Dyslexia and Dysgraphia: More Than Written Language Difficulties in Common

David S. Mather

Abstract

A dual-task paradigm involving concurrent finger tapping and line orientation judgment was used to investigate brain processing differences in early adolescent good readers/poor spellers (dysgraphia), poor readers/poor spellers (dyslexia) and good readers/good spellers. Whereas all groups were similarly affected during the left-hand tapping condition, in the right-hand tapping condition the good spelling group displayed significantly less tapping disruption than both poor spelling groups, who did not differ significantly from each other. From these results, it can be inferred that individuals with dyslexia and dysgraphia share a left-hemisphere processing limitation that is not confined to written language. In light of other relevant research findings, I suggest that this limitation is due to the absence of a disembedding scanning mechanism for converting spatial arrays (e.g., spelling patterns) to temporal form—an impairment putatively caused by attempting to teach written language to children who are late in establishing left-hemisphere motor dominance.

Dual-task time-sharing procedures have been used to infer cerebral lateralization of verbal and nonverbal activities (Hellige & Longstreth, 1981; Kinsbourne & Hiscok, 1983). Commonly, these procedures involve tapping with one hand while performing verbal or spatial tasks, such as reading aloud from unfamiliar text or solving nonverbal block design problems (e.g., Hellige & Longstreth, 1981). Tapping interference is taken as indicating that the hemisphere on the opposite (contralateral) side of the performing hand is involved in the dual processing of both tasks.

Stellern, Collins, Cossairt, and Gutiérrez (1986) adopted this paradigm to investigate the hemispheric specialization of First Nations children. The Judgment of Line Orientation Test (JLOT; Benton, Varney, & Hamsher, 1978) was employed because studies of unilateral brain disease had found it to be a strong measure of right-hemisphere integrity (Benton, Hannay, & Varney, 1975; Poizner, Klima, & Bellugi, 1987). Stellern et al. (1986) were interested in investigating the possibility that First Nations students process spatial tasks in the left hemisphere (LH) in view of studies suggesting unusual right-hemisphere (RH) involvement in language processing in this culture (e.g., Rogers, Ten Houten, Kaplan, & Gardiner, 1977). Among other findings, a post hoc comparison showed that performance on the reading, spelling, and arithmetic subtests of the Wide Range Achievement Test (WRAT; J. Jastak, Bijou, & Jastak, 1978) predicted which hand experienced the greater tapping disruption during concurrent JLOT performance. Of high WRAT performers, 26 out of 27 demonstrated left-hand (i.e., RH) interference, whereas 17 out of 21 low WRAT performers demonstrated right-hand (i.e., LH) disruption. The distinction between high and low WRAT performance was based on scoring above or below a standard score of 95 on at least two of the WRAT math, reading, or spelling subtests (see Note 1).

One possible explanation of the findings by Stellern et al. (1986) comes from the speculation that hemispheric specialization for nonverbal tasks occurs by default, in consequence of language development in LH space (LeDoux, Wilson, & Gazzaniga, 1977). From this perspective, the left-hand (i.e., RH) tapping interference experienced by the high WRAT performers would signify the typical LH-RH default condition, whereas the low WRAT performers’ right-hand interference would imply incomplete LH language specialization, with consequent LH availability of functional space for JLOT processing. Such LH availability is consistent with evidence of bitemporal representation of spatial function in developmental dyslexia (Witelson, 1977). It is also in keeping with research indicating that poor readers who are poor spellers (i.e., individuals with dyslexia) and good readers who are poor spellers (i.e., individuals with dysgraphia) both show deficits in orthographic processing (Holmes & Ng, 1993; Maul & Ehri, 1991; Seymour, 1987). That is, an orthographic (spelling) deficit may be accompanied by an LH efficiency for nonverbal tasks requiring similar attention to detail (see

In the present study, this default hypothesis was tested by using the concurrent tapping/line orientation procedure with three groups of White early adolescents differing in spelling ability: good readers/good spellers (GRPS), good readers/poor spellers (GRPS), and poor readers/poor spellers (PRPS). It was predicted that concurrent right-hand tapping disruption would be similar for both poor spelling groups (GRPS and PRPS) and significantly higher than that of the good spelling group (GRPS) and, further, that concurrent left-hand tapping would be disrupted only in the GRPS group.

Method

Participants

Twelve good readers/poor spellers (GRPS), 12 poor readers/poor spellers (PRPS), and 12 good readers/good spellers (GRPS), ages 11-4 to 14-6, were selected from six schools located in Victoria, BC, Canada. All were White; all 12 PRPS group members were boys. There were 5 boys in the GRPS group and 3 in the GRPS group. Teacher reports and psychoeducational assessments served to screen out participants whose academic deficit may have resulted from neurological, medical, socioeconomic, or emotional factors. Only right-handed participants were used, as identified by questions adapted from the Edinburgh Inventory (Oldfield, 1971) in accordance with a dual-task study of handedness and speech lateralization conducted by Orsini, Satz, Soper, and Light (1985). Passage comprehension and spelling substests from the Woodcock-Johnson Psychoeducational Battery (Woodcock & Johnson, 1977) were used to establish reading and spelling levels consonant with the following criteria:

PRPS—reading and spelling at least 2 years below grade level;
GRPS—reading at or above grade level while spelling at least 2 years below grade level;
GRPS—reading at or above grade level while spelling at least 2 years above either grade or reading level.

Table 1 lists the means and standard deviations for age, reading, spelling, and grade level for the three groups. The mean reading score of the PRPS group was significantly less than that of the GRPS group, \( t(22) = 72.6, p < .0001 \). The difference between the PRPS and GRPS spelling scores was also significant, \( t(22) = 24.4, p < .0005 \). Thus, although both groups were poor spellers, PRPS participants were more so—a result consistent with the findings of Frith (1980) and Jorm (1981). In comparison to the GRPS, the GRPS group did not differ in reading, \( t(22) = .10, p > .50 \), but scored significantly lower in spelling, \( t(22) = 142.8, p < .0001 \). This result is in agreement with previous research findings that the spelling deficiencies of adolescent GRPS participants do not affect reading comprehension (Bruck & Winters, 1988; Frith, 1980; Maul & Ehri, 1991).

Materials

The Judgment of Line Orientation Test (JLOT; Benton et al., 1978) was used to assess lateralization effects of visuospatial processing. This test examines the ability to estimate angular relationships between line segments by visually matching angled line pairs to 11 numbered radii forming a semicircle (see Figure 1). The test consists of 30 items, each showing a different pair of angled lines. Its two forms, H and V, present the same items, but in a different order.

Tapping was counted using a Gerbrands Model 1271-F recorder consisting of a 3-mm diameter button-switch mounted in a 4 × 2 × 1 inch box.

Procedure

The JLOT is usually administered as an untimed test with accuracy of line orientation as the measure of performance. However, to effectively measure the interference of this task with tapping rate, it was important to present the cards as quickly as they could be processed. Pilot tests demonstrated that this could be accomplished by mounting the alternate forms, H and V, side by side in an 11 × 14-inch four-ring binder. This procedure permitted a new design to be displayed while the participant was solving the adjacent one. In this manner, there was no interruption in JLOT task performance from delays in the sequencing of card presentation.

Each child was tested individually by the same experimenter. Tapping duration for all trials was 15 seconds. After 3 seconds of finger tapping practice, baseline single-task finger tapping rate was determined for each hand. The recorder was positioned so that the

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Means and Standard Deviations for Demographic Variables by Group</strong></td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>M</td>
</tr>
<tr>
<td>Chronological age</td>
</tr>
<tr>
<td>Reading grade level</td>
</tr>
<tr>
<td>Spelling grade level</td>
</tr>
<tr>
<td>Enrolled grade level</td>
</tr>
</tbody>
</table>

Note. PRPS = poor readers/poor spellers; GRPS = good readers/poor spellers; GRPS = good readers/good spellers.

\(^{a}n = 12\).
In the single-task tapping, the participant was instructed to tap with the index finger as rapidly as possible. In the JLOT task, the participant was told to perform as accurately as possible. Instructions for the dual-task condition emphasized equally the tapping and JLOT tasks. In all trials, the participants were required to identify correct line choices by number, and the answers were tape-recorded for error analysis.

The degree to which tapping rate or JLOT solution rate was disrupted by the concurrent task was represented by the difference between the right-hand percentage decrement and the left-hand percentage decrement. This was derived from the following formula for each hand:

$\frac{[B-P]}{B} \times 100$,

where $B$ is the baseline performance (number of taps or lines judged), and $P$ is the dual-task score. This measure of decrement has been found to be relatively independent of tapping baseline rate (Kinsbourne & Hiscock, 1983).

### Results

#### Tapping Rate

Baseline tapping performance (i.e., the number of taps with the right and left hands without concurrent JLOT activity) was analyzed in a 3 (GRGS vs. GRPS vs. PRPS) x 2 (hand) analysis of variance, with repeated measures on the second factor. This yielded a single main effect for hand, $F(1, 33) = 62.88$, $p < .001$. Paired t-test analysis showed that in each case the mean right-hand baseline tapping rate of each group was significantly higher than that of the left hand (see Table 2).

Table 3 lists the means and standard deviations for the JLOT tapping decrement scores. A 3 (GRGS vs. GRPS vs. PRPS) x 2 (hand) analysis of variance, with repeated measures on the second factor, was used to compare JLOT interference effects between and within groups. The results indicated a significant interaction between groups and

---

**TABLE 2**

<table>
<thead>
<tr>
<th>Group</th>
<th>Hand</th>
<th>Baseline tapping rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>PRPS</td>
<td>Right</td>
<td>66.83</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>59.58</td>
</tr>
<tr>
<td>GRPS</td>
<td>Right</td>
<td>68.75</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>57.00</td>
</tr>
<tr>
<td>GRGS</td>
<td>Right</td>
<td>71.00</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>61.75</td>
</tr>
</tbody>
</table>

*Note:* PRPS = poor readers/poor spellers (dyslexia); GRPS = good readers/poor spellers (dysgraphia); GRGS = good readers/good spellers.

$^*p < .001$. $^**p < .001$
hand trials, \(F(2, 33) = 4.40, p < .027\). Probes of this interaction showed that the GRGS mean right-hand tapping interference score (\(M = 3.00\)) was, as predicted, significantly lower than the GRPS mean, \(M = 9.83, t(11) = 15.27, p < .005\), and the PRPS mean, \(M = 12.08, t(11) = 13.50, p < .005\). There was no significant difference between PRPS and GRPS right-hand tapping interference means, \(t(11) = 0.72, p > .20\). These results support the hypothesis that GRGS differs from both GRPS and PRPS in LH processing of line orientation judgment, as inferred from dual-task interference effects.

Unexpectedly, however, there was no significant difference among the left-hand tapping decrement means of any of the three groups. Also, in contrast to the results obtained by Stellern et al. (1986), the GRGS participants in this study did not demonstrate left-greater-than-right interference. Instead, the GRGS group showed no significant between-hand difference in interference, \(t(11) = .66, p > .20\), in contrast to the difference observed with the GRPS group, \(t(11) = 3.67, p < .005\), and the PRPS, \(t(11) = 2.12, p < .05\), groups. These findings provide no support for the hypothesis that visuospatial processing is lateralized to the RH by default.

**Line Orientation Processing Rate**

A 3 (GRGS vs. GRPS vs. PRPS) \(\times\) 2 (hand) analysis of variance, with repeated measures on the second factor, was used to determine whether one hand interfered more than the other on the rate of JLOT processing. No significant effects were found.

**Line Orientation Processing Accuracy**

Correct response on the JLOT was evaluated by a 3 (GRGS vs. GRPS vs. PRPS) \(\times\) 3 (left-hand vs. right-hand vs. no tapping) analysis of variance, where the repeated measures included line judgment errors without concurrent tapping or with left- or right-hand tapping. This analysis yielded two significant effects. The main effect for group, \(F(2, 33) = 3.45, p < .044\), was attributable largely to the higher performance of the GRGS group under concurrent right- and left-hand tapping conditions. The main effect for condition (left-hand tapping vs. right-hand tapping vs. no tapping), \(F(2, 33) = 8.14, p < .001\), reflects a differential effect of left-hand tapping on JLOT correct responses across groups. Paired \(t\)-test

### Table 3

<table>
<thead>
<tr>
<th>Group</th>
<th>Hand</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRPS</td>
<td>Right</td>
<td>12.08</td>
<td>8.14</td>
</tr>
<tr>
<td>PRPS</td>
<td>Left</td>
<td>6.58</td>
<td>7.57</td>
</tr>
<tr>
<td>GRPS</td>
<td>Right</td>
<td>9.83</td>
<td>5.20</td>
</tr>
<tr>
<td>GRPS</td>
<td>Left</td>
<td>4.25</td>
<td>4.75</td>
</tr>
<tr>
<td>GRGS</td>
<td>Right</td>
<td>3.00</td>
<td>2.70</td>
</tr>
<tr>
<td>GRGS</td>
<td>Left</td>
<td>4.25</td>
<td>4.11</td>
</tr>
</tbody>
</table>

*Note.* PRPS = poor readers/poor spellers; GRPS = good readers/poor spellers; GRGS = good readers/good spellers.

\(n = 12\).
analyses showed significant interference effects only for the left hand in the GRPS, t(1, 11) = 6.77, p (2-tailed) < .05; the PRPS, t(1, 11) = 9.48, p (2-tailed) < .05; and the GRCS, t(1, 11) = 5.04, p (2-tailed) < .05; groups. These data indicate that the contrast in right-hand tapping performance between good and poor spellers cannot be accounted for by trade-offs in the ability to correctly respond to the line orientation task. That is, there is no evidence that the GRCS group sacrificed the accuracy of their JLOT performance in order to minimize right-hand tapping interference. The data also suggest that JLOT responses in the poor spelling groups involved a degree of RH processing not dissimilar to that of the good spelling group.

Discussion

As anticipated, spelling rather than reading impairment predicted right-hand tapping disruption during a concurrent line orientation judgment task. By implication, this could also have been the case with the right-hand interference observed by Stellem et al. (1986) in First Nations students deficient in at least two unspecified subtests of the WRAT. Unexpectedly, however, the good readers/good spellers (GRCS) in the present study did not demonstrate the same left-hand interference observed by Stellem et al. in their high-performing students. Instead, the left-hand tapping decrement of the GRCS group was not significantly different from either their own right-hand score or the left-hand score of the poor spelling groups. Similar bilateral asymmetrical interference was found in a study of White average readers (Grades 2–5) that used a modified version of the JLOT (Hiscock, Antoniuk, Prisciak, & von Hessert, 1985). The reason for this cultural difference is unclear. Perhaps there was a relative inattentiveness on the part of White participants with this visuospatial task. For example, McShane and Plas (1984) noted that “the ability of WISC-R performance scale subtests to predict achievement gains in such verbally-oriented areas as reading and language, may represent an over-utilization of spatial processing strengths on the part of [American] Indian children” (p. 64).

If visuospatial processing does occur in the RH by default, as LeDoux et al. (1977) speculated, it is not apparent in the present group of White participants using this dual-task procedure. Instead, the GRCS group's bilaterally equal interference observed in this study, and in that by Hiscock et al. (1985), suggests that both the LH and the RH normally participate in JLOT processing. This eventuality is consistent with several studies that have attempted to determine the separate contributions of the two hemispheres in solving this task (Kim, Morrow, Passafiume, & Bolier, 1984; Gur et al., 2000; Mehta & Newcombe, 1991; Mehta, Newcombe, & Damasio, 1987; Ng et al., 2000).

The present experiment controlled for age, ethnic origin, and handedness, but not for gender, as the numbers of boys in each group were highly unequal (12 PRPS, 5 GRPS, and 3 GRCS). However, it is unlikely that this difference was a significant source of variation, because the group contrasts in gender distribution predict that the JLOT performance of the GRPS group should be closer to that of the GRCS group than that of the PRPS group. That is, the PRPS group consisted entirely of boys, whereas a majority of girls were present in both of the other groups. Furthermore, Hiscock et al. (1985), studying good readers in Grades 2 to 5, found that boys performed more accurately than girls in a dual-task line orientation judgment experiment, and with significantly less disruption in tapping. These effects are in the opposite direction to those encountered in the present study.

How, then, to explain the right-hand tapping disruption of the poor spelling groups during dual-task processing? To begin with, Eden, Stein, Wood, and Wood (1996) found that the incidence of reversed scanning (right to left rather than left to right) of JLOT stimuli by Grade 5 students with reading disabilities was related to low performance on this task. Right-to-left scanning is more typical of RH than of LH oculomotor control (Girotti, Casazza, Musico, & Avanzini, 1983; Ogden, Mateer, & Wyler, 1984) and, congruently, line orientation processing by individuals with dyslexia disproportionately favors the RH (Rumsey et al., 1987; Shaywitz et al., 1998) and underactivates LH frontal areas (Rumsey et al., 1987). Moreover, LH frontal lesions impair JLOT processing (Kim et al., 1984), consistent with the importance of anterior brain regions for visual scanning (Luria, 1966). Thus, although the poor spellers in the present study showed no deficits on the JLOT task, LH processing (scanning) may have been more effortful or less automatic (see Wiersma & Wijnamaaen, 1991), indirectly interfering with right-hand tapping. This explanation is consistent with the observation of Hiscock et al. (1985) that “children appear to ‘protect’ their nonmanual performance at the expense of their performance on the tapping task” (p. 44).

The idea that atypical scanning may have something to do with faulty spelling receives added support from a variety of convergent sources. First, in Eden et al.’s (1996) study, reversed (i.e., right-to-left) JLOT scanning by Grade 5 children correlated negatively with reading level (see Note 2). Concordantly, reading deficiency and academic delay has been shown to be associated, respectively, with less orderly left-to-right scanning of pseudowords (Schwantes, 1979) and unsystematic scanning of nonverbal stimuli (Locher & Worms, 1981). As Morrison and Manis (1982) concluded in an integrative critique of reading disability research, “deficits appear to be most pronounced in tasks requiring rapid scanning, encoding, and rehearsal of multiple-stimulus arrays, whether the arrays are composed of verbal or nonverbal stimuli” (p. 85).

Second, First Nations elementary school low achievers have been found

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
sively researched model of skilled reading, at the heart of which is a scanning mechanism that uses orthographic knowledge, gained from reading practice, to convert written language from spatial to temporal form. In less skilled readers, this orthographic learning process appears to be absent, precluding comparable scanning efficiency (Butler, Jared, & Hains, 1984).

Collectively, the foregoing evidence supports the view that individuals with dyslexia (PRPS) and dysgraphia (GRPS) have a print-scanning deficit in common. This conclusion is in harmony with research indicating that poor spelling accompanied by good reading comprehension is a milder form of developmental dyslexia (Bruck & Waters, 1988, 1990; Burden, 1992; Newman, Fields, & Wright, 1993; see also Gallagher, Laxon, Armstrong, & Frith, 1996). Bruck and Waters (1988) found this to be particularly so for the mis-spellings of participants of about the same age (early adolescence) as the present study, which is of some interest in light of the evidence that spelling, more so than reading difficulty, appears subject to genetic influences at this age (DeFries, Alarcón, & Olson, 1997). Putatively, then, early adolescence may be the developmental stage at which the products of an LH scanning faculty (e.g., orthographic representations of written words; Mewhort & Campbell, 1981) are fully internalized (see Posner & McCandliss, 1999), just as the development of other visuospatial skills is prolonged in childhood (e.g., Moulden, Viviani, Hauert, & Guyon, 1985). This would be in keeping with evidence that between the ages of 10 and 12, for good but not for poor spellers, there is a transition from a reliance on spelling by sound to a reliance on spelling with the aid of stored orthographic representations (Marsh, Friedman, Welch, & Desberg, 1980; Nolen & McMartin, 1984; Smith, 1992). Thus, the link between spelling difficulties and heritability in early adolescence (DeFries et al., 1997) may be rooted in an unreadiness to adopt an orderly left-to-right scanning strategy during the beginning stages of learning to read. Consistent with this possibility, Gordon (1980, 1988, 1989) has argued that a majority of individuals with dyslexia have a genetically mediated predisposition for RH processing, and Mather (2001) has suggested how this may result in forms of letter learning that preclude the use of a spatiotemporal scanning mechanism for abstracting orthographic rules.

The preceding account, although speculative, is important because it provides an explanation for why some beginning readers have great difficulty learning to scan consistently in a left-to-right direction (McGuinness, 1997). Although it appears that saccadic directionality is trainable (Clay, 1972, 1985), for RH-dominant children, it may be the wrong hemisphere that is trained, as either hemisphere is capable of learning rightward saccades (Aschoff, 1974). Such mislearning could prevent a shift to LH scanning control that, given time, would occur naturally (Aaron & Handley, 1975). This possibility is compatible with evidence that between the ages of 5 and 7, when reading is normally taught, maturational delay predicts subsequent reading difficulties (Fletcher & Satz, 1980; Jansky, 1978; Satz, Taylor, Frield, & Fletcher, 1978). For example, children in this age range who are better at suppressing associated movements (e.g., symmetrical or mirror-image movements of the hands) also do better academically (Blondis, Snow, & Accardo, 1990; Wolff, Gunnoe, & Cohen, 1985). Furthermore, such inhibitory control also correlates with superior performance in disembedding figures (Todor & Lazarus, 1986), a task that is analogous to disentangling lines on the JLOT (Mehta & Newcombe, 1991), is poorly performed by individuals with reading impairment (Elkind, Larson, & van Doornick, 1965; Lovell, Gray, & Oliver, 1964), and involves independent contributions from both cerebral hemispheres for best results (Russo & Vignolo, 1967; E. Zaidel, 1973). Together, these findings suggest that as-
sociated movement suppression, which even in adolescence differentiates individuals with and without reading disabilities (Kliepera, Wolff, & Drake, 1981), is a marker of LH motor (e.g., scanning) dominance (Denckla, 1973, 1974)—a developmental event that may be delayed in children prone to develop reading and spelling disorders. For example, Denckla (1985) observed that 6- to 8-year-olds at risk for dyslexia had difficulty performing pantomimes with the left hand in response to a verbal command—a finding indicative of a problem in callosally transferring motor commands from the LH to the RH (Risse, Gates, Lund, Maxwell, & Rubens, 1989; D. Zaied & Spery, 1977).

Convergent support for this dysmaturation perspective comes from studies that have investigated specific reading disability within a Piagetian framework. Given that Piagetian conservation responses and high reading scores of 6- to 8-year-olds have been found to be related to electroencephalographic measures of hemispheric integration (Kraft, Mitchell, Languis, & Wheatley, 1980), it is reasonable to suppose that maturational differences in hemispheric integration also lie behind the association between reading skill and Piagetian tasks observed by other investigators (e.g., Arlin, 1981; Lunzer, Dolan, & Wilkinson, 1976; Speece, McKinney, & Appelbaum, 1986; Turner, Herriman, & Nesdaie, 1988; see Note 4). Kraft (1976), in noting that the LH of her high reading/conservation participants was superior in tapping RH visuospatial knowledge, suggested that Piaget's cognitive stages behaviorally index the maturing of neural communication between the two hemispheres. From this perspective, the reason why individuals with dyslexia persist in using perceptual strategies characteristic of RH processing (e.g., Blank, Berenzweig, & Bridger, 1975; Guyer & Friedman, 1975; Kershner, 1975; Klee & Lebrun, 1972) may be that they are maturationally incapable, when first introduced to written language, of callosally relaying this information for LH processing (see Mather, 2001; Simos et al., 2002).

This conception can account for the behavior, observed by Elkind and Weiss (1967), of second-grade children with reading impairment perseverating with a left-to-right (local) visual scan of a triangular array of objects, instead of exploring it in accord with its hierarchical (global) triangular property, as did their unimpaired peers. Apparently, the children with reading impairment lacked the global framework or preview that the RH typically provides for subsequent LH local processing (e.g., Robertson & Lamb, 1991; Sergent, 1982) and, thus, were arguably locked into RH processing. In line with this premise, the eye movements in one subtype of dyslexia are overly involved in local processing during reading (De Luca, Di Pace, Judica, Spinelli, & Zoccolani, 1999; Pirozzolo & Rayner, 1988) with a tendency to scan from right to left (Pirozzolo & Rayner, 1988) that is suggestive of RH oculomotor control. The difference between individuals with dyslexia and individuals with dysgraphia may then be that maturational or instructional factors allowed the latter to disengage from RH oculomotor control in order to callosally tap RH global processing—a hypothesis that is consistent with the tendency that good readers/poor spellers have of neglecting the interior of words (Holmes & Ng, 1993).

Before concluding, it is important to take note of evidence that situates the development of a scanning or disembedding function in a wider context. As might be anticipated from the analysis thus far, research with schoolchildren, nonliterate (unschooled) adults, and literate persons who became so in adulthood has shown that disembedding skill does not develop spontaneously but rather depends on instruction or experience usually gained in primary school (Kolinsky, Morais, Content, & Cary, 1987; Kolinsky et al., 1990). However, there is some evidence to suggest that it also develops in unschooled individuals such as lace makers and seamen navigating in starlight (Kolinsky et al., 1990). The relevance to the present study is that in a carefully selected group of children with dyslexia (above-average intelligence and free from social or medical risk factors for learning disorders), about 25% were found to come from families in which a generational history of learning disabilities was accompanied by a facility for spatial visualization: “Something one might call ‘visual excellence’—architects, weavers who could remember a pattern after seeing it once, television lecturers who never need to use a teleprompter since one just ‘calls up the page in memory’ if needed” (Symmes, 1972, p. 62). Assuming that weaving and architecture, like lace making and celestial navigation, require efficacious LH scanning, an important question is whether the development of such visuospatial talents is compatible with the dedication of this disembedding faculty to the spelling process (see Martino & Winner, 1995; Winner & Casey, 1992; see Note 5).

To sum up, this study demonstrated that individuals with dyslexia (PRPS) and dysgraphia (GRPS) differed from controls in not being able to maintain right-hand tapping performance while judging the spatial orientation of lines. As no similar left-hand tapping disruption was observed, it can be inferred that this difference is restricted to LH processing—an assumption that is consistent with brain mapping studies of line orientation judgment. Evidence from a variety of related research was cited in support of the hypothesis that this LH processing limitation resulted from the absence of a scanning mechanism for disembedding, encoding, and rehearsing visual patterns (e.g., words)—hypothetically due to introducing written language prematurely to children late in developing LH motor dominance. Presumably, these would include children with early language delay who experience reading failure despite early speech and language interventions (Bishop & Edmundson, 1987; Padget, 1988) as well as children genetically
at risk for literacy problems (e.g., Gallagher, Frith, & Snowling, 2000). For these populations, the readiness for alphabetic writing should coincide with an absence of right-hand disruption during line orientation judgment. This prediction remains to be tested.

ABOUT THE AUTHOR

David S. Mather, PhD, is independently involved in dyslexia research and learning disability remediation. He received his PhD from the University of Victoria, Victoria, British Columbia, Canada. Address: David S. Mather, 2402 S. Otter Bay Road, Pender Island, BC V0N 2M1, Canada; e-mail: dmather@yahoo.com

NOTES

1. On the Wide Range Achievement Test-Revised (WRAT-R; S. Justak & Wilkinson, 1984), this cutoff probably would have approximated a standard score of 85 (Stevenson, 1990).

2. In this study, and in other studies cited, poor readers are presumed to be poor spellers, as no exception to this rule seems to have been reported in the English language (Joshi & Aaron, 1991). Thus, Bruck and Waters (1988), in a study of 343 Grade 3 children and 357 Grade 6 children, failed to find any good spellers/poor readers (noted in Bruck & Waters, 1990).

3. Within a Piagetian framework, difficulty in discriminating between mirror-image letters (e.g., b/d) is a Euclidean error but a topological success and may flag a developmental need for further exploration of topological space before tackling Euclidean representations (Friedland & Muesel, 1975). This line of thinking is particularly relevant in light of evidence that topological discrimination is characteristic of RH processing (Franco & Spery, 1977).

4. In view of the current emphasis on the teaching of phonological awareness, it is important to note that Tunmer et al. (1988) found improvement in this ability during the first year of school to be significantly correlated with preschool skills at solving Piagetian tasks.

5. The present study is not alone in being informed by research on spelling outside the context of written language. Other studies include the follow-up of preschool children with expressive phonology disorders (Levis, Freiberg, & Taylor, 2000a, 2000b), the comparison of sensory temporal processing in average and above-average readers (Aiu & Lovegrove, 2001), the examination of laterality in schoolchildren (Kraft, 1985; Kraft & Burger, 1986), and the cognitive profiling of individuals excelling in art and mathematics (Martino & Winner, 1995; Winner & Casey, 1992).

REFERENCES


Eisenberg, L. (1966). The epidemiology of reading retardation and a program for


Seymour, P. H. K. (1987). Developmental dyslexia: A cognitive experimental analysis. In M. Coltheart, G. Sartori, & R. Job (Eds.), The cognitive neuropsychology of lan-


