Differential Laterality of Hand Function in Right-Handed and Left-Handed Boys

(human development, fine motor skills, lateralization, handedness)

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This study was designed to investigate differences in the degree of manual lateralization between right-handed and left-handed normal boys. Sixty-three 5, 7, and 9 year olds were tested on the Minnesota Rate of Manipulation Test (displacing subtest and turning subtest), the Finger Tapping Test, the Purdue Pegboard (placing subtest and assembly subtest), and the Southern California Motor Accuracy Test—Revised. Significant differences between right- and left-handed subjects were obtained on two of the six measures, and a third measure approached significance, with less lateralization among the left-handers than among the right-handers. Subsequent analyses indicated that differences in lateralization were significant or near-significant in the 5 and 7 year olds. By 9 years of age, right- and left-handed subjects no longer differed in the degree of laterality. Differences in degree of laterality, or the lack of such differences, between young right- and left-handed boys might be a function of the nature of the fine motor task or a function of the child's previous experience with the task.

The establishment of manual laterality or hand "dominance" is considered to be a significant development milestone (1-5). It is particularly important as a child progresses through the early school years when increasing skill in one hand for purposeful tool use is required. It is also one indication of the neurological lateralization process (6-10). Occupational therapists therefore frequently consider differential hand skill development in the evaluation of children who demonstrate delays or difficulties in the areas of motor or perceptual skills (10, 11).

Developmental studies of handedness have indicated that younger, right-handed children tend to be more asymmetrical in their performance of fine motor tasks and therefore tend to show larger right-left differences between hands than older children (2, 7, 12). A child's hand performance improves significantly, both in skill and in speed, with increasing age (2, 7, 12-14). This is characteristic of function in the nonpreferred hand as well as in the preferred hand (2). The development of differential hand skill also appears to be a function of the child's sex; the results of some studies have suggested that girls acquire an earlier and more pronounced asymmetry between the right and left sides than boys (2, 7, 15, 16).

Reported variations in hand skill development are also thought to result from the type of task being performed. Right-handed children have been found to demonstrate a consistent right-sided superiority for pure motor tasks such as finger tapping and grip strength (7, 12, 13, 17). However, the right and left hands were found to perform equally well on tactile-perceptual tests (17) and in isolated finger lifting (13). In addition, Ingram (13) reported that the nonpreferred left hand performed better than the right on "hand postures" and "finger spacing" tasks. In a group of right-handed children aged 6-14 years, Finlayson and Reitan (18) demonstrated that differential hand function was associated with motor or efferent measures, but that similar differentiation between the preferred and nonpreferred hands did not occur with tactile-perceptual (afferent) measures.

Hand use patterns and the expression of laterality have been found to differ between right-handed and left-handed populations. A relatively consistent degree of laterality is characteristic of right handers, whereas left handers tend to be more variable both in their hand preference over different tasks and in their preferred hand performance (1, 9, 14, 19-21).
Research studies addressing the comparative performances of preferred versus nonpreferred hand function in left-handed adult subjects produced conflicting and disparate findings. In general, preferred hand superiority appears to be less established in left handers than in right handers; in other words, their “preferred” and “nonpreferred” hands are less clearly differentiated in terms of relative skill (9, 20, 22). Satz, Achenbach, and Fennell (20) also found that, under some test conditions, a large proportion of the self-classified left handers actually performed better with their nonpreferred hands. Findings from other studies indicated that left handers do not lack proficiency with their preferred hand and, in fact, do as well with their left hand as right-handers do with their right. This has been demonstrated in young school-aged children (2, 23), in older children and adolescents (1, 24), and in adults (1, 25). In a developmental study of right- and left-handed children, it was found that left-handed children displayed patterns of maturation similar to right-handed children on bimanual tasks (i.e., they increasingly kept one hand in a stable position while the other hand moved), although they did develop these behaviors at a slower rate (14).

Relatively few studies have been conducted on the development of laterality in both right-handed and left-handed children. However, from those studies available, there are indications that left-handed children may be more variable than their age peers in the performance of hand skills (14) and may demonstrate smaller right-left differences on a fine motor task than right-handed children (26). Researchers have also suggested that left-handed children may differ in their neurological maturation rate and may therefore be somewhat “slower” to develop stability in their lateralization (14, 27). Current developmental expectations and assessment measures of preferred and nonpreferred hand function are in need of further qualification, particularly for left-handed children. It would seem important to consider whether manual laterality patterns may, in fact, differ between right-handed and left-handed children so that occupational therapists can more accurately assess and identify problems and/or delays.

The following questions were addressed in this study:
1. Are right-handed boys more completely lateralized for hand function than left-handed boys of the same age?
2. Is there an interaction between age and handedness on the degree of manual lateralization such that younger left handers are especially poorly lateralized?
3. Are there differences in manual lateralization as a function of the type of performance task?

Method
Subjects. The subjects were 63 normal male children, aged 5, 7, and 9 years, from public and private schools and from one day care center. Subjects were selected as they became available by reports of school authorities, with no systematic bias. All subjects were judged by their teachers to be functioning adequately in a regular academic setting without any known physical, sensory, or perceptual deficits. Children were categorized before testing according to their age and preferred handedness. Determination of preferred handedness was based on teacher and parent reports together with identification of the child’s writing hand. In the 5-year-old group, there were 10 right handers and 10 left handers; the 7-year-old group consisted of 11 right handers and 9 left handers; and the 9-year-old group included 11 right handers and 12 left handers.

Measures. Testing materials were chosen in accordance with the basic areas of skilled hand function outlined by Gagne and Fleishman (28) and by Fleishman and Ellison (29) to include: 1. manual dexterity, 2. finger dexterity, and 3. arm-hand steadiness. Factor extraction studies (29) of the Minnesota Rate of Manipulation Tests (30) have identified high loadings on the manual dexterity factor, whereas the Purdue Pegboard (31) has been found to load high on the factor of finger dexterity. The Southern California Motor Accuracy Test—Revised (11) emphasizes accuracy or “steadiness” of the visually directed hand use of a pen and is specifically designed for comparison between the more- and less-accurate hands. A fourth instrument, the Finger Tapping Test (with electronic counter), was also included. Although not a standardized performance tool, finger tapping has become a well-established means for comparing differential rapid movement control between the two hands (7) and is considered to be a sensitive measure of laterality (32).

Procedure. Subjects were tested individually in a quiet location during one 20-minute session. The order of presentation for the four tests was counterbalanced. In addition, for all tests, presentation was with the preferred hand first for half of the group and with the
Table I
Means and Standard Deviations of the Six Dependent Variables

<table>
<thead>
<tr>
<th>Age:</th>
<th>5 years</th>
<th>7 years</th>
<th>9 years</th>
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<tbody>
<tr>
<td>Handedness:</td>
<td></td>
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<tr>
<td>No. Subjects</td>
<td>R-H</td>
<td>L-H</td>
<td>R-H</td>
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<tr>
<td></td>
<td>n=10</td>
<td>n=10</td>
<td>n=11</td>
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<tr>
<td>Preferred (P)/</td>
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<td></td>
<td></td>
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<tr>
<td>Nonpreferred (NP)</td>
<td>P</td>
<td>NP</td>
<td>P</td>
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Test Measures:

- Minnesota-Displacing
  - Mean: 25.7, 23.5, 22.3, 21.9, 30.5, 32.2, 29.9, 35.0, 32.3, 35.0, 32.1
  - S.D.: 1.4, 1.8, 2.9, 3.0, 3.1, 4.0, 3.3, 2.5, 3.1, 2.9, 2.8

- Minnesota-Turning
  - Mean: 19.3, 18.6, 18.0, 17.7, 22.1, 21.2, 23.6, 22.7, 26.2, 24.9, 27.8, 25.9
  - S.D.: 1.1, 1.4, 2.3, 3.1, 1.9, 3.0, 3.6, 2.8, 2.9, 2.5, 2.6, 3.9

- Finger Tapping
  - Mean: 87.8, 76.0, 84.6, 80.3, 103.8, 92.8, 102.6, 93.0, 120.5, 105.7, 119.7, 111.3
  - S.D.: 14.6, 11.0, 10.8, 9.1, 13.3, 11.8, 11.5, 9.1, 13.2, 11.1, 16.1, 22.0

- Purdue-Placing
  - Mean: 11.2, 9.7, 8.6, 8.7, 13.5, 11.2, 12.3, 12.1, 14.6, 13.2, 14.7, 12.9
  - S.D.: 1.7, 1.5, 1.4, 1.3, 1.6, 1.4, 1.7, 1.5, 1.7, 1.2, 1.8, 1.8

- Purdue-Assembly
  - Mean: 12.7, 11.2, 10.5, 10.3, 16.8, 14.6, 16.9, 15.6, 19.5, 17.5, 19.3, 17.8
  - S.D.: 2.5, 2.0, 2.4, 2.2, 2.7, 1.7, 2.8, 2.1, 2.3, 2.4, 2.6, 1.6

- Motor Accuracy
  - Mean: 145.7, 135.6, 144.7, 139.9, 169.6, 152.5, 155.5, 149.5, 161.5, 156.2, 160.7, 154.2
  - S.D.: 9.5, 9.9, 6.6, 8.6, 7.9, 7.3, 7.6, 6.6, 5.9, 4.8, 5.8, 7.0

Key: Minnesota = Minnesota Rate of Manipulation Test.
Finger Tapping = Finger Tapping Test.
Purdue = Purdue Pegboard.
Motor Accuracy = Motor Accuracy Test-Revised.

nonpreferred hand first for the other half of the group to control for any order effects.

A short demonstration and practice session were provided prior to testing of the first hand only on each of the test measures. Standardized or recommended directions for each test were adhered to with the following modifications and adaptations.

*Minnesota Rate of Manipulation Test.* The displacing subtest was administered first, followed by the turning subtest.

1. **Displacing subtest:** Subjects were asked to displace the blocks, one at a time, in a horizontal sequence (first row—left to right; second row—right to left; etc.), rather than in vertical columns in order to reduce the number of directional changes and possible confusion. This adaptation is permissible since raw scores are used in the statistical analysis instead of standardized scores. Each subject's score was based on the number of blocks displaced by each hand, respectively, in 30 seconds.

2. **Turning subtest:** Turning was performed by only one hand; the test was then repeated using only the other hand. Blocks were turned in the same sequence specified under "displacing subtest." Each subject's score was based on the number of blocks turned by each hand, respectively, in 30 seconds.

*Purdue Pegboard.* The placing subtest was administered first, followed by the assembly subtest.

1. **Placing subtest:** Each subject's score was based on the number of pins placed by each hand, respectively, in 30 seconds.

2. **Assembly subtest:** Assembly was performed by only one hand; the test was then repeated using only the other hand. One model was left in place during testing, but was
not included for scoring purposes. Assembly consisted of placing a pin in the hole first, then placing a washer, then a collar. The arrangement of pins, collars, and washers in the trays was reversed before testing of the second hand so that pieces could be picked up in the same sequence for each hand. Each subject's score was based on the number of parts assembled by each hand, respectively, in 45 seconds.

Motor Accuracy Test—Revised. Subjects were given appropriate encouragement to complete the test by using a 60-second time interval for both their preferred and nonpreferred hands as suggested on the test manual (11). The adjusted raw scores were used for data analysis.

For the six test measures, each of the six dependent variables was computed by subtracting the nonpreferred hand raw score from the preferred hand raw score. This difference can be considered a measure of manual laterality in that a large difference would indicate that the preferred hand was more skilled in that task than the nonpreferred hand.

Results
Table 1 presents the raw scores (Minnesota Rate of Manipulation Test, Finger Tapping, Purdue Pegboard) and adjusted raw scores (Motor Accuracy Test—Revised). Using these scores, simple (1-way) analyses of variance were performed on each of the measures to test for order effects. There were no significant effects for either the order of test presentation or for the order of the preferred and nonpreferred hands.

A 2-way (3 X 2) analysis of variance (age x handedness) was performed for each of the six dependent measures (the measures of manual laterality).

Minnesota Rate of Manipulation Test: Displacing subtest. Left-handed subjects were found to be significantly less lateralized than right-handed subjects, \( F(1,57) = 8.68, p < .01 \). The significant interaction between age and handedness, \( F(2,57) = 3.35, p < .05 \), further specified that the degree of lateralization between right handers and left handers was a function of age. A subsequent F-test for simple effects indicated that 5-year-old left-handers were significantly less lateralized than 5-year-old right-handers, \( F(1,18) = 6.63, p < .05 \), and that 7-year-old left-handers were also significantly less lateralized than 7-year-old right-handers, \( F(1,18) = 6.33, p < .05 \). However, 9-year-old left-handers were not significantly different in degree of lateralization from 9-year-old right-handers, \( F(1,21) = 0.05, p > .05 \). In fact, the mean difference score of 9-year-old left-handers was slightly greater than that of 9-year-old right-handers, although not significantly greater. See Figure 1 for a graphic description of the difference between preferred and nonpreferred hands across ages.

Minnesota Rate of Manipulation Test: Turning subtest. This dependent variable did not indicate significant differences in the degree of lateralization between right-handed and left-handed subjects; nor was there a significant interaction.

Finger Tapping Test. Differences in laterality approached significance, \( F(1,57) = 3.27, .05 < p < .10 \), between right-handed and left-handed subjects, suggesting the possibility of less lateralization among the left handers. There was no significant interaction.

Purdue Pegboard: Placing subtest.
This dependent variable indicated significantly less lateralization among left-handed subjects than among right-handed subjects, $F(1,57) = 6.70, p < .05$. The interaction between age and handedness approached significance, $F(2,57) = 2.77, .05 < p < .10$. A subsequent F-test for simple effects specified that 7-year-old left handers were significantly less lateralized than 7-year-old right handers, $F(1,18) = 10.48, p < .01$, and that differences in degree of laterality approached significance between 5-year-old right and left handers, $F(1,18) = 3.23, .05 < p < .10$, but that there were no significant differences between 9-year-old right and left handers, $F(1,21) = 0.18, p > .05$. As was noted for the displacing subtest (Minnesota Rate of Manipulation Test), the mean difference score for this variable was also greater among 9-year-old right handers, although not significantly greater. See Figure 2 for a graphic description of the differences between preferred and nonpreferred hands across ages.

**Figure 2**
Purdue Pegboard: Assembly subtest. Differences between preferred and nonpreferred hands for right-handed and left-handed boys across ages.

Within the six hand function tests used in this study, right-handed and left-handed boys demonstrated significantly different degrees of manual laterality on two of the measures, with a third measure approaching significance. These statistical differences were in the direction of less lateralization among the left handers than among the right handers. In addition, it may be noted that manual laterality scores tended, although not significantly, to be greater for right handers than for left handers on two out of the remaining three tests. The sixth test reflected an almost equal manual laterality score between right and left handers.

The reasons why some of these tests produced significant results whereas others did not are unclear. However, as documented in the literature, it may be assumed that different motoric demands will cause variable performance outcomes. This apparently holds true for the degree of lateralized function that will be reflected when comparing the right and left hands on the same task. Recognition should be made of the fact that, of the six tests, only one test (Motor Accuracy Test—Revised) could be considered a well-practiced and familiar task to most of the children. Results of the Motor Accuracy Test—Revised, which requires tracing around a curved black line, did not reveal any sign-
Significant differences in the degree of lateralization between right- and left-handed subjects. This is probably not surprising, since Provins (34) asserts, "... it may be expected that a one-handed task which depends on the skilled execution of a particular movement pattern will be carried out very much more successfully with the hand which has received considerable practice in the task than with the other relatively untrained hand. ..." (p 469) It can perhaps be expected that tasks of this nature will result in similarly better performance by the right hand in right-handed children and by the left hand in left-handed children. In sum, the effects of practice on this task by the left-handers might have made them appear almost as well lateralized as the right-handers.

Results from this study further indicate that variability in lateralization patterns between right- and left-handed boys is a function of age. On the Minnesota Rate of Manipulation Test: Displacing subtest, and the Purdue Pegboard: Placing subtest, the younger age groups (5 and 7 year olds) were found to be significantly or almost significantly different in the degree of laterality between right handers and left handers; whereas by 9 years of age there were no differences in lateralization between right and left handers. Although scores were not statistically analyzed on four of the tests because of nonsignificant interactions, manual laterality scores tended to be greater for right handers than for left handers on all six tests for both the 5 and 7 year olds; however, by 9 years of age the left-handers demonstrated the greater manual laterality score on four out of the six tests. It was further noted that growth in preferred hand skill, as reflected by proportionate score increases on all six tests across the three age groups, was generally greater for left handers than for right handers between the ages of 5 and 7 years and again between the ages of 7 and 9 years. A comparison of right- and left-handed subjects at 9 years of age indicates that, on most of the tasks, preferred as well as nonpreferred hand scores were more similar between the two groups at this age than at the two younger ages.

These findings are congruent with researchers' suggestions that left handers may differ in their neurological development and may therefore be more delayed than right-handers in acquiring stable lateralizations (14, 27). An alternative explanation is that sociocultural factors might bias the young left hander toward right-hand use and therefore might delay the development of stable dominance. However, Levy (35) presents data that indicate environmental factors currently have less influence on handedness than in the past.

The clinical relevance of these findings may be considered on two levels. First, the results suggest that significant differences do exist for at least some aspects of hand function, in the degree of manual laterality between right- and left-handed boys. The direction of this difference is toward more complete expression of preferred hand skill among right handers than among left handers. This distinction is of value for occupational therapists who use lateralization information in assessing children with learning disabilities, sensory integrative dysfunction, or perceptual deficits. Of somewhat contradictory but related importance are the findings in this and an earlier study by an occupational therapist (23) that a familiar, well-practiced task (such as tracing in the Motor Accuracy Test—Revised) should most probably reflect similar degrees of lateralization among right handers and left handers.

Second, and perhaps more importantly, the results indicate that variable lateralization patterns between right- and left-handed boys are influenced by age, at least in some tasks. This is useful information from a developmental perspective. It may be inferred that lateralized hand use patterns appear earlier (i.e., by the age of 5 years) in right-handed boys, so that subsequent development is characterized by mild fluctuations with stabilization in handedness achieved by 9 years of age. In contrast, left-handed boys appear to undergo the greatest growth in preferred hand development after the age of 5 years; but, like right-handers, they also obtain stable lateralization by the age of 9 years.

Clinical implications of these findings for occupational therapists apply primarily to evaluation and assessment practices. Caution should be exercised with younger left-handed boys in the interpretation of test results that might appear to indicate poorly developed lateralization, particularly if this information is obtained from tasks that are not well practiced. In addition, expectations regarding the acquisition of differential hand skill should perhaps be reconsidered in view of tentative evidence that the development of lateralization patterns may differ between right handers and left handers.

Several areas of future research...
are suggested. Because of previous research findings, that males and females differ both in their hand skill development and in their performance on hand function tasks, only males were included in this investigation. It would be of interest to conduct a similar study with young girls. Also, subjects in this study were classified on handedness according to teacher/parent reports and one functional preference (handwriting). In view of the influence that familial left handedness exerts on hemispheric specialization and the expression of lateralization, it may be worthwhile to classify subjects according to their familial history. Future research might also address manual lateralization in clinical populations, such as the learning-disabled, autistic, developmentally delayed, and schizophrenic groups.

Conclusions
Well-established hand dominance has often been considered a significant developmental milestone and one indication of neurological maturation. Occupational therapists and others frequently assess differential hand function in children suspected of developmental deviations or delays. The results of this study indicate that evaluators should not expect as much differential hand function in certain fine motor tasks in 5- and 7-year-old left handers as in 5- and 7-year-old right handers. Nine-year-old left handers and 9-year-old right handers, however, should be expected to have a similar degree of differential hand function.

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