

Purdue Pegboard Performance of Disabled and Normal Readers: Unimanual versus Bimanual Differences

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Differences between dyslexics and controls in the unimanual and bimanual conditions of the peg placement section of the Purdue Pegboard Test were examined. Twenty-three disabled and twenty-three normal readers were studied. The groups were carefully screened on a neuropsychological battery. The disabled readers were comprised of a relatively homogeneous language-disordered subgroup exhibiting deficits in naming. Significant Group \times Condition interactions were obtained for both raw and percentile scores and indicated that disabled readers performed worse than controls in the unimanual compared to bimanual conditions. The dyslexics performed particularly poorly compared with controls on the left hand condition. The implications of these data for hypotheses which argue for left hemisphere dysfunction, as well as those which posit interhemispheric transfer deficits in reading disabled children, are discussed. © 1985 Academic Press, Inc.

INTRODUCTION

The effectiveness of the peg placement section of the Purdue Pegboard Test (PPT) in differentiating various clinical populations from normal controls has been well documented. Costa and colleagues (Costa, Vaughan, Levita, & Farber, 1963), for example, have demonstrated the utility of this measure as an indicator of the presence and laterality of brain damage in adult patients. Other investigators have successfully used this measure of fine sequential motor movements to discriminate brain-damaged, retarded (Rapin, Tourk, & Costa, 1966), and learning disabled (Gardner & Broman, 1979) children from normal control children. The standard peg placement section of the Purdue is administered as three separate subtests: right hand alone, left hand alone, and bimanually. Although the studies referred to above have uncovered various between-group differences in the samples

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they studied, no studies to date have included a systematic examination of differences between groups in the patterning of scores across these three conditions.

Recently, Wilson and colleagues (Wilson, Iacoviello, Wilson, & Risucci, 1982) have explicitly examined differences in the pattern of subtest scores across age for a normative sample of 206 right-handed children ranging in age from 2 years, 6 months to 5 years, 11 months. In general, the preferred hand was found to be superior to the nonpreferred in all but the youngest age group.

The present paper reports on the PPT which was included as part of a larger ongoing research project on hemispheric interaction in reading disabled and normal children. The PPT was administered to each subject as part of a battery of neuropsychological tests. As the Purdue has been shown to correlate with other indices of sensorimotor performance and, unlike other perceptual and cognitive tasks, is relatively independent of educational level in normals (Costa et al., 1963), it appears to be an excellent instrument for exploring differences in neurobehavioral function between these two groups.

Although differences in the Purdue Pegboard performance between reading-disabled and normal control children have been previously reported (Gardner & Broman, 1979), questions regarding the specific differences between these groups in the relations among the three hand conditions (i.e., dominant, nondominant, and bimanual) have not yet been explored. We regard this comparison as particularly important in light of recent findings which suggest that at least a subgroup of disabled readers may have deficits in interhemispheric communication (e.g., Badian & Wolf, 1977; Obrzut, Obrzut, Hynd, & Pirozzola, 1981; Yeni-Komshian, Isenberg, & Goldberg, 1975). The precise nature of this deficit remains to be characterized. However, given that the bimanual condition is likely to depend upon hemispheric collaboration, we expected that the relation between the unimanual and bimanual conditions would differ for reading disabled and control children.

METHOD

Subjects. Forty-six males were run in this study. The subjects were all right-handed as assessed by the Harris Tests of Lateral Dominance (Harris, 1958), and were between the ages of 9 and 12 years. Half of the subjects were reading disabled ($N = 23$, M age = 11.25 years) and half were normal readers ($N = 23$, M age = 11.16 years). Subjects came from school districts in Westchester County, New York. All children were from either middle or upper middle income families.

All subjects had to obtain a full scale IQ of 90 or above on the WISC-R (Wechsler, 1974) in order to participate. In addition, all subjects were required to score 85 or above on performance IQ and achieve a scaled score of 7 or above on the Block Design Subtest. The PIQ and Block Design criteria were established to exclude those children with perceptually based learning disability. All subjects also were required to score 70% or more in the right-handed direction on the Harris Tests of Lateral Dominance. Other criteria common to both groups included (1) scoring 17% or more on the quiet condition of the Goldman,

Fristoe, and Woodcock Test of Auditory Discrimination. This criterion served to screen out any subject with gross auditory impairment; (2) eliminating any subject with obvious emotional or neurological problems (e.g., seizures, meningitis, encephalitis) or with a history of such problems; (3) eliminating those subjects who took medication with known CNS effects for longer than 6 months or those subjects who are currently taking such medication; and (4) eliminating any subject who was adopted due to lack of adequate history information.

In an effort to reduce the variability within our reading-disabled group, we chose to focus on a previously identified language-disordered subgroup of dyslexics who have been characterized by naming deficits (Mattis, French, & Rapin, 1975). This specific subgroup was targeted for study based upon two major considerations: (1) the subgroup accounts for the largest percentage of reading disabled children compared with all other identified subgroups (Denckla, 1977; Doehring, Hoshko, & Bryans, 1979; Mattis et al., 1975); and (2) we have hypothesized that this specific subgroup would exhibit deficits in interhemispheric transfer. To select our sample, we included only those dyslexics who scored more than one standard deviation below the mean on at least one of two naming tests: the Visual Naming subtest from the Neurosensory Comprehensive Examination for Aphasia (Spreen & Benton, 1977), and/or any of the four subtests of the Rapid Automatized Naming Test (Denckla & Rudel, 1976).

A child was considered reading disabled if he scored .85 or below on the reading quotient proposed by Myklebust (1968): $(2 \times \text{Reading Age})/(\text{Mental Age} + \text{Chronological Age})$. A child qualified as a control subject if he scored .95 or above on the same reading quotient and if he also scored less than 1 year below actual grade level on any of the reading tests which were administered. The mental age used in Myklebust formula was derived from the WISC-R and the reading age was derived from the Word Identification subtest from the Woodcock Reading Mastery Tests (Woodcock, 1973). Table 1 presents the descriptive data on our dyslexic and normal samples.

In an effort to determine whether our dyslexics had an attentional dysfunction in addition to their reading disability, we compared the performance of each group on the noise subtest of the Goldman, Fristoe, and Woodcock (1970) Test of Auditory Discrimination. This provides a measure of the degree to which auditory attention is compromised by the presence of background noise. On this test, we found that dyslexics performed similarly to controls (M for dyslexics = 40.91; M for controls = 46.57; $t < 1$). Therefore our dyslexic sample did not show any gross dysfunction in attentional performance.

Procedure. The PPT was administered during the first of two 3-hr psychometric sessions

TABLE 1
PSYCHOMETRIC CHARACTERISTICS OF THE GROUPS^{a,b}

	Age	PIQ	VIQ	FIQ	MQ	WI	WA	GO	GM
Dyslexics									
<i>M</i>	11.25	116.35	109.00	113.65	.73	16.13	31.22	19.43	30.89
<i>SD</i>	1.16	11.68	10.33	10.41	.09	13.80	24.24	13.50	24.67
Controls									
<i>M</i>	11.16	113.74	122.61	120.57	1.17	76.09	83.74	82.37	82.47
<i>SD</i>	1.06	14.63	11.17	12.66	.16	12.58	.95	13.34	17.48

^a Means for the reading tests are based on percentile scores. $N = 23$ per group for all variables except for GO ($N = 21$ for dyslexics; $N = 19$ for controls) and GM ($N = 18$ for dyslexics; $N = 19$ for controls).

^b MQ = Myklebust Quotient. WI = Woodcock Word Identification Subtest. WA = Woodcock Word Attack Subtest. GO = Gray Oral Reading Test. GM = Gates-MacGinitie Reading Test—Level D.

which were held on separate days. Initially each subject's hand dominance was assessed using Subtest 2 of the Harris Tests of Lateral Dominance (Harris, 1958). This test requires subjects to pantomime their performance of 10 commonly performed tasks which require the use of one hand or the other. Only those subjects who used their right hand on 7 or more of the 10 tasks were included in our study. The peg placement section of the Purdue was administered according to the instructions in the test manual (Tiffin, 1968). The number of pegs the subject placed, first using his preferred hand (i.e., the right hand), then his nonpreferred hand, and finally both hands simultaneously, was recorded. The order in which the three hand conditions were administered was identical to that used by Gardner and Broman (1979) and Wilson et al. (1982).

RESULTS

A 2×3 analysis of variance (ANOVA) for balanced groups was performed on the raw scores with Group (dyslexic versus control) and Condition (dominant versus nondominant versus bimanual) as between- and within-group factors, respectively. A significant main effect for Condition [$F(2, 88) = 113.41, p < .0001$] was obtained (M for right hand = 13.35; M for left hand = 12.76; M for bimanual = 10.48]. The difference between the right hand versus the bimanual and left hand versus the bimanual condition were both significant ($p < .01$ for both).¹ In addition, performance in the right hand condition was better than performance in the left hand condition ($p < .01$). These results support previous findings which indicate that the best performance is displayed by the right hand and that the unilateral conditions result in better performance compared with the bimanual condition. No significant main effect for Group was obtained [$F(1, 44) = 2.83$]. The Group \times Condition interaction was significant [$F(2, 88) = 5.65, p = .005$] and indicates that dyslexics placed fewer pegs compared with controls in both the dominant ($p < .05$) and nondominant ($p < .01$) conditions. However, no differences in peg placement emerged between the controls and dyslexics in the bimanual condition (see Fig. 1). Within the dyslexic group, each condition was reliably different from every other condition (all comparisons, $p < .01$) with best performance observed during the dominant hand condition, worst performance during the bimanual condition, and an intermediate level of performance during the nondominant hand condition. Within the control group, performance in both dominant and nondominant conditions was superior to that during the bimanual condition ($p < .01$ for both). No difference was found between the two unimanual conditions in this group.

Raw scores were converted to percentile scores using Gardner's norms (Gardner & Broman, 1979) in order to compare each subject to a large group of age-matched normal children. This conversion seemed warranted in light of the previously documented effects of age on performance in both preschoolers (Wilson et al., 1982) and in Gardner and Broman's normative sample which ranged in age between 5 years, 0 months and 15 years, 11 months.

¹ All post hoc paired comparisons were evaluated by the Newman-Keuls procedure.

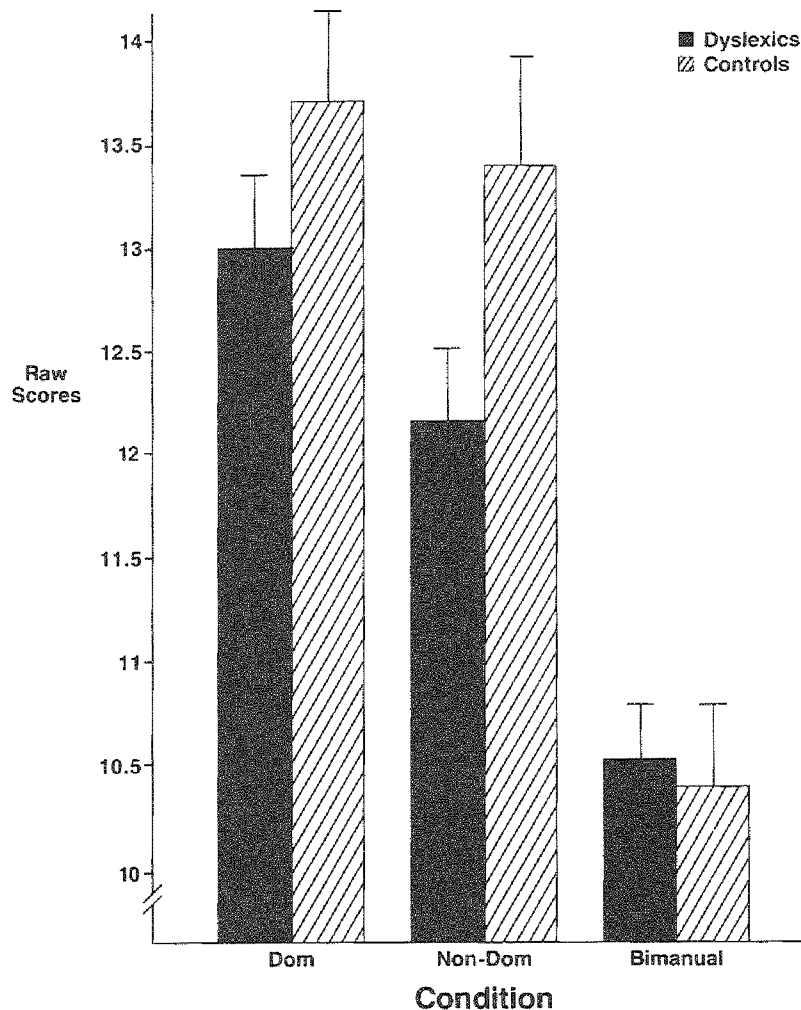


FIG. 1. Mean raw score performance (i.e., number of pegs placed) for dyslexics and controls ($N = 23$ for both) separately for each of the three hand conditions.

A 2×3 ANOVA for balanced groups was performed on the percentile scores, again with Group and Condition as the between- and within-group factors. The main effect for Condition was not significant [$F(2, 88) = 2.53, p = .09$]. A significant main effect for Group was obtained [$F(1, 44) = 3.98, p = .05$]. The controls showed a higher percentile score compared with dyslexics (M for controls = 38.74; M for dyslexics = 26.83). A significant Group \times Condition interaction [$F(2, 88) = 3.34, p = .04$] was obtained and demonstrates differences in performance between the dyslexics and controls in the dominant ($p < .05$) and non-dominant ($p < .01$) conditions (see Fig. 2). The bimanual condition, however, did not discriminate between these two groups. When performance within each group was examined, a different pattern emerged for dyslexics and controls. The dyslexics showed no difference among the three hand conditions. The controls performed better on the left hand condition compared with both the right hand ($p < .05$) and bimanual conditions ($p < .05$).

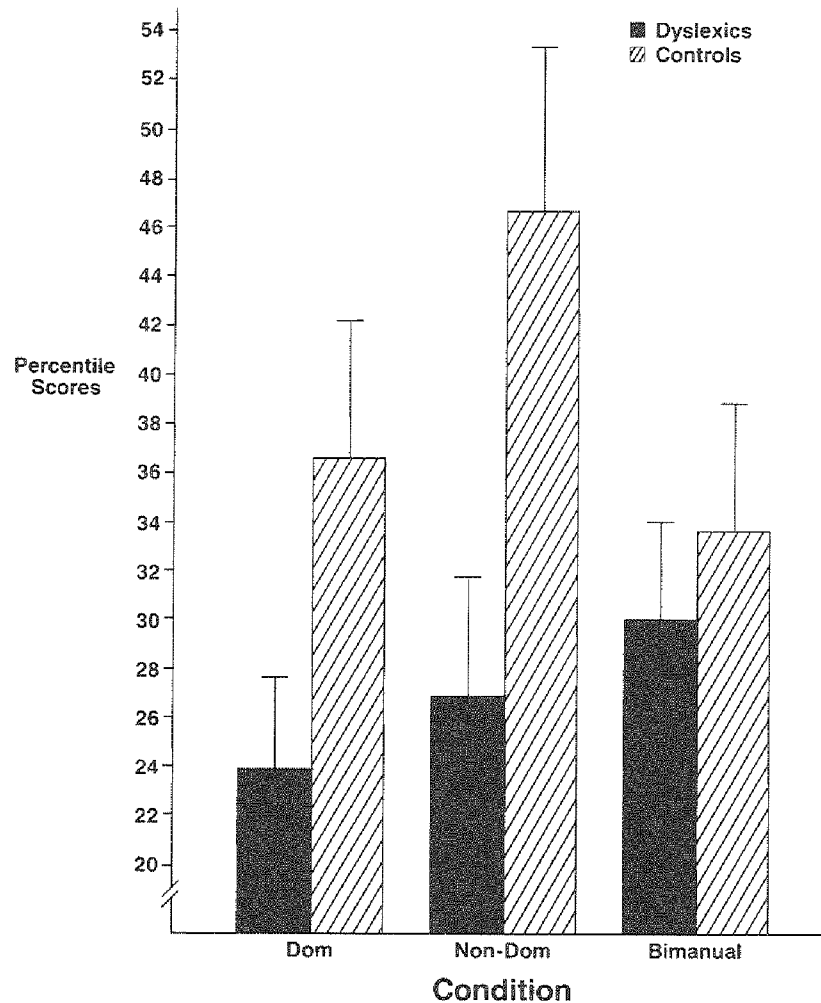


FIG. 2. Mean percentile scores for dyslexics and controls separately for each of the three hand conditions. Percentiles are based upon Gardner and Broman (1979).

In order to compare unimanual versus bimanual performance, we combined the dominant and nondominant percentile scores into a single average unimanual score. A 2×2 ANOVA was then performed with Group (dyslexic versus control) and Condition (bimanual versus unimanual) as between- and within-group factors, respectively. Although the main effects for Condition ($F < 1$) and Group [$F(1, 44) = 2.83$] were not significant, the Group \times Condition interaction was [$F(1, 44) = 5.59, p = .02$]² (see Fig. 3).

Paired comparisons revealed that the controls showed significantly better performance in the unimanual compared with the bimanual condition ($p < .05$). No difference between condition was found in the dyslexics.

² The identical analysis was also performed on the raw scores and a similar pattern of results was obtained. The Group \times Condition interaction for the raw scores was $F(1,44) = 10.26, p = .003$. In addition, a significant main effect for condition was obtained [$F(1,44) = 240.13, p < .0001$]. This condition effect was a function of better performance during unimanual versus bimanual trials [M for unimanual = 13.05; M for bimanual = 10.48].

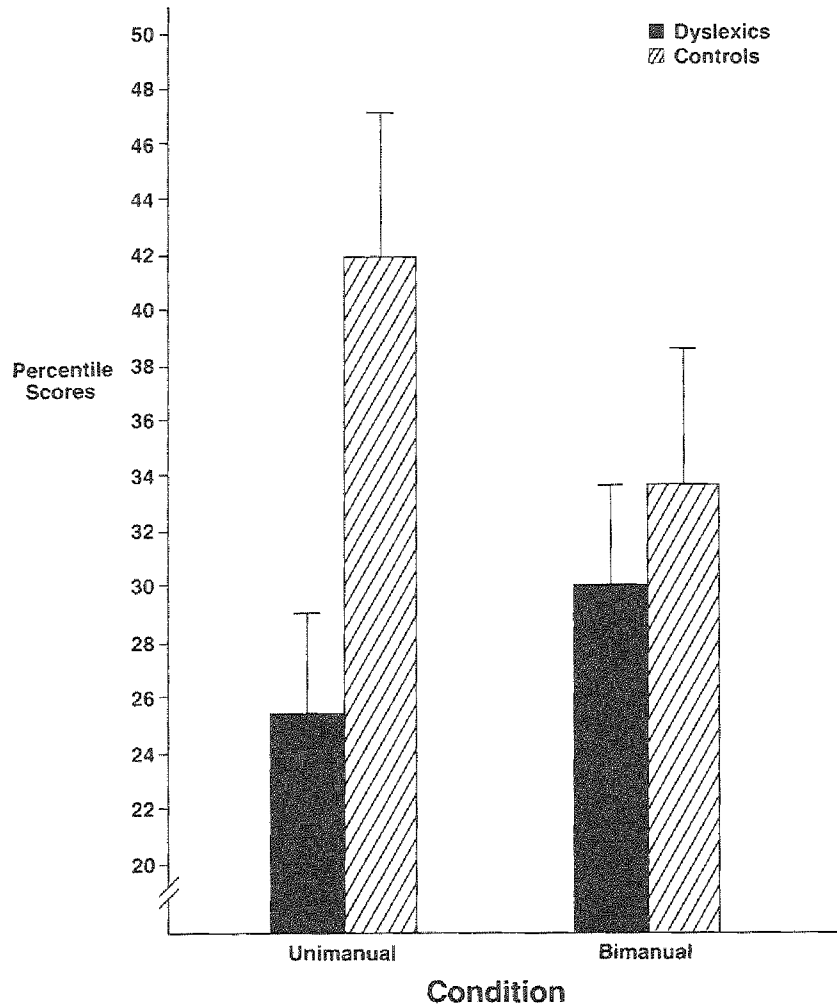


FIG. 3. Mean percentile scores for dyslexics and controls for unimanual (i.e., average of left and right hand conditions) and bimanual conditions.

On the unimanual tasks, the controls showed better performance compared with dyslexics ($p < .01$) while on the bimanual task, no group difference was observed.

Pearson product-moment correlations based on the percentile scores were computed among the three Purdue conditions for each group separately. For the control group, these correlations were all high and positive, ranging in value from 0.63 to 0.83. It appears, therefore, that performance in all three conditions is highly interrelated for this group. Interestingly, a different pattern of correlation among the three conditions emerged for the dyslexic sample. Specifically, the correlation between the two unimanual conditions was high and positive (.54), similar to that obtained in controls. However, the relations between each unimanual condition and the bimanual condition were low and nonsignificant (dominant with bimanual = .28; nondominant with bimanual = .30) (see Table 2). When the difference in correlation between each pair of conditions for the dyslexics versus controls was tested, we found, as expected, no significant

TABLE 2
PEARSON PRODUCT-MOMENT CORRELATIONS BETWEEN CONDITIONS, SEPARATELY BY GROUP
BASED UPON PERCENTILE SCORES

	Dominant	Nondominant	Bimanual
	Dyslexics		
Dominant		.535	.281
Nondominant			.296
	Controls		
Dominant		.676	.627
Nondominant			.832

difference in the correlation between the two unimanual conditions for dyslexics versus controls. A significant difference, however, did emerge between the two groups for the bimanual versus nondominant correlation ($Z = 2.80, p < .01$). The correlational data indicate that the relation between the bimanual and unimanual conditions differs depending upon whether the subject is a dyslexic or a control. Pearson product-moment correlations based on the raw scores were also computed and the results were almost identical to those obtained using percentile scores (see Table 3).

DISCUSSION

This study uncovered three important new findings: (1) disabled readers perform comparably to normal controls on the bimanual condition, but differ significantly in the unimanual conditions; (2) the largest between-group difference for both raw scores and percentiles is in the left hand condition; and (3) the pattern of correlations among the three task conditions differs between disabled and normal readers. Specifically, the bimanual condition was correlated weakly with the unimanual conditions among dyslexics whereas in the controls, all tasks were highly correlated.

TABLE 3
PEARSON PRODUCT-MOMENT CORRELATIONS BETWEEN CONDITIONS, SEPARATELY BY GROUP,
BASED UPON RAW SCORES

	Dominant	Nondominant	Bimanual
	Dyslexics		
Dominant		.529	.294
Nondominant			.293
	Controls		
Dominant		.671	.612
Nondominant			.843

The data from this study are consistent with theories arguing for left hemispheric dysfunction in dyslexics (e.g., Gordon, 1980; Rudel, in press) and models proposing interhemispheric transfer deficits (e.g., Obrzut et al., 1981). The fact that dyslexics perform worse than controls in the right hand condition is suggestive of the left hemispheric dysfunction. This suggestion is based upon data implicating the left hemisphere motor region in the control of fine manual dexterity and planned sequential action (e.g., Geschwind, 1975; Heilman, 1979; Kimura, 1977; Kimura & Archibald, 1974), skills which are utilized in Purdue Pegboard performance. Deficits in the left hand condition among the dyslexics could also arise from left hemisphere dysfunction. Left hand performance may be affected by left hemisphere processing either through commissural pathways or through direct ipsilateral connections. To the extent that the executive controls for left hand fine manual action are initiated by the left hemisphere and then sent to right hemisphere regions directly involved in the control of the left hand, the deficit in this condition in the dyslexics compared with controls may be a function of an interhemispheric transfer problem. The fact that the group difference for both raw scores and percentiles was largest for the left hand condition argues for more than just left hemisphere dysfunction. If unimanual performance with either hand was simply a function of left hemisphere processing, comparable dyslexic deficits should be observed in both. Our raw score data indicate that dyslexics are significantly worse in the left versus right hand condition while controls show no difference between these conditions.

Our finding that the two groups show no difference in the bimanual condition may be a function of the fact that dyslexics utilize a different strategy to perform this task compared with the unimanual tasks. This interpretation is based upon the different pattern of correlations between the unimanual and bimanual tasks observed in each of the groups (see Tables 2 and 3). These correlational data indicate that performance in the unimanual and bimanual tasks for the dyslexics is relatively independent while in the controls, performance on all tasks is highly intercorrelated. Some investigators have suggested that the bimanual task requires interhemispheric communication and have implied that the left hand condition does not. The fact that performance in the bimanual condition did not differ between dyslexics and controls cannot be interpreted as evidence against the hypothesis of interhemispheric transfer differences between the groups, since the pattern of correlation among tasks differs as a function of group. These findings also underscore the widespread clinical belief that isolated summary measures of performance in and of themselves are insufficient to draw inferences about underlying processing styles, strategies, and/or their concomitant neural substrates. In the data we present, the different pattern of subtest correlation between the two groups strongly suggests that while performance on the bimanual task

may not have differed between the groups, they clearly accomplished the task in different ways. The specific underlying hemispheric mechanism associated with bimanual task performance among the dyslexics must await future studies where this issue is examined more directly.

Two additional issues are raised by these data which are noteworthy. Other investigators who have examined Purdue performance in dyslexics versus controls have not reported the pattern of differences which we present here (e.g., Gardner & Broman, 1979). We believe that this inability to detect more subtle differences in the patterning among conditions between dyslexics and controls may arise from a failure to isolate a relatively homogeneous group of disabled readers. Many workers have commented on the critical need to subtype dyslexics in order to investigate neural dysfunctions (e.g., Denckla, 1977; Doehring et al., 1979; Mattis et al., 1975; Mattis, 1978) since it is reasonable to assume that different dyslexia subtypes will be associated with different patterns of brain function. We believe that this is the first study to investigate Purdue Pegboard performance in a very carefully selected, homogeneous group of disabled readers and controls.

The more subtle features of task performance which we found to differentiate between dyslexics and controls raises a related methodological point. A voluminous literature exists which reports overall task differences between dyslexics and controls. We believe that with more careful selection criteria, features of task performance may be revealed which are more specifically indicative of particular parameters of neural function rather than nonspecific indices of gross performance deficits. Our major findings were Group \times Condition interactions. We propose that interactions of this nature will be much more informative in furthering knowledge of brain mechanisms associated with reading disability.

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