:

1. There are no asymmetries for DS or non-DS participants on laterality testing. This might be the case if: (a) cerebral organization did not lateralize in those with severe mental retardation, or (b) early brain damage of diverse distribution disrupted lateralization in a random pattern across individuals with severe retardation.
2. Perceptual but not executive laterality tests show a reversal for language-related asymmetries in DS but not in non-DS participants.
3. Asymmetries correspond to those found in the general population. This might be expected if the presence and direction of lateralization is unrelated to cognitive efficiency in general and to DS in particular.

Because little is known about the relationship between central laterality measures, handedness, and cognitive function in this population, the relationship of these measures with two outcome measures—IQ and language ability—was also examined. To our knowledge, this is the first study in this literature to do so.

METHOD

Participants

The records of all DS residents at the Waverley campus of the Walter E. Fernald State School (N = 85) were screened for suitable participants. This large and well-respected residential institution continues to care for adult clients who for various reasons have not proven adaptable to community placement. First, we identified those residents who were most likely to be capable of performing our tasks (i.e., in the highest functional level at this institution, $N = 24$). Individuals in this category live in small residential groups and have attained some level of self-help and communication skills. Most work in sheltered workshops under supervision. Because the institution was participating in a long-term study of Alzheimer's disease and DS, the medical status of our prospective participants had been followed closely. Their medical records were unusually complete and included regular physical and neurological examinations. After obtaining permission from the legal guardians, their medical records were examined for the following exclusionary criteria: (a) recent functional losses or personality changes that might indicate the onset of dementia or motor slowing; (b) severe or asymmetric auditory or visual impairment, or both; (c) focal neurological abnormality (e.g., weakness on one side); or (d) other evidence of ill health (e.g., use of a prescription medication, seizures, gait deterioration or incontinence). The exclusionary criteria were reviewed in a meeting with staff members associated with each prospective participant, to ensure that this information was accurate and that there had been no recent changes. The final sample consisted of 8 DS participants; 5 women and 3 men. Their ages ranged from 32 to 50 years ($M = 42.00$, $SD = 6.12$), and their average IQ, based on Stanford-Binet scores (Terman & Merrill, 1960) obtained from institutional records was estimated at 29.88 ($SD = 12.15$; range 18–50).

The team of staff members most familiar with each participant was asked to recommend a non-DS match based on gender and functional ability (i.e., with similar levels of self-help skills, communication ability and social adjustment). Again, permission from the legal guardians was obtained before examining their records. The 8 control participants included in the final sample all met the same screening criteria as the DS sample. Two had cerebral palsy associated with birth trauma. Four had genetic disorders: Noonan's syndrome, Prader-Willi syndrome, Rubinstein-Taypi syndrome and Barlow's syndrome. One had suffered malnutrition and neglect early in life, with a subsequent seizure disorder. One had no known cause for the mental retardation. To our knowledge, none of these conditions has been associated with lateralized brain damage. The average age of the non-DS group was 40.13 years ($SD = 5.44$); their average IQ was 31.38 ($SD = 11.61$; range 17–48). Statistical analyses subsequently confirmed that there were no significant differences between the non-DS and DS groups as to age or IQ, all values of $F(1, 14) < 1$, $p > .25$.

Language ability was examined using a brief test based loosely on the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983). Four areas were assessed:

1. *General communication:* 5 points, 1 point each for a correct response to the following questions: (a) "What is your name?"; (b) "Where do you live?";

(c) "How old are you?"; (d) "When is your birthday?"; and (e) "What do you like to do with your best friend?"

2. *Naming familiar objects:* 4 points: ball, pen, hammer, shoelace.
3. *Reciting familiar sequences:* 2 points each for a total of 4 points, scored as per the Boston Diagnostic Aphasia Examination: days of the week and numbers from 1–10.
4. *Repeating words and phrases:* 5 points: (a) "what"; (b) "fifteen"; (c) "Massachusetts"; (d) "Methodist Episcopal"; (e) "no ifs, ands, or buts."

The maximum total score, summed across subtests, was 18 points. Poor articulation was not penalized. Scores on this test ranged from 6 to 15 in the DS group ($M = 10.69$, $SD = 3.17$) and from 6 to 14 in the non-DS group ($M = 10.00$, $SD = 3.34$). A comparison of the two groups confirmed that the groups were well matched on language ability, $F(1, 14) < 1, p > .25$.

Handedness was assessed using five items, described below. The two groups were found to be well matched on handedness: for DS participants, $M = 6.25$, $SD = 4.33$, range = 0 to 5; for non-DS participants, $M = 5.50$, $SD = 4.87$, range = 0 to 5; $F(1, 14) < 1, p > .25$.

Materials and Apparatus

The handedness test consisted of five items: (a) a broad-tipped (and large-handled) felt pen, (b) a toy hammer, (c) a spoon, (d) a rubber ball, and (d) a shoelace game. In the absence of a generally accepted standardized test for assessing handedness in populations suffering from retardation, these items were chosen as being safe to handle and familiar to our participants. They required minimal dexterity and were similar to items included in standard questionnaires (e.g., Edinburgh Handedness Inventory; Oldfield, 1971). The tasks are similar to items loading on what Bryden and Steenhuis (1991) called Factor 1: moderately skilled unimanual behaviors closely linked to conventional notions of handedness. To improve reliability, participants were required to actually manipulate the objects and not simply to indicate their preference.

The dichotic stimuli had been computer-generated and recorded on tape for use in a previous study (see Hiscock & Kinsbourne, 1977). The original master for this tape was located and copied to chrome tape. The tape contained 15 pairs of digits, from 1 to 6, with an interstimulus interval of 13 s between pairs. Each digit appeared five times, three times on one channel and twice on the opposite, each time paired with a different digit and never with itself. The tape was played twice, with headphones reversed the second time. In total, each digit was presented five times to each ear. A Sony stereo professional cassette recorder (Sony Corp., Tokyo, Model WM–D6C, Dolby C setting) was used to present the dichotic stimuli.

Participants listened to the stimuli via Sony stereo headphones (Model MDR–1) at a volume of approximately 70 to 75 dB. The volume was adjusted up or down in 3 dB increments until the participant could repeat all or most of the stimuli correctly when these were presented unilaterally to either ear.

A tapper was connected to a microswitch and digital counter for use in the dual-task interference tests. A stopwatch was used to time the trials. Each tap generated a sound pulse audible on the tape recorder. A lapel microphone was used to transduce the speech signal. Speech and tapping data were recorded on separate channels and the tapping data later transcribed onto chart paper using a Grass polygraph (Grass Instruments Co., Quincy, MA). The transcriptions were performed by assistants blind to the purpose of the study as well as to group membership.

Procedure

Participants were tested individually in a familiar, quiet setting recommended by the staff member most familiar with them (in the workshop area, at their residence, or in our laboratory). The location was always the same for each participant. Each participant was seen on three occasions. The first was a practice session, followed within 2 to 7 days by the first test day, and approximately a month later (range = 21–28 days) by the second test day. Oral agreement was obtained from participants before proceeding each day, and a "treat" arranged for the conclusion of the session. The nature of the treat had previously been negotiated with the client and approved by the head of their team at their residence (e.g., a gold star, a diet soda, a "certificate of participation," 50 cents). In some cases, pennies were used to shape behavior during the session and traded in for the agreed-upon treat at the end.

The practice session was used to familiarize participants with the experimental tasks and for pretraining the tapping and repetition responses used in the dual-task and dichotic tests. After the tapping response was modeled by the experimenter, the participant was encouraged to tap with the experimenter and then alone, and to start when the experimenter said "go," and end when the experimenter said "stop." The length of the tapping trial was gradually extended using verbal encouragement or pennies (predetermined on an individual basis) until the participant could tap continuously for 10 s.

The pretraining for the dichotic listening test consisted first of asking participants to count from 1 to 10, assisted by the experimenter if necessary. Then the participant was asked to repeat four individual numbers and four pairs of numbers. Finally, numbers were presented monaurally over headphones and the participant was asked to repeat each number after hearing it. The volume was adjusted until all (or almost all) items were responded to correctly when played monaurally to either ear. One non-DS participant refused to put on the headphones and was not required to complete this task.

The following tasks were administered on each test day in the order given below:

1. *Handedness:* This was assessed by asking each participant to perform five manual tasks: (a) to write their name with a large felt pen, (b) use a spoon and pretend to eat soup from a bowl, (c) throw a ball, (d) thread a shoelace through the holes in a plastic toy, and (e) use a toy hammer. Each tool was placed at midline and the participant was invited to pick it up and demonstrate its use. The hand used was recorded for each task. For one task, throwing, participants were asked to throw the ball three times, with the hand used for two throws recorded. This was done because this task was less familiar and therefore less practiced by our participants. The frequency of right-hand preference was summed across tasks and across the two test days. This score served as an index of handedness.

2. *Fingertapping interference:* This was assessed as follows. Baseline tapping rates were established with the index finger of each hand. The participant completed six 10 s trials (including three with each hand), alternating hands between trials, beginning with the preferred hand. The participant was then asked to speak or hum continuously (see following item) while tapping. Each interference condition was performed first by itself to ensure adequate comprehension and performance, and then concurrently with the tapping task. Two 10 s trials were obtained, one with each hand, per condition. One DS participant did not complete the tapping tests on Day 2 and the scores for that participant were derived from performance on Day 1 only. The number of taps was determined for each trial. Scores were subsequently averaged across the two test days.

3. *Verbal interference:* Here, participants repeated their name and residence (e.g., "Jane Smith, South Nurses") until asked to stop.

4. *Musical interference:* In this phase of the experiment, participants hummed or sang the syllables, "la, la, la" to the melody of a familiar song, "Happy Birthday to You."

5. *Dichotic listening test:* In this test, participants were oriented to the task by repeating four numbers and four pairs of numbers presented orally by the examiner and then monaurally by headphone. The dichotic stimuli were then presented. Three practice pairs preceded the 15 digit pairs. The tape was then played a second time with the headphones reversed. The participant was instructed to repeat the numbers after each pair and the response was recorded by the experimenter. Initial headphone configuration was counterbalanced. The maximum score possible for this task was 30 for each ear. Two dependent measures were obtained for each participant by calculating the number of correct responses averaged across test days for the left and right ears.

RESULTS

To reduce the likelihood of falsely rejecting the null hypothesis, power is reported for nonsignificant effects that pertain directly to the hypotheses (Cohen, 1969).

Dichotic Listening

Although all participants could correctly repeat pairs of stimuli presented orally during pretraining, none were able to produce more than one response when stimuli were presented dichotically. As a result, the probability of guessing one of the stimuli correctly on a given trial was 2 in 6 (33%). Mean correct response rates were therefore examined to determine whether they differed from guessing levels. It was determined that participants produced a correct response on average 19.7 ($SD = 5.6$) of 30 trials or 65.7% of the time, well above chance.

The dichotic listening scores were then entered into an analysis of variance (ANOVA) to examine the effects of ear (left vs. right) and group (DS vs. non-DS). Ear was treated as a within-participants variable and group as a between-participants variable.

The only significant effect was for ear. Collapsed across group, the right ear ($M = 10.37$, $SD = 3.20$) was superior to the left ear ($M = 9.00$, $SD = 2.44$), $F(1,13) = 4.62$, $p < .05$.

Contrary to expectation, the two-way interaction of Ear × Group did not differ significantly from zero, $F(1, 13) = 1.95$, $p > .10$ (power = .253). Examination of group means (see Table 1) failed to confirm any trend in the data to reversed lateralization in the Down sample.

Dual-task Interference

Two preliminary analyses were performed. The first examined baseline tapping rates. These scores were averaged across six trials and entered into a 2 (Hand) × 2

TABLE 1
Mean Scores (and Standard Deviations) of Down Syndrome (DS) and non-Down Syndrome (non-DS) Groups as a Function of Side and Task[a]

	DS		*Non-DS*	
Task	*Left*	*Right*	*Left*	*Right*
Dichotic listening[b]	8.75	9.25	9.29	11.64
(Number correct)	(2.36)	(2.99)	(2.69)	(3.15)
Baseline tapping	28.52	27.50	29.94	27.33
(Taps per trial)	(5.28)	(6.37)	(9.71)	(6.88)
Speech interference	19.60	28.71	19.59	19.52
(Percent drop relative to baseline)	(16.62)	(23.30)	(23.14)	(15.12)
Music interference	43.62	30.27	27.68	22.75
(Percent drop relative to baseline)	(20.20)	(33.97)	(8.99)	(23.05)

[a]$N = 16$. [b]One subject in the non-DS group did not complete the dichotic listening test.

(Group) ANOVA, which revealed no significant effects. For hand, $F(1, 14) = 3.39$, $p = .087$; for group, $F(1, 14) < 1, p > .25$. The second analysis verified that the mean decrement scores obtained for the two dual-task conditions were significantly different from zero, omnibus $F(1, 14) = 43.50, p < .001$. This confirmed that we had elicited interference, a necessary assumption for the analysis that followed.

Tapping interference decrement scores were calculated separately for each hand and condition by subtracting the participants' average dual-task scores from their mean baseline tapping scores for that hand (averaged across the 2 test days), then dividing by the baseline score, and multiplying the result by 100. This score indicated the proportionate extent to which tapping performance declined with the addition of the concurrent task. The scores were then entered into a 2 (Hand) × 2 (Interference Condition) × 2 (Group) ANOVA. Hand and condition were analyzed as within-participants variables, and group as between-participants variables.

The analysis revealed a significant two-way interaction of Hand × Condition, $F(1, 14) = 7.84, p < .05$. Humming interfered more with left-hand tapping (indicating right-hemisphere control) while speaking interfered more with right-hand tapping (indicating left-hemisphere control; see Fig. 1).

The three-way interaction was not significant, $F(1, 14) = 3.25, p < .10$ (power $= .390$). Examination of the means revealed that the DS group displayed in a more exaggerated form the same asymmetry in hand performance displayed by the non-DS group. These findings are inconsistent with the hypothesis that DS participants have reversed lateralization.

Handedness

A preliminary analysis comparing Day 1 and Day 2 scores revealed that hand preference was highly consistent across days (left- and right-hand scores were

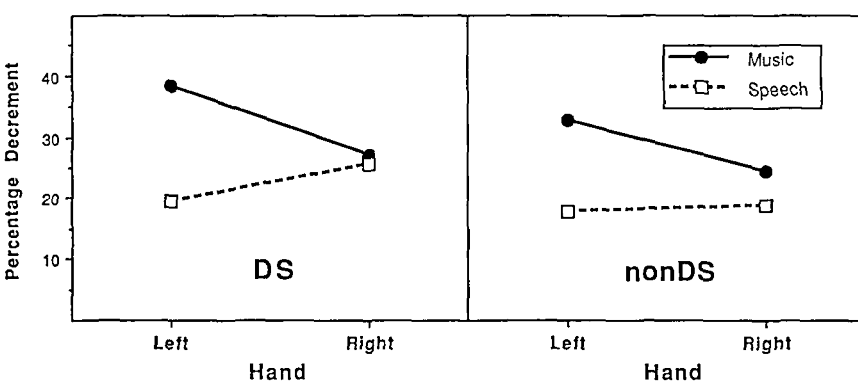

FIGURE 1 Percentage decrement in fingertapping scores as a function of group, hand, and interference condition. DS = Down syndrome.

analyzed separately; Pearson $rs = .98$, $p < .001$. The frequency of right-hand preference was summed across days for use in subsequent analyses (maximum handedness score = 10, range = 0–10).

The relative frequency of left- and right-handers within the sample was determined. Participants were classified as left-handed (or non-right-handed) if their handedness score was between 0 and 2, and right-handed if the score was between 8 and 10. Handedness was classified ambiguous or non-right-handed if the score was between 2 and 8. Two of the DS participants and four of the non-DS participants were identified as left-handers, and one DS participant was ambiguous (scoring 6 on this scale). In total, 38% of the DS participants and 50% of the non-DS participants were identified as non-right-handers.

Additional Analyses

Standard regression analyses were conducted to examine the predictive value of the peripheral and central laterality measures on three dependent measures (group, IQ, and language ability).

Because of the small sample size, the number of independent variables in each analysis was limited to three. To accomplish this, left- and right-side scores were replaced with a single laterality score for each task and one task (nonverbal interference) was dropped. This task was not associated with speech interference scores ($r = .44$, $N = 16$, $p = .091$) and as it did not pertain directly to the issue of speech lateralization, was deemed of minor interest. Assumptions of normality, linearity and homoscedasticity of residuals were tested before proceeding with each analysis.

Of the three analyses, only the regression coefficient calculated for language ability differed significantly from zero, $F(3, 11) = 4.98$, $p < .05$.

In this regression, language ability was entered as the dependent variable and three measures of laterality as the independent variables (a) a verbal interference relative decrement (right-hand decrement - left-hand decrement); (b) a dichotic laterality score, where $Y = 100 \times (\text{RE} - \text{LE})/(\text{RE} + \text{LE})$ (RE = right ear, LE = left ear); and (c) the handedness score used in previous analyses.

Table 2 displays the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficient (b), the semipartial correlations (sr^2) and R, R^2, and adjusted R^2. The standard regression analysis looks only at the unique contribution of each variable. Only two of the independent variables were found to have contributed significantly to the prediction of language ability; dichotic ($sr^2 = .49$) and handedness ($sr^2 = .32$). Altogether 58% (47% adjusted) of the variability in language ability was predicted by knowing scores on the three independent variables.

TABLE 2
Standard Multiple Regression Analysis for Variables Predicting Language Ability[a]

Variables	*Language Ability*	*Dichotic*	*Handedness*	*Speech Interference*	*B*	β	sr^2 *(unique)*
Dichotic	−.50*				−.19	−.79**	.49
Handedness	−.30	−.37			−.50	−.72**	.32
Speech	−.11	.07	.47*		.05	.29	.06
					Intercept = 14.34		
M	10.57	6.20	5.63	4.67			
SD	3.14	13.11	4.48	19.86			$R^2 = .58$
							Adj $R^2 = .47$
							$R = .76$*

[a]$N = 15$.
*$p < .05$. **$p < .01$.

The large proportion of variance accounted for is due, in part, to the presence of suppressor variables, which enhanced the importance of the other independent variables by reducing the variance in other independent variables or the dependent variable. In this respect, the verbal interference decrement appears to have acted as a classic suppressor (Carbonari, 1990). It was uncorrelated to language ability, but highly correlated to handedness. Higher verbal interference scores (suggestive of left-hemisphere lateralization for expressive language) were associated with higher handedness scores (ie., with "right-handedness"). Thus, in effect, the role of this variable in the equation was to reduce the variability in language ability associated with handedness. In contrast, the handedness variable behaved in a more complex way. Handedness was modestly (and negatively) associated with both language ability and dichotic listening, in addition to the aforementioned association with verbal interference.

When verbal interference was dropped from the analysis, the regression was still significant, $F(2, 12) = 6.50$, $p < .05$. This regression accounted for 52% (a drop of only 6%) of the variability in language ability. Thus whether or not one controlled for verbal interference, higher language scores were associated with lower dichotic laterality scores (suggestive of bilateral or right-hemisphere lateralization for receptive language), and lower handedness scores (suggestive of left-handedness).

The analysis was repeated, using a different formula to measure dichotic laterality: Percentage of correct response = RE/(RE + LE). This measure is recommended by Repp (1977) where levels of performance are low. The outcome was not changed.

When the original regression analysis was repeated using first group and then IQ as the independent variable, the regression coefficients did not differ significantly from zero. For group, multiple $r = .48$, $F(3, 11) = 1.073$, $p > .25$; for IQ, multiple $r = .36$, $F(3, 11) < 1$, $p > .25$.

DISCUSSION

The results of both perceptual (dichotic) and executive (dual-task) laterality tests supported our third hypothesis, namely that any asymmetries observed would correspond to those found in the general population. The dichotic listening procedure produced the expected overall right-ear advantage, and under dual-task conditions a verbal task was associated with a greater decrement in right-hand finger tapping while a musical task was associated with a greater decrement in left-hand finger tapping. These data suggest the usual pattern of left-hemisphere language lateralization. We conclude that lateralization in the populations with severe mental retardation, with or without DS, does not grossly deviate from that found in the normal population. Conversely, our data demonstrate that normative lateralization is no guarantee of normal cognitive function.

Comparisons of DS and non-DS participants for each measure did not reveal any DS-specific aberrant lateralization pattern. Specifically, the pattern proposed by Elliott et al. (1994) of left-lateralized verbal output but right-lateralized verbal input in DS was not observed in our study. The discrepancy may reflect differences in age and educational or institutional experience between our sample and previous samples. Our data cannot address these possibilities. Rather, our data indicate that differences in handedness and IQ cannot account for the discrepant findings. Furthermore, a third factor, language ability, looks more promising.

With respect to handedness, our sample contained, as expected, a relatively high proportion of non-right-handed participants. In fact, only 56% of the participants were consistently right-handed. This was true for both DS and non-DS participants. This fact makes our findings even more remarkable and makes it clear that the presence of non-right-handers cannot account for the anomalous dichotic findings associated with DS in previous studies.

Regression analyses revealed that anomalous laterality (both peripheral and central–perceptual) was not associated with IQ but did predict language ability in our sample. Executive laterality scores did not play a part in either regression. The linguistically least-impaired participants within our cognitively limited sample were more likely to have scores on the dichotic listening test suggestive of bilateral or right-hemisphere speech processing. They were also more likely to be left-handed. We suggest that the presence of more verbally adept participants distributed asymmetrically among groups may have played a role in previous studies finding differences between DS and non-DS participants on dichotic tests. This possibility needs further study.

The relationship between anomalous laterality, verbal ability, and spatial ability in this population remains unknown. This is unfortunate, as the latter function is believed to be an area of strength in the DS population (Elliott, Weeks, & Elliott, 1987). Unfortunately, our data cannot address this issue.

So, what can we conclude from these data? First, the data from our small sample study provide no support for the idea that reversed central laterality characterizes the DS population or the population with mental retardation in general. In fact, despite its popularity, the idea that reversed laterality is associated with cognitive disability has never been supported in non-retarded populations (e.g., left-handers, see Kinsbourne, 1988). Furthermore, if true, it should be most apparent in the lowest-functioning subgroups (just as is known to be the case with reversed peripheral laterality—and indeed in our sample, reversed hand preference was more frequent than in higher-functioning samples). Our sample is among the lowest functioning, if not the lowest functioning, reported in this literature. We conclude that left-lateralization of language is more resistant to brain malfunction than is right-hand preference, just as language abilities themselves seem to be resistant to aberrations in low functioning populations.

Second, the finding that reversed central (perceptual) and peripheral laterality may be associated with relatively *greater* cognitive ability (at least in the area of language) is of some theoretical interest. This finding will, of course, have to be confirmed by future studies with a larger sample size. If confirmed, it might indicate the following: In mental retardation (DS and non-DS), the left hemisphere is relatively inhospitable to language function. Those individuals in whom (for whatever reason) language representation bilateralizes or includes right-hemisphere territory benefit in terms of their language development. This could be either because the right hemisphere in them makes a significant contribution, or because the processing space for verbal computations is more extensive. That is, the right hemisphere may provide more needed space for language functions that cannot be maintained otherwise within the left hemisphere in these populations.

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