

DUAL-TASK INTERFERENCE EFFECTS IN EARLY ADOLESCENTS  
WHO DIFFER IN READING AND SPELLING ABILITIES

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### ABSTRACT

Few studies have investigated the differences between poor readers/poor spellers (SRD) and good readers who demonstrate unexpectedly poor spelling skills (SSD). Those that have done so have been mainly concerned with searching for psycholinguistic similarities and differences. This dissertation project is believed to be the first comparison of the two disorders on a task that did not involve the use of alphanumeric stimuli.

From a review of neuropsychological and language arts research into reading and spelling failure, it was hypothesized that both SSD and SRD might be differentiated from good reader/superior spellers (GRS) by their responses to a line orientation task which had been proven to be a valid indicator of right hemisphere function. A previous study had found that this task, presented concurrently with right or left hand tapping, discriminated between good and poor Native Indian readers (Stellern, Collins, Cossairt & Gutierrez, 1986). The theoretical underpinning of the current study suggested that these results may have been more closely related to spelling than reading ability.

Empirical support for this hypothesis was sought by comparing the performance of SSD, SRD and GRS early adolescents on the concurrent tapping-line orientation judgement task. The data supported this hypothesis in that the SSD and SRD groups differed from the GRS group in demonstrating

significantly more tapping interference in the right hand condition. Unexpectedly, however, all three groups performed similarly with respect to rate and accuracy in judging line orientation. As these results were ambiguous as to whether the right hand tapping interference experienced by the poor spellers was the result of differences in hemisphere processing of spatial stimuli, other possible explanations are considered in the discussion.

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## DEDICATION

Dedicated to Brian, Adam, Graham and Michael, whose giftedness motivated this project.

## Chapter I

### INTRODUCTION

Specific reading disability (SRD) and specific spelling disability (SSD) are terms which have been adopted to describe disorders of symbol processing that have yet to be explained. Specific reading disability, also referred to as dyslexia, has received a great deal of research attention over the past 50 years, usually aimed at uncovering an underlying genetic or constitutional explanation (see Aaron, 1989, for a recent review). In contrast, interest in SSD is fairly recent and is focused more on drawing comparisons between the spelling patterns of SRD and SSD in the hope of obtaining a better understanding of the underlying linguistic characteristics of both disorders (Bruck & Waters, 1988; Frith, 1980, 1985; Schwartz, 1983). The type of spelling disability exhibited by good readers/poor spellers (SSD) has been found to differ from that displayed by poor readers/poor spellers (SRD) both in the nature of the spelling disorder (Frith, 1980, 1985; Jorm, 1981) and of the underlying cognitive deficit (Naidoo, 1972; Nelson & Warrington, 1974). However, similarities have been observed in that both may be associated with poor handwriting skill (Share, Silva & Adler, 1987) and both may respond to remediation which emphasizes the motor patterns used in writing (Bradley, 1981).

Frith (1980) found that the major difference between good early adolescent readers who differed significantly in spelling skill was in the number rather than the type of errors. Frith described this difference as a breakdown at the level of

grapheme (letter) selection. While both groups produced phonologically intact misspellings, the unexpectedly poor spellers appeared to lack the mental store of visual representations of words which the good spellers called upon to select the correct letter when more than one could be used to represent a given sound (e.g. *their/there*). Sloboda (1980), from research with adults, arrived at a similar hypothesis: "... good spellers store information about which letters ... word contains whilst less good spellers store mainly information about which phonemes a word contains" (p. 246). Jorm (1981), in comparing SSD and SRD spelling patterns, of 10-year-old children, also concluded that SSD was characterized by difficulties at the grapheme selection stage but further observed that the phonological spelling accuracy of good reader/poor spellers exceeded that of poor readers. To make matters somewhat more complex, differences in phonological accuracy have also been observed in subtypes of poor readers (Boder, 1973; Sweeney & Rourke, 1978).

In attempting to account for the phonetically accurate but orthographically (visually) irregular spelling performance of poor readers, Sweeney and Rourke (1978) hypothesized that the fundamental problem may be "a deficit in the evocation of language-related visualizations" (p. 214). They also suggested that this may represent a left hemisphere deficit, recalling Luria's (1973) observations that lesions within the left parieto-temporo-occipital region in adults interfere with the production of visual images which prompt, or are prompted by, appropriate verbal labels. Thus both the Frith (1980) and Sweeney and Rourke studies suggested that phonetically accurate misspellings may represent a phoneme-grapheme visualization deficit common to both SSD and SRD subjects.

If Luria's observations apply, it may be that both groups differ from good reader/spellers (GRS) in left hemisphere processing of nonverbal visual stimuli. In other words, an absence of left hemisphere language-related visualization may be associated with the presence of atypical non-language-related visualization capacity. Evaluating this hypothesis is the focus of this dissertation.

The formulation of this study was influenced by the theoretical stance of Frith (1985) who hypothesized that SSD might be the consequence of prematurely learned strategies which had failed to merge with others learned in later phases of development (see Kirk, 1983, for a similar opinion). She also hypothesized that dyslexia may represent a developmental arrest in the learning of alphabetic skills, possibly due to a disorder of phonological awareness. From this perspective, a language-related visualization deficit may represent a failure to learn how to encode visual spelling patterns in the left hemisphere. An important question is whether this is due to a general visual encoding deficit or whether it is specific to alphanumeric symbols. The latter possibility is suggested by dual-task research which compared dyslexics and good readers/good spellers (GRS) on dichaptic stimulation tasks, requiring the identification of both meaningless shapes and letters presented simultaneously to each hand with sight occluded (Witelson, 1976). Witelson found that, for the haptic identification of nonsense shapes, dyslexics behaved as if they had two sight hemispheres. That is, while the two groups demonstrated comparable left hand (right hemisphere) performance, dyslexic right hand (left hemisphere) performance was significantly better than GRS from age 10 to age 14 (the upper test limit). With letters, a right hand (left hemisphere) advantage was obtained with GRS whereas the opposite pattern (left

hand-right hemisphere advantage) was found with dyslexics. This pattern was consistent from age 8 to the upper age test limit of 14 years. These results suggest that dyslexics differ from GRS in the manner in which they encode alphabetic stimuli and that this is not due to a general left hemisphere deficit in visualization.

Le Doux, Wilson, and Gazzaniga (1977) speculated that hemispheric specialization for nonverbal tasks occurs by default, in consequence of language development in left hemisphere space. From this perspective, Witelson's (1976) findings may imply a "default mechanism" deficit in dyslexia, one that may be related to deficiencies in the hemispheric encoding of alphabetic symbols and which may even be responsible for the posited developmental arrest in alphabetic learning skill (Frith, 1985).

Dual-task time-sharing procedures have been used to infer cerebral lateralization of verbal and non-verbal activities (Hellige & Longstreth, 1981; Kinsbourne & Hiscock, 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 & Longstretch, 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 Gutierrez (1986) used this paradigm to investigate the hemispheric specialization of Native American Indian children. They employed the Judgement of Line Orientation Test (JLOT) (Benton, Varney, & Hamsher, 1978) which has been demonstrated in studies of unilateral brain disease to be a strong measure of right hemisphere integrity (Benton, Hannay & Varnay, 1975; Poizner, Klima, Bellugi, 1987).

Stellern et al. expected that this procedure would provide inferential evidence that Native Indians process spatial tasks in the left hemisphere, in view of studies which have suggested that Native Indian languages require greater right hemisphere involvement in language processing (cf. Rogers, Ten Houten, Kaplan, & Gardener, 1977). Instead, in a post hoc comparison, they found that reading ability predicted which hand experienced the greater tapping disruption during concurrent JLOT performance. Over 95% of the good readers demonstrated left hand (right hemisphere) interference, whereas 80% of the poor readers demonstrated right hand (left hemisphere) disruption.

In this dissertation, the concurrent tapping - line orientation judgement procedure is used to evaluate the lateralization of spatial processing in Caucasian early adolescent SSD, SRD and control subjects with good reading and superior spelling skills (GRS). As the Stellern et al. (1986) study did not control for spelling ability, the present research should provide a clearer picture of the relationship between performance on this interference task and reading/spelling proficiency.

### 1.1 Purpose of the Study

The purpose of this study is to investigate whether SSD and SRD right-handed early adolescents demonstrate abnormal right hand tapping disruption when performing a line-orientation task that has been validated as a clinically useful indicator of right hemisphere impairment (Benton, Varney & Hamsher, 1978). In younger normal Caucasian reader/spellers (grades 2 to 5) this task has been found to disrupt left and right hand tapping performance equally, leading the investigators to suggest that it produces symmetrical hemispheric interference

(Hiscock, Antoniuk, Prisciak, & von Hessert, 1985). However, after the age of 10 there is a transition from a phonological stage, wherein words are spelled largely by sounding out their phonemic elements, to a visual-orthographic stage characterized by greater use of visual word patterns (Nolen & McCartin, 1984; Smith, 1992). In other words, at approximately 11 years of age, verbal labels appear to become amalgamated with visual word images (Ehri, 1980), a development that may depend on left hemisphere parieto-temporo-occipital function (Luria, 1973). Speculatively nonverbal spatial tasks, such as the JLOT, may be lateralized to the right hemisphere by default with the result that early adolescent GRS may demonstrate only left hand disruption while performing the JLOT. On the other hand if early adolescent SSD and SRD subjects demonstrate a right hand tapping decrement, such a finding would be compatible with Frith's (1985) hypothesis that spelling disability results from an arrest at a pre-orthographic stage of alphabetic learning. That is, a failure to develop orthographic representation may leave functional space in the left hemisphere for processing line orientation judgements.

## **1.2 Research Hypotheses**

The specific questions addressed in the study with 11 to 14 year old subjects are as follows:

1. Right hand tapping disruption resulting from a concurrent line orientation judgement task will be significantly greater for SSD and SRD as compared to GRS.

This question is exploratory in nature, designed to contribute to the understanding of underlying cerebral strategies related to spelling ability. In good

reader/spellers the line orientation judgement task could be expected to disrupt left hand tapping performance since this spatial task has been shown to be a robust indicator of right hemisphere integrity (Benton, Hannay & Varney, 1975). Right hand tapping disruption in poor spellers would therefore indicate atypical left hemisphere spatial processing that may be related to the difficulty these subjects have with correctly ordering the spatial components (i.e., letters) of words.

2. SSD and SRD right hand performance will not be significantly different on this task.

This question addresses the issue of whether the right hand tapping disruption during a line orientation judgement task (cf. Stellern, Collins, Cossairt, & Gutierrez, 1986) is related to reading ability. The theoretical underpinnings of this study (see Chapter II) suggest that any such interference is more likely to be related to spelling rather than reading dysfunction.

3. The right hand disruption differences will not be significantly related to either the rate or accuracy of performance on the line orientation judgement task.

This question addresses the issue of whether poor spellers will perform the non-manual line orientation judgement task at the expense of disruption on the manual tapping task. Hiscock et al. (1985) found this to be the case with children who were without deficits in the areas of reading or spelling.

### 1.3 Significance of the Study

This study grew out of the researcher's interest in whether the cause of dyslexia is constitutional, environmental, or a combination of both. Most neuropsychological research has been focused on uncovering an underlying genetic or constitutional explanation of reading disorders (see Aaron, 1989, for a recent review) in contrast to the psycholinguistic orientation of the far less prevalent SSD research. This study is designed to explore whether both SSD and SRD share a commonality which is relevant to spelling ability. If this hypothesis is validated, it may spark further neuropsychological research into the similarities and differences between SSD and SRD. It may also lead to more research emphasis on environmental-constitutional interactions since it is difficult to envision an innate neurological deficit, common to both SSD and SRD, that would compromise spelling but not reading.

### 1.4 Limitations of the Study

The dual task interference task, used in this study to infer cerebral processing differences, does not provide a direct measure of the neuronal substrates involved in the spelling process. For example, if this procedure is found to discriminate between the hemispheric processing of good and poor spellers there is no way of knowing whether both SSD and SRD are using the same intrahemispheric strategy to solve the task. Right hemisphere lesions involving frontal, temporal, parietal, and parietal-occipital cortical areas have all been found to compromise judgement of line orientation (Benton, Hanny, & Varney, 1975). The most that may be inferred by right hand tapping interference during line orientation processing is

that both SSD and SRD demonstrate atypical left hemisphere involvement in spatial tasks such as the JLOT.

A second limitation is that there is limited control for intelligence due to difficulties in obtaining school permission for administering IQ tests.

A third limitation is that time constraints made it necessary to rely on reports and/or school psychologist's assessments in order to eliminate subjects whose academic deficit may have resulted from neurological, medical, socioeconomic, or emotional factors. This procedure may not have identified children whose learning difficulties may have resulted from preschool factors such as, for example, inner ear infections or the sequelae of pre-natal or natal birth injury.

A fourth limitation is that SSD and GRS groups were not easily formed. In each category, many of the students selected by their teachers did not meet the spelling discrepancy criteria. The results of this study are therefore of limited generality for good readers. That is, classroom teachers were, on average, only able to identify approximately five percent of their good readers as having a marked contrast between reading and spelling ability. However this was not the case for the SRD group as, in all cases, poor reading was accompanied by poor spelling.

### 1.5    Definition of Terms

The following terms are defined for the purpose of this document:

**Dyslexia** - A developmental reading disorder originating from unknown causes.

**Synonymous term:** specific reading disability (SRD) (Vellutino, 1979).

**Laterality - A term that is used to mean lateral specialization of the cerebral hemispheres.**

**Orthography - The study of spelling and the conventions of correct spelling.**

**Parietal lobe - A term used to define a region underlying the parietal skull bone of each cerebral hemisphere that is involved in spatial functions.**

**Phonological awareness - A term used to describe the ability to detect the order of sounds within words.**

**Temporal lobe - A term used to define the lobe of each hemisphere that is situated below and in front of the parietal lobe and is involved in phonological functions.**

## Chapter II

### LITERATURE REVIEW

In this chapter literature is reviewed from a number of areas of research which have been identified as important to this study. These include studies (a) that have been concerned with examining the etiology of reading and spelling disorders, (b) which have provided a basis for understanding how spelling may be dissociated from reading performance, (c) which are relevant to the dual task paradigm used to infer hemispheric processing strategies and (d) which have described subtype differences of disabled readers and spellers.

#### 2.1 Current Theories of Reading and Spelling Disorders.

Most of the research into dyslexia (specific reading disability) has adopted the premise that this disorder is attributable to developmental problems of basic constitutional (neurological) origin (Aaron, 1989; Vellutino, 1979). Geschwind and associates (Geschwind & Behan, 1982; Geschwind & Galaburda, 1985a, 1985b; Galaburda, Sherman, Rosen, Aboitiz & Geschwind, 1985; Galaburda, Signoret, & Ronthal, 1985), on the basis of structural anomalies detected in autopsied dyslexic brains, have theorized that the majority of cases of developmental dyslexia spring from prenatal microscopic cellular anomalies. Briefly, the theory states that dyslexia is due to an excess of testosterone during prenatal development which, in some males, slows the maturation of the left hemisphere. This putatively

activates compensatory functions in the right hemisphere leading to a shift in hand preference (left) and the development of superior visuospatial abilities (e.g., Symmes & Rapoport, 1972). The underdevelopment of the left hemisphere is hypothesized to foster later reading and writing disturbances. The theory also postulates that testosterone impacts on the thymus gland, leading to an increased risk for autoimmune disorder in later life. In sum, the theory predicts a triadic association involving handedness (left), cognition (reading/language ability) and immunological status (autoimmune disorder) in males who are exposed prenatally to excessive amounts of testosterone (see Geschwind & Galaburda, 1986, for a recent summary).

This "imbalance hypothesis" has attracted considerable attention. For example Aaron (1989), in a pilot study, obtained WISC-R scores from two 10-year-old dyslexic monozygotic twins. Both showed a large difference between their verbal and performance IQ scores (PIQ > VIQ by 40 and 50 points). Aaron concluded that:

The fact that both boys show a similar degree of discrepancy renders birth injury unlikely. The influence of prenatal genetic-neurochemical factors is a more likely explanation. (p. 129)

However Satz and Soper (1986) have criticized the hypotheses advanced by Geschwind and Galaburda for significant design and methodological deficiencies. Further Hynd and Semrud-Clikeman (1989), in an extensive review of postmortem and neuroimaging (CT/MRI) studies of dyslexics, concluded that the available evidence does not establish the claim that the brains of developmental dyslexics are characterized by deviations in normal brain asymmetry:

Although there should be no doubt that the neuroimaging studies in general and the post mortem/cytoarchitectonic studies specifically suggest that symmetry in the region of the planum temporale and

parieto-occipital cortex is found with significantly greater frequency than in the normal population, there is neither sufficient agreement among the neuroimaging studies nor independent verification of (the postmortem/cytoarchitectonic) findings to be more affirmative with regard to this question. (p. 476-477)

Hynd and Semrud-Clikeman concluded that methodological deficiencies characterize the literature relating dyslexia to brain morphology, particularly regarding the diagnosis of dyslexia, appraisal of handedness and neurolinguistic deficits, and the lack of evidence that unusual brain asymmetries are unique to the dyslexic syndrome.

Satz (1990) provided an important critique of the "imbalance" hypothesis, taking a different perspective. From a review of studies which have assessed speech and language recovery after early childhood brain lesions, he concluded that pre- or postnatal brain damage would have to occur bilaterally, in order to account for dyslexia. This is because left hemisphere lesions which occur before the first birthday are likely to cause a shift of both speech and handedness to the right hemisphere without significantly affecting the subsequent development of reading and writing skills. The imbalance hypothesis, according to Satz, cannot explain why this does not occur in the case of dyslexia.

A different approach to understanding dyslexia, and one that is closer to the position taken in this study, has been advanced by Frith (1985) who emphasized the need for understanding the interaction of constitutional and environmental factors:

If there were an innate deficiency in the brain structure underlying a specific skill, one would then expect a particular type of reading failure.... At the price of faith in predestination this theory essentially dispenses with developmental factors. Thus, it ignores not only maturational processes and their complex interaction with the environment, but also social, cultural, and educational factors that influence the acquisition of literacy. (p. 302)

Frith did not, however, abandon the notion that a brain deficit is primary in the etiology of dyslexia. What she argued against is a direct comparison between reading disabilities resulting from brain injury (acquired dyslexias) and those which are developmental in nature. For the latter, she stressed the need to study the interaction of developmental factors with impairments in basic cognitive processes.

Frith's adoption of this theoretical position was influenced by her studies of children who were excellent readers but poor spellers (Frith, 1980). She hypothesized that the spelling disability might be the consequence of prematurely learned strategies which had failed to merge with others learned in later phases of development (Frith, 1985). Kirk (1983) was of the same mind, arguing that spelling disability may represent "too much, too soon" (p. 16), pointing to research by Bradley (1981) which indicated that reading and spelling may represent very different skills. While Frith did not specifically suggest that dyslexia might be the result of premature learning, she did formulate a plausible theory (Frith, 1985) that it may represent a developmental arrest in the learning of alphabetic skills, possibly due to a disorder of phonological awareness.

Neither Frith (1985) nor Kirk (1983) speculated on why some children may be at risk for reading or spelling disorders, or how phonological dysfunction may prevent normal reading progress. In contrast Mesker (Mesker, 1969; van Eyck, 1980), whose ideas have not received attention by researchers into dyslexia, had some interesting thoughts about the interaction between maturational processes and schooling. Mesker observed that reading problems were associated with poorly established laterality as evidenced by a lack of clear-cut dominance in

handedness and eyedness (see Orton, 1937, for a similar viewpoint). From a neurological viewpoint he suggested that such children could be prematurely stimulated to lateralization (e.g., with writing) and that this could lead to learning difficulties later on in a child's development. He therefore stressed the importance of bimanual activities (e.g. clay modelling) to fully develop symmetric motor skills prior to lateralization. Lamme (1982), a professor involved in early childhood curriculum design, was of a similar opinion believing that bimanual coordination should be prerequisite to learning to write.

Satz and Sparrow (1970) also conceptualized the etiology of dyslexia within the context of a developmental rather than a disease model. They postulated that the dyslexic child is delayed on a number of developmental skills which are not obviously related to the reading process. This position was first broadly suggested by Money (1966) who stated that:

...the majority of reading disability cases will be classifiable not on the basis of brain pathology, but simply as representative of a lag in the functional development of the brain and nervous system that subserves the learning of reading. (p. 35)

Satz and Sparrow (1970) extended this view by conceptualizing the behavioral signs within the framework of left hemisphere integration. Satz and van Nostrand (1973) added further evidence in support of a possible lag in the maturation of the left hemisphere while observing that the nature of the underlying mechanism still remained obscure. In general they found support for the hypothesis that many of the high risk children who enter pre-school, particularly boys, may not be maturationally or developmentally ready to cope with the early formal demands of reading.

Others who have also favoured a maturational lag explanation of dyslexia include Bender (1963), Cohn (1961), de Hirsch, Jansky and Langford (1966).

Critchley (1964) observed that:

Most neurologists... would be reluctant to visualize in developmental dyslexia any focal brain lesion, dysplastic, traumatic, or otherwise.... To do so would be to ignore the important factors of immaturity as applied to chronological age, cortical development and process of learning. (p. 21)

The foregoing review has suggested that some reading and spelling disorders may represent a developmental arrest in the early stages of alphabet learning that cannot, with any certainty, be attributed to brain damage. In contrast, there is some convergence of opinion (Frith, 1985; Kirk, 1983; van Eyck, 1980) that certain children may not be biologically ready to learn to read at the normal chronological age and may consequently adopt dysfunctional learning strategies.

## 2.2 SSD and SRD Similarities and Differences

Much less is known about the neuropsychological characteristics of SSD as compared to SRD. While there is some evidence that SSD may be associated with poor handwriting skill (Share et al., 1987) and difficulties in remembering physical detail of the printed page (Ormrod, 1986), there has been little effort spent in researching the visual or motor characteristics of this disorder. Instead the focus has been on psycholinguistic spelling comparisons between SSD, SRD and GRS children at different age levels (e.g., Bruck & Waters, 1988; Schlapp & Underwood, 1988; Schwartz, 1983; Smith, 1992; Waters, Bruck & Seidenborg, 1985). In general these studies have found that spelling differences between these three groups emerge by grade 6 (early adolescence). At this time poor spellers, regardless of

reading ability, appear to have problems converting phonemes into graphemes that are positionally (orthographically) accurate. Two studies have found differences between SSD and SRD in phonetic spelling accuracy in this age range (Frith, 1980; Jorm, 1981), while another did not (Bruck & Waters, 1988). However comparing and interpreting these studies is problematic since the relative emphasis on phonics vs whole word instructional approaches was not reported.

Stronger evidence that there are variations in phonetic spelling accuracy, at least within SRD, is provided by an earlier neuropsychological investigation (Sweeney & Rourke, 1978). While this study also found that differences in spelling ability become more evident during early adolescence, it further observed the emergence of differences in sound-spelling accuracy which discriminated between two major SRD subtypes that have been identified by different investigators in the field. In general these two subtypes are distinguished by a preference for auditory left-hemisphere strategies or visual right-hemisphere strategies in reading tasks. They include the audiles and visiles of Money (1962) and Wepman (1968); the auditory and visual dyslexics of Johnson and Myklebust (1967); the dysphonetic-dyseidetic dyslexics of Boder (1971, 1973); the L- and P- types of Bakker (1984); the dysphonemic sequencing and audiophonetic disorders of Denckla (1979); and the language and visuo-spatial disorder subtypes which have been identified by several investigators (e.g., Lyon, 1983; Rourke, 1985; Satz & Morris, 1981). Mixed subtypes have also been identified that demonstrated combinations of both visual and auditory disorders (Denckla, 1979; Lyon, 1983; Mattis, French, & Rapin, 1975). It is possible that these two major subtypes of reading disability represent differences in learning style that are not specific to dyslexia, as a

similar contrast has been found with SSD (Bruck & Waters, 1988) and GRS (Baron, Treiman, Wilf, & Kellman, 1980) subjects. Thus the influence of this variable on the tasks used in the present research may be consistent across the three groups to be evaluated.

In summary, studies which have examined the difference in spelling performance between early adolescents who differ in reading and/or spelling ability agree that poor spellers share a common difficulty in producing orthographically correct spellings. There is less agreement on whether they differ with respect to the phonological accuracy of misspellings. Until instructional variables are controlled in studies of this nature, it may be unwise to speculate on constitutional differences in the phonological processing of print.

### 2.3 Reading-Spelling Dissociation

One reason for the sparsity of neuropsychological research into SSD is the fact that it is not an academically threatening disorder. Two to fifteen percent of the population of normal language users do not become proficient spellers but nevertheless exhibit average or above-average abilities in other areas of language function (Frith, 1980; Nolen, 1980). Frith, however, has focused attention on spelling disability by describing a group of twelve-year-old good readers who possessed unusually poor spelling skill. Her research suggested that "reading by eye and spelling by ear" (p. 512) characterized the print-processing behavior of these early adolescents. While able to distinguish between homophones (e.g. their/there) in reading, these were frequently misspelled in written work. Other research suggested that SSD adolescents may achieve word recognition in reading

by partial cues (Frith, 1978; Ormrod, 1985) and may differ from GRS in having short-term memory problems with printed material (Ormrod, 1986).

There is general agreement that word-recognition can be accomplished either through direct phonological encoding of whole words or by indirect phoneme-grapheme conversion of letter sequences (see Barron, 1986, for a review). The indirect route uncovers word meaning by segmenting words into graphemes (letters or letter clusters such as oa, th, gh) which correspond to phonemes. These are then assembled into strings which approximate spoken words. In contrast the direct route uncovers meaning phonologically, without first having to identify the individual parts of words. It seems a reasonable conjecture that SSD may represent a developmental dissociation between these two routes for accessing word meaning. Direct phonological access, without the ability to decode print graphemically, could explain a partial-cue style of reading as well as memory deficits for print detail. The discrimination of homophones in reading but not spelling might be aided by contextual rather than spelling cues. This hypothesis may have relevance to the following studies which were designed to examine the cortical localization of functions involved in the sequential processing of language.

Kimura (1982), from an analysis of neurological injuries restricted to either the left or right hemisphere, found both oral and manual sequencing control to be under left hemisphere control. Her research indicated that these two functions were more separable in the frontal than in the parietal region, suggesting that the latter may play a general programming role that is then enacted through the frontal region. Thus injury to the parietal area affected the ability to program

non-repetitive oral or manual movements (e.g., syllables or pantomimes).

Importantly, when the temporal system was intact it was able to bypass defective frontal or parietal oral motor systems. That is, the left temporal region appeared to be not only necessary, but also sufficient, for the reproduction of auditorily presented familiar speech material. Other research, using electrical stimulation mapping techniques (Ojemann, 1981), has demonstrated that oral movements are cortically linked with the ability to discriminate the parts (phonemes) of words, a commonality that was found only in the left hemisphere motor (pre frontal) and sensory (parietal and temporal) lobes.

Kimura's (1982) and Ojemann's (1981) findings, taken together, indicate that the left hemisphere parietal and temporal systems can independently function in tasks which require awareness of the phonological constituents of words. This research may provide some insight into the etiology of both SSD and SRD.

Dyslexia is associated with a delay in the development of phonological skills (Beech & Harding, 1984; Olson, Davidson, Kliegl & Davies, 1984; Siegal & Linder, 1984) whereas such has not been documented in the case of SSD. Other research has shown that phonological awareness is a strong predictor of reading success (see Wagner & Torgesen, 1987, for a review). It is tempting to suggest that the difference between SSD and SRD is that the former is able to bypass dysfunctional parietal lobe phoneme processing by utilizing a temporal lobe faculty for receiving word meaning by direct phonological conversion.

The possibility that the temporal and parietal lobes may play distinct roles in print encoding receives support from Luria's (1970) observations of the word-writing characteristics of hundreds of patients who sustained left

hemisphere local brain wounds or tumors. Patients with left temporal lobe damage had difficulty finding the correct letter for the sound they wanted to write (e.g., writing "pull" instead of "bull" or "tome" instead of "dome"). In contrast, patients with lesions to the visual and spatial zones (occipital and parietal lobes), while perfectly able to analyze speech sounds, showed marked difficulty in recognizing and forming written letters. These subjects found it difficult "to visualize the required structure among the parts of the letter and to put the parts together to form the whole" (p. 71). In this light it is suggestive that both SSD and SRD have been found to be associated with handwriting deficits in a large scale longitudinal study (Share, Silva & Adler, 1987).

More recent research, reviewed by Farah, Hammond, Levine and Calvanio (1988), has supported a distinction between visual representation of appearance (forms, patterns, objects) in the temporal lobe and visual representation of spatial location in the parietal lobe. These two visual systems have been respectively termed the "what" system and the "where" system (Ungerleider & Mishkin, 1982). Convergent evidence from several disciplines indicates that the latter (parietal) system may be dysfunctional in dyslexia (Conners, 1990; Livingstone, Rosen, Drislane, & Galaburda, 1991; Mason, 1980).

Mason (1980) compared skilled and less skilled high school reader's ability to identify a briefly exposed letter embedded in a row of dollar signs. Both groups performed identically when cued in advance as to the location of the letter, however, only the skilled reader's performance suffered when advance location information was withheld. Mason concluded that "...the role of perception in reading has been underestimated because emphasis has been on item perception,

and the perception of spatial location has been largely ignored" (p. 89). Similarly, Conners (1990) from a comprehensive review of neurophysiological research on dyslexia, concluded that "abnormalities in central parietal mechanisms for visual selective attention cause both the symptoms of dyslexia as well as the accompanying abnormal eye movements" (p. 181). Finally Livingstone et al. (1991) presented physiological and anatomical evidence from studies of dyslexics consistent with the hypothesis that the disorder is associated with abnormalities in the visual system responsible for spatial localization. Without similar investigations into the nature of SSD, one can only speculate as to whether comparable "where" deficits would be uncovered.

It is also impossible to ascertain from this evidence whether the posited spatial localization deficit in dyslexia is limited to the processing of alphanumeric stimuli. Le Doux et al. (1977) hypothesized that the manipulospatial superiority of the right hemisphere may occur by default, in consequence of language development in left hemisphere space. Further, Ehri (1985) has presented evidence which suggested that the learning of spelling exerts a considerable influence on children's speech. She observed that it is much easier to detach language from its communicative function, treat it as an object, and study its form when one has fixed visual-spatial symbols to see and manipulate. If SSD and SRD involve an arrest in the development of alphabetic spelling skills, it is possible that both disorders may be associated with anomalous left hemisphere lateralization for nonverbal visual-spatial functions. In other words if, for whatever reason, the faculty for visual-orthographic spelling has failed to develop in the left hemisphere, the affected space may be functional for other nonverbal tasks.

In summary, a case can be made for the functional independence of the temporal and parietal lobes in processing different aspects of phonological and visual representation. While there is mounting evidence of left hemisphere parietal lobe anomalies in SRD, research into SSD is too limited to do anything but speculate on whether the two disorders are similar in this respect. However, studies which have investigated the effects of localized brain injuries on language performance provide some rationale for hypothesizing that both SSD and SRD may have a dysfunctional parietal "where" system for spelling and that differences in the temporal "what" system function may be relevant to the contrast in reading ability. That is, SRD and SSD may be similar with respect to parietal system deficits for spatially locating the letter components of words but different in that reading disability may additionally involve temporal lobe problems with the phonological identification of print meaning. As the line orientation judgement task to be used in the present study can be regarded as a "where" rather than a "what" task (McGee, 1979), it may provide a means for inferring whether the putative parietal lobe deficit in SSD and SRD is restricted to verbal stimuli.

#### **2.4 The Dual Task Paradigm**

The dual task paradigm has become a frequently used behavioral method to infer hemispheric language lateralization. Its basic assumption is that an asymmetrical decrement in tapping performance of the hands produced by various concurrent tasks versus tapping alone indicates that the manual task and the cognitive task are competing for resources from the same hemisphere (Kinsbourne & Hiscock, 1983). Because the finger tapping movement of the hand is primarily

controlled by the cerebral hemisphere on the opposite side of the body (Brinkman & Kuypers, 1972), greater right hand interference produced by the concurrent task purportedly indicates more left hemisphere involvement for the cognitive activity (Hellige & Kee, 1990; Kinsbourne & Hiscock, 1983).

This paradigm was first introduced by Kinsbourne and Cook (1971) who reported that in right handers, vocalizing disrupted the concurrent balancing of a dowel rod with the right hand but not the left. This asymmetry of interference was attributed to the lateralization of speech to the left hemisphere. Numerous subsequent studies have reported similar asymmetrical effects for normal right-handed monolingual speakers (see Kinsbourne & Hiscock, 1983, for a comprehensive review). More recent language research with this procedure has examined the influence of handedness (Orsini, Satz, Soper & Light, 1985; Simon & Sussman, 1987), stuttering (Webster, 1989), bilingualism (Furtado & Webster, 1991), preprogramming of tapping responses (Inhoff, 1990), rate and variability of tapping (Hiscock, Cheesman, Inch, Chipuer, & Graff, 1989) and controlled vs automatic verbal production (Wiegersma & Wijnmaalen, 1991) on the concurrent task. Of relevance to the present investigation, Hiscock et al. found tapping rate, rather than variability, to be the more sensitive measure of laterality. Further, depending on whether the tapping task was performed under speed or consistency instructions, the rate of tapping either decreased or increased as reading was conjoined with tapping. The right hand rate was observed to change more than the left hand rate irrespective of the direction of change. This latter finding led Hiscock et al. to suggest that these particular tasks, when conjoined, affect each other via cross-talk rather than as a result of competition for some general resource such as attention.

Various models have been put forth to account for concurrent-task performance (Green & Vaid, 1986; Heuer & Wing, 1984; Hiscock, 1986). In general the theoretical assumptions underlying this procedure are closely tied to methodological issues (Hisock, 1986). These concerns are examined in detail by Green and Vaid (1986) and include variables extrinsic to the paradigm (i.e., individual difference variables) and those intrinsic to it (i.e. methods for differential allocation of attention, counterbalancing procedures, and measurement of concurrent performance).

Attempts to demonstrate greater left- than right-hand interference using nonverbal tasks have produced equivocal findings. One possible reason is that it is difficult to find interference tasks that are sufficiently lateralized to the right hemisphere. For example, some studies have used concurrent musical tasks of various types and have reported results ranging from greater right- than left-hand disruption to equal disruption of both hands (Johnson & Kozma, 1977; Hicks, 1975; Lomas & Kimura, 1976). Unfortunately, the use of musical tasks is problematic because lateral specialization for various aspects of music processing is still poorly understood (e.g., Gates & Bradshaw, 1977).

Results have been somewhat more promising for concurrent tasks that require visuospatial processing. It has been found that such activities either disrupt concurrent left- and right-hand performance equally (Bowers, Heilman, Satz, & Altman, 1978; McFarland & Ashton, 1978a) or disrupt the left hand more than the right (Hellege & Longstreth, 1981; McFarland & Ashton, 1978b, 1978c). Those studies which demonstrated symmetrical interference involved respectively facial recognition and concealed figure detection. The ones which found greater

left-hand interference may have tapped additional cognitive resources as respectively they required solving a block design problem, and performing running memory identification of shapes and faces. Further, in contrast to Bowers et al., the more difficult McFarland and Ashton facial recognition design required recognition and tapping to be performed simultaneously whereas Bowers et al. discontinued tapping during the facial identification phase of the experiment.

Studies with children have followed two paths. Much of the research has addressed the question of developmental change in cerebral dominance for speech. This line of investigation has yielded quite consistent results. Verbal interference asymmetries resembling those occurring in adults are found in young children (Kinsbourne & McMurray, 1975) and remain invariant in magnitude across the age range of 3 to 12 years (Hiscock & Kinsbourne, 1980; White & Kinsbourne, 1980). Visuospatial lateralization of line orientation was examined in one study (Hiscock, et al., 1985) and generated bilaterally equal interference with children in grades 2 to 5. The second line of research has been concerned with learning disabled subjects and the findings are more diverse. For example, Dalby and Gibson (1981) found that recitation produced bilaterally equivalent interference in "dysphonetic" and "dyseidetic" (subtypes of reading disability) boys while producing the expected right hand asymmetric interference in average readers. A non-verbal task (Ravens Progressive Matrices) yielded left-greater-than-right interference for average readers and dyseidetic boys, but not for the dysphonetic group. However other research (Sperry, 1974) has demonstrated that this task does not reliably distinguish between left and right hemisphere processes.

Stellern et al. (1986) appears to be the only study which has examined the role of tapping interference in older children using a test (line orientation judgement) which has been found, at least with adults, to be a robust indicator of right hemisphere processing (Benton et al., 1978; Poizner, et al., 1987; Warrington & Rabin, 1970) The test has also been found to be a correlate of right hemisphere cognitive style in children aged 7 to 12 years (Stellern, Marlow, & Jacobs, 1983).

Importantly, a similar relation between cognitive style and spatial orientation judgement was found with undergraduate college students performing the dual task paradigm (Bowers & LaBarba, 1988). This study used a spatial orientation (SO) subtest from the Guilford-Zimmerman Aptitude Survey (Guilford & Zimmerman, 1953) to select right-handed subjects who scored in the upper (high SO) and lower (low SO) quartiles. Both groups were then required to concurrently tap with either their left or right hands while solving this subtest. Successful performance required maintaining a boat on course by compensating its angle relative to horizon changes presented in a sequence of pictures. The construct validity of this subtest was demonstrated in a factor analysis reported by McGee (1979). Bowers and LaBarba observed significantly greater right hand disruption with high SO subjects and significantly greater left hand disruption with low SO subjects. These results suggest left hemisphere involvement in high SO subjects and right hemisphere involvement in low SO subjects in processing the boat-horizon task. Unfortunately reading and spelling levels were not measured. This information would have been of particular relevance to the present study in view of reports that dyslexic performance on a spatial orientation map-walking task changes abruptly after age 10 from poor to superior performance (Denckla,

1985) and that dyslexic family members frequently demonstrate superior visuospatial abilities without concomitant reading deficits (Denckla, 1979; Gordon, 1980, 1989; Symmes & Rapoport, 1972). Conceivably, both SSD and SRD may be associated with high left hemisphere spatial ability as a "by-product" of their failure to develop visual word pattern (orthographic) knowledge.

The dual task studies which have been reviewed thus far have all been concerned with obtaining inferential evidence for hemispheric lateralization of cognitive abilities. For about the same number of years this paradigm has also been used to explore the characteristics of verbal and visual alphanumeric short term memory abilities (see Baddeley, 1992, for a recent review). This research provided evidence for a multi-component short term memory model controlled by a limited capacity attentional system termed the "central executive" and supported by at least two active "slave" systems: an articulatory or phonological "loop" and a visuospatial temporary store or "sketchpad." The articulatory loop was assumed to be responsible for maintaining and manipulating speech-based information whereas the sketchpad was assumed to perform similar functions for visuospatial information involving letters or numbers. For example, visuospatial tasks such as tracking a spot of light disrupted performance in a verbal memory task requiring spatial imagery whereas there was no effect in an analagous non-spatial rote verbal memory condition (Baddeley, Grant, Wight, & Thomson, 1975).

The research of Baddeley and colleagues (Baddeley, 1992) is particularly relevant to the present study because of a recent rapprochement between disciplines with respect to understanding the nature of visual short term memory

processing. Logie (1986), on the basis of spatial imagery interference evidence, and Farah et al. (1988), from neuropsychological and psychophysiological data, independently concluded that this memory system may have separate visual and spatial components. As noted earlier, Farah et al. found evidence in support of the possibility that these components may respectively involve the left hemisphere temporal and parietal lobes. While Baddeley (1992) stressed that the two components are difficult to tease apart in normal subjects, the evidence which has been presented in this review suggests that this may not be the case with SSD. That is, the SSD short term memory deficit for printed material (Ormrod, 1986) may represent an impairment of the spatial (parietal) component of visuospatial memory, affecting "where" rather than "what" alphanumeric decoding. Thus, while access to the meaning of print may be unaffected, there is difficulty in converting phonemes into graphemes that are positionally (spatially) acceptable (Bruck & Waters, 1988).

A recent conceptual concern with dual-task/time sharing studies is that the asymmetric interferences observed may be a statistical artifact of baseline differences and not hemispheric lateralization (Sussman, 1989; Willis & Goodwin, 1987). As expressed by Willis and Goodman:

A potential problem with analyzing raw scores generated through these paradigms is that they may be insensitive to lateralized interference effects. This is because research participants are usually right handed and interhand comparisons of initial (i.e., baseline) tapping rates typically favor the right. Given this initial discrepancy between the hands, differential interference effects associated with the concurrent performance of an unrelated task may be due to initial differences in tapping speed rather than lateralization effects. In this respect, interference might be greater for right- than left-handed tapping because, due to the higher range of initial values for the right hand, there is a higher possible range for reduction. (p. 719)

However several studies have demonstrated that baseline asymmetries (i.e., manual dominance) are neither a necessary or sufficient condition for producing asymmetric dual-task interference (Cherry & Kee, 1991; Hiscock et al., 1989; Kee & Cherry, 1990).

In summary, the dual task paradigm has engendered extensive research in the domains of both neuropsychology and cognitive psychology. In both areas there has been much more emphasis on its use for investigating verbal rather than spatial information processing. However, a recent convergence of evidence between the two disciplines in the interpretation of visuospatial processing systems, promises to heighten research activity using dual-task methodology. While its use in investigating visuospatial processing differences in learning disorders has produced equivocal results, a post hoc analysis of a Native Indian study (Stellern et al., 1986) points to a need for further research with these populations.

## 2.5 Summary of the Literature

This review began with a look at current theories regarding the etiology of specific spelling (SSD) and specific reading (SRD) disorders. From this examination it became evident that a great deal of uncertainty remains as to the relative importance of constitutional and environmental factors in the development of these disabilities. As Ehri observed: "We cannot legitimately conclude that the source of dyslexia lies in individual learner deficiencies until we have perfected the way we teach children to read and spell" (1989, p. 364).

Possibly because it is much easier to accept that SSD results from inappropriate teaching or learning strategies than to envision this possibility for SRD, few studies were located which examined the nature of specific spelling disability. Most of the investigations that did so were concerned with understanding the developmental psycholinguistic characteristics of this disorder (cf. Bruck & Waters, 1988; Smith, 1992). Their findings were in general agreement that marked differences in spelling ability emerged in early adolescence and that, regardless of reading ability, spelling problems were strongly associated with deficits in the use of sound-spelling rules that place positional constraints on the selection of letter combinations.

Various neuropsychological studies of brain function suggested a possible cortical locus for such orthographically inaccurate spelling errors. Evidence from several lines of investigation converged towards the possibility that SSD and SRD may be associated with a deficit in left hemisphere parietal lobe function. A review of dual task research indicated that this paradigm might serve as an appropriate inferential means for determining whether the hypothetical parietal system dysfunction is restricted to the processing of alphanumeric symbols.

## **2.6 Purpose of the Present Study**

The investigation by Stellern et al. (1986) of Native American fourth, fifth and sixth graders, which prompted the present study, sought evidence to support the hypothesis that Native American Indian children would show a reversal of the usual verbal-spatial pattern of hemispheric lateralization. Instead they obtained post hoc inferential evidence for reversal of spatial function alone, and this only

for poor readers. The theoretical position of the present study holds that these findings indicate an absence of spelling function in the left hemisphere parietal system of the poor readers. That is, the procedure that was employed (tapping concurrent with line orientation judgement) provided an inferential measure of left hemisphere processing mechanisms essential for spelling but not reading proficiency. In pursuit of this hypothesis, the present study investigates the use of a methodologically refined version of this task with Caucasian early adolescent children who differ in both reading and spelling ability. The comparison of SSD and SRD is of particular interest as, while there has been a considerable volume of research investigating dyslexic visuomotor deficits (see Gladstone, Best & Davidson, 1989, for a review), a possibility that has yet to be evaluated is that SSD may be characterized by similar anomalies. This would have important etiological implications for both disorders.

## Chapter III

### METHODS, PROCEDURES AND FINDINGS

This chapter provides a description of the data collection and analysis procedures for the groups in the study. Further discussion will be provided in the relevant sections of Chapter 4.

#### **3.1   Subjects**

Twelve good readers/poor spellers (SSD), 12 poor readers/poor spellers (SRD) and 12 good readers/superior spellers (GRS), aged 11.4 to 14.6, were obtained through teacher referral from a total of six schools located in the Greater Victoria District No. 61, Victoria, B.C., Canada. All were Caucasian with boys in each group numbering 12 SRD, five SSD and three GRS. Teacher reports and school district psychologist's assessments, due to time constraints were the only means used to screen out subjects whose academic deficit may have resulted from neurological, medical, socioeconomic or emotional factors. Only right handed subjects were used. Handedness was determined from questions adapted from the Edinburgh Inventory (Oldfield, 1971) as selected in a dual-task study of handedness and hemispheric speech specialization conducted by Orsini et al. (1985). Passage comprehension and spelling subtests from the Woodcock-Johnson-Psychoeducational Battery (Woodcock & Johnson, 1977) were used to provide independent means of reading and spelling performance. The

selection criteria was as follows: SRD - reading and spelling at least two years below grade level; SSD - reading at or above grade level while spelling at least two years below reading level; GRS - reading at or above grade level while spelling at least two years above either grade or reading level. Table 1 lists the means and standard deviations for age as well as reading, spelling and enrolled grade levels for the three groups of subjects. The mean reading score for the SRD group ( $M = 3.69$ ) was significantly less than the SSD mean reading score ( $M = 9.73$ ),  $t(22) = 72.58$ ,  $p < .0001$ . The difference between the SRD mean spelling score ( $M = 3.65$ ) and the SSD mean spelling score ( $M = 5.42$ ) was also significant,  $t(22) = 24.43$ ,  $p < .0005$ . Thus, while both groups were poor spellers, SRD subjects were more seriously deficient in this faculty. This result is consistent with the findings of Frith (1980) and Jorm (1981). The GRS mean spelling score ( $M = 12.02$ ) was significantly higher than the SSD mean spelling score ( $M = 5.42$ ),  $t(22) = 142.82$ ,  $p < .0001$ , whereas the GRS mean reading score ( $M = 9.56$ ) did not differ significantly from the mean for SSD ( $M = 9.73$ ),  $t(22) = .10$ ,  $p > .50$ . This result is in accord with Frith's (1980, 1985) research which demonstrated that spelling performance does not predict the reading comprehension of early adolescents.

### 3.2 Materials

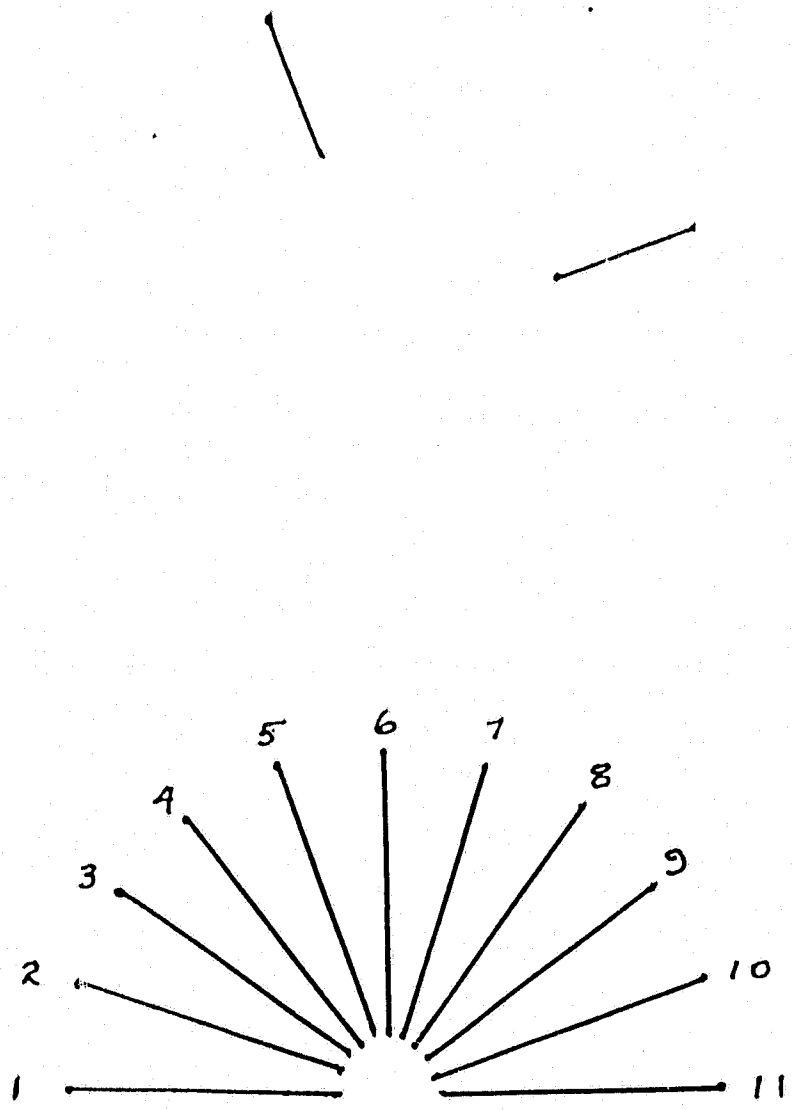
The Judgement of Line Orientation Test (JLOT) (Benton, Varney & Hamsher, 1975) was used to infer hemispheric specialization of visuospatial processing. This test examines the ability to estimate angular relationships between line segments by visually matching angled line pairs to 11 numbered radii forming a semicircle. An example is shown in Figure 1. The test consists of 30 items, each showing a

Table 1

Means and Standard Deviations for Demographics

	Poor Readers		Good Readers		Good Readers	
	Poor Spellers		Poor Spellers		Superior Spellers	
	SRD		SSD		GRS	
	<u>n</u> = 12		<u>n</u> = 12		<u>n</u> = 12	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
<b>Chronological Age</b>	12.76	.91	13.01	.52	12.56	.84
<b>Reading Grade Level</b>	3.69	.94	9.73	2.07	9.56	2.49
<b>Spelling Grade Level</b>	3.65	.65	5.42	1.08	12.02	1.46
<b>Enrolled Grade Level</b>	6.97	.58	7.08	.71	7.30	.52

Figure 1: Judgement of Line Orientation



different pair of angled lines to be matched to the display cards. Its two forms, H and V, present the same items but in different order.

Tapping was counted using a Gerbrands Model 1271-F recorder. The finger tapping device consisted of a 3mm. diameter button-switch mounted in a 4 x 2 x 1 inch box.

### 3.3 Procedures

The JLOT is normally administered as an untimed test with accuracy of line orientation as the measure of performance. However to effectively measure the interference of this task on 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 a 11 x 14 inch four ring binder. This procedure permitted a new design to be displayed while the subject was solving the adjacent one. In this manner there was no interruption in JLOT task performance introduced by 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 five seconds of finger-tapping practice, baseline single-task finger tapping rate was determined for each hand. The recorder was positioned so that the participant could not see the counter. The first six cards of JLOT - Form H were then administered as practice trials. The remaining three tasks were then performed in counterbalanced blocks of three trials each. Each block consisted of a trial in which the JLOT was performed by itself, a trial in which it was conjoined with left hand finger-tapping, and a trial in

which it was conjoined with right hand finger tapping. Thus each subject performed five trials: Trials 1 and 2 consisted of tapping with the left and with the right index fingers; trials 3, 4 and 5 consisted of performing the JLOT without concurrent tapping, with concurrent left hand tapping, and with concurrent right hand tapping respectively. The order in which the hands were tested was counterbalanced within the three groups.

In the single-task tapping, the subject was instructed to tap with the index finger as rapidly as possible. In the JLOT task, the subject was told to perform as accurately as possible. Instructions for the dual-task condition emphasized equally the tapping and JLOT task. In all trials, subjects 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 formula for each hand:  $[(B-P)/B] \times 100$ , 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).

For each subject, complete demographics and task performance scores are listed in Appendix A.

### **3.4 Results**

In Table 2 the tapping and JLOT decrement means and standard deviations are listed for each group and task condition.

Table 2

**Means and Standard Deviations for JLOT Accuracy Scores and Tapping and JLOT  
Decrement Scores**

Category	Group	<u>n</u>	Condition	Mean	S.D.
Percentage tapping rate decrement	SRD	12	RH	12.08	8.14
			LH	6.58	7.57
	SSD	12	RH	9.83	5.20
			LH	4.25	4.75
	GRS	12	RH	3.00	2.70
			LH	4.25	4.11
Percentage JLOT processing rate decrement	SRD	12	RH	17.00	10.96
			LH	20.75	17.02
	SSD	12	RH	18.50	19.17
			LH	11.17	9.27
	GRS	12	RH	13.33	11.78
			LH	15.00	10.75
JLOT performance accuracy	SRD	12	BL	0.83	0.83
			RH	1.58	1.08
			LH	1.67	1.07
	SSD	12	BL	0.92	0.67
			RH	1.25	0.75
			LH	1.58	1.08
	GRS	12	BL	0.42	0.52
			RH	0.83	0.84
			LH	1.00	0.74

SRD = poor readers/poor spellers  
SSD = good readers/poor spellers  
GRS = good readers/superior spellers

BL = base line  
RH = right hand  
LH = left hand

### 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(SRD vs SSD vs GRS) x 2(hand) analysis of variance, with repeated measures on the second factor (Table 3). This yielded a single main effect for hand,  $F(1, 33) = 62.88, p < .0001$ . As expected, the mean right hand baseline tapping rate in each group was higher than that of the left hand. Paired t-test analysis of each group showed that, in each case, the right hand baseline tapping rate was significantly higher than that of the left hand (Table 4).

A 3(SSD vs SRD vs GRS) x 2(hand) analysis of variance, with repeated measures on the second factor, was used to compare JLOT interference effects between and within groups (Table 5). The results indicated there was a significant interaction between groups and hand-trials (Figure 2),  $F(2, 33) = 4.04, p < .027$ . Probes of this interaction showed that the GRS mean right hand tapping interference score ( $M = 3.00$ ) was, as predicted, significantly lower than the SSD mean ( $M = 9.83$ ),  $t(11) = 15.27, p < .005$  and the SRD mean ( $M = 12.08$ ),  $t(11) = 13.50, p < .005$ . Importantly there was no significant difference between SRD and SSD right hand tapping interference means [ $t(11) = 0.72, p > .20$ ] The results support the hypothesis that GRS differ from both SSD and SRD in left hemispheric processing of line orientation judgement as inferred from dual task interference effects. However an unexpected finding was that of no significant difference between the groups with respect to left handed interference effects. It had been anticipated that the GRS left hand disruption would be significantly greater than that of the other two groups, indicating right hemispheric processing of

Table 3

**Summary of Analysis of Variance of Baseline Tapping Performance for SRD, SSD  
and GRS Groups.**

Source	df	SS	MS	F
<b><u>Between Subjects</u></b>	<b>35</b>			
A (Groups)	2	139.11	69.56	.77
Error	33	2986.04	90.49	
<b><u>Within Subjects</u></b>	<b>36</b>			
B (Hand)	1	1413.35	1413.35	62.88*
AB (Group x Hand)	2	25.44	12.72	0.57
Error	33	741.71	22.48	
	<b>71</b>	<b>5305.65</b>		

\*  $p < .0001$

Table 4

Group Comparison of Baseline Tapping Rate Means and Standard Deviations

Group	<u>n</u>	Hand	Mean	S.D.	<u>t</u>
SRD	12	Right	66.83	7.49	5.51*
		Left	59.58	8.83	
SSD	12	Right	68.75	7.69	4.44*
		Left	57.00	8.29	
GRS	12	Right	71.00	5.17	5.00
		Left	61.75	8.45	

\* p &lt;.005

\*\* p &lt;.001

Table 5

**Summary of Analysis of Variance of the Effects of Line Orientation Judgement on Right- and Left-Hand Tapping Rates for SRD, SSD and GRS Groups.**

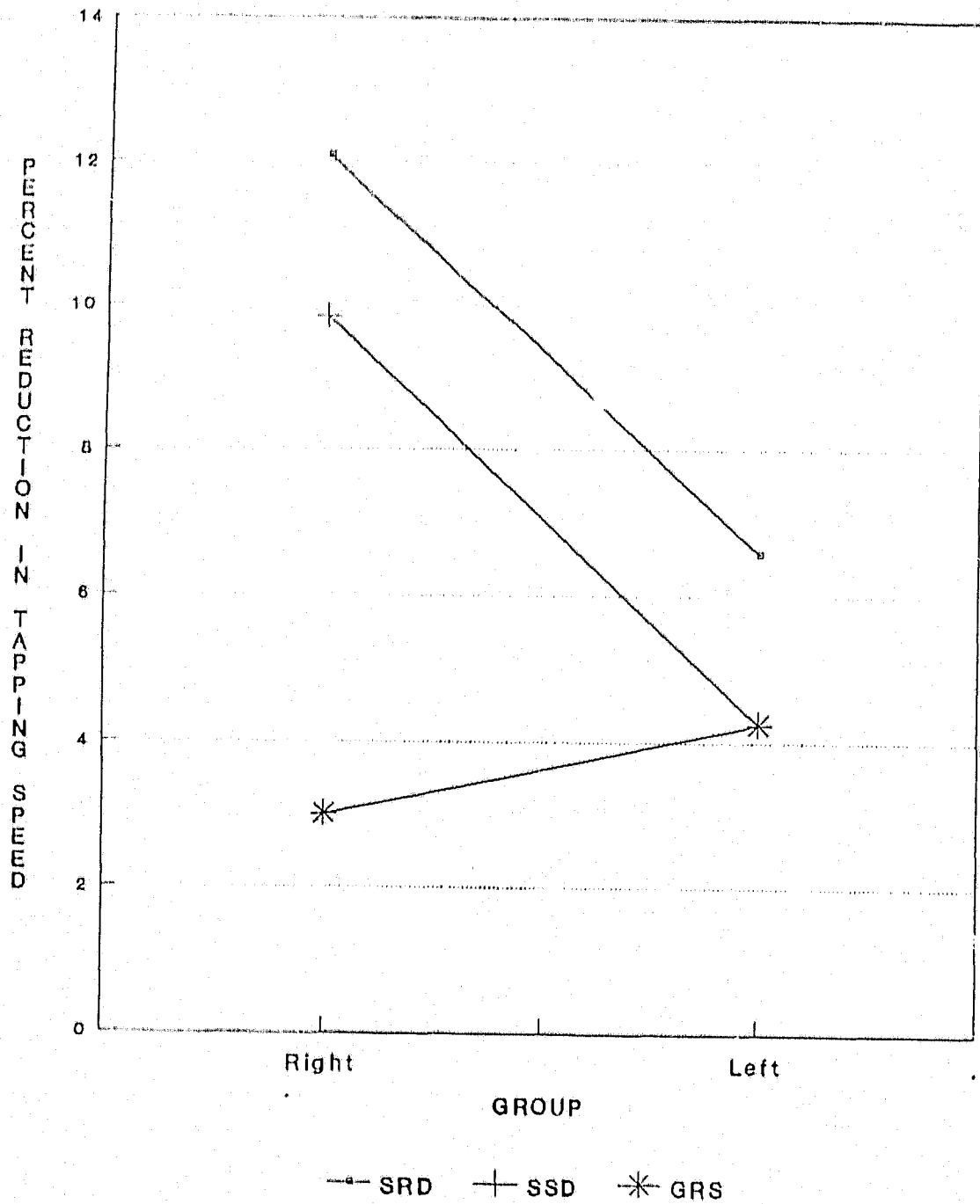
Source	df	SS	MS	F
<b><u>Between Subjects</u></b>				
	35			
A (Groups)	2	396.08	198.04	4.61*
Error	33	1417.92	42.97	
<b><u>Within Subjects</u></b>				
	36			
B (Hand)	1	193.39	193.39	8.46**
AB (Group x Hand)	2	184.53	92.26	4.04***
Error	33	754.08	22.85	
<b>Total</b>	<b>71</b>	<b>2946.00</b>		

\*  $p < .017$

\*\*  $p < .006$

\*\*\*  $p < .027$

**Figure 2: Right-and Left-Hand Tapping Interference During Judgement of Line Orientations.**



visuospatial stimuli. In fact the GRS group showed no significant between-hand difference in interference,  $t(11) = .66$ ,  $p < .20$ , in contrast to that observed with the SSD,  $t(11) = 3.67$ ,  $p < .005$  and the SRD,  $t(11) = 2.12$ ,  $p < .05$ , groups. These findings are difficult to reconcile with the concept that visuospatial processing is lateralized to the right hemisphere by default. Chapter 4 discusses this problem in detail.

As was discussed in the literature review, a potential artifact in the interpretation of dual-task outcomes is that of manual dominance. That is, is it possible that the greater right hand interference effects in the poor spellers (SSD and SRD) results from a higher range of initial (baseline) values for the poor spellers as compared to the good spellers? As shown in Table 3 the right hand baseline tapping rates were actually higher for the good spellers, ruling out this potential confound.

#### Line Orientation Processing Rate

A 3(SSD vs SRD vs GRS) x 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 processing line orientation judgements (Table 6). No significant effects were found. Hiscock et al. (1985) observed that "children appear to protect their non-manual performance at the expense of their performance on the tapping task" (p. 44). In the present study this appears to be the case for the rate but not, as will be shown, for the accuracy of JLOT performance.

Table 6

Summary of Analysis of Variance of Right- and Left-Hand Tapping Effects on  
JLOT Line Judgement Processing Rate for SRD, SSD and GRS Groups.

Source	df	SS	MS	F
<u>Between Subjects</u>	35			
A (Groups)	2	311.58	155.79	.93
Error	33	5506.79	166.87	
<u>Within Subjects</u>	36			
B (Hand)	1	7.35	7.35	.04
AB (Group x Hand)	2	416.36	208.18	1.01
Error	33	6784.79	205.60	
Total	71	13026.88		

### Line Orientation Processing Accuracy

Correct response on the JLOT was evaluated by a 3(SSD vs SRD vs GRS) x 3 analysis of variance where the repeated measures included line judgement errors without concurrent tapping and with left- and right-hand tapping (Table 7). This analysis yielded two significant effects (Figure 3). The main effect for group,  $F(2, 33) = 3.45$ ,  $p < .044$ , was attributable largely to the superior performance of the GRS group under concurrent right- and left-hand tapping conditions. The main effect for condition (left hand tapping; right hand tapping; no tapping),  $F(2, 30) = 8.14$ ,  $p < .001$ , reflects a differential effect of left hand tapping on JLOT correct responses across groups. Paired t tests performed across conditions for each group showed significant interference effects only for the left hands of the SSD, [ $t(1, 11) = 6.77$ ,  $p(2\text{-tailed}) < .05$ ] the SRD, [ $t(1, 11) = 9.48$ ,  $p(2\text{-tailed}) < .05$ ] and the GRS, [ $t(1, 11) = 5.04$ ,  $p(2\text{-tailed}) = < .05$ ], groups. This data indicates 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 GRS group sacrificed accuracy of JLOT performance in order to minimize right hand tapping interference.

Table 7

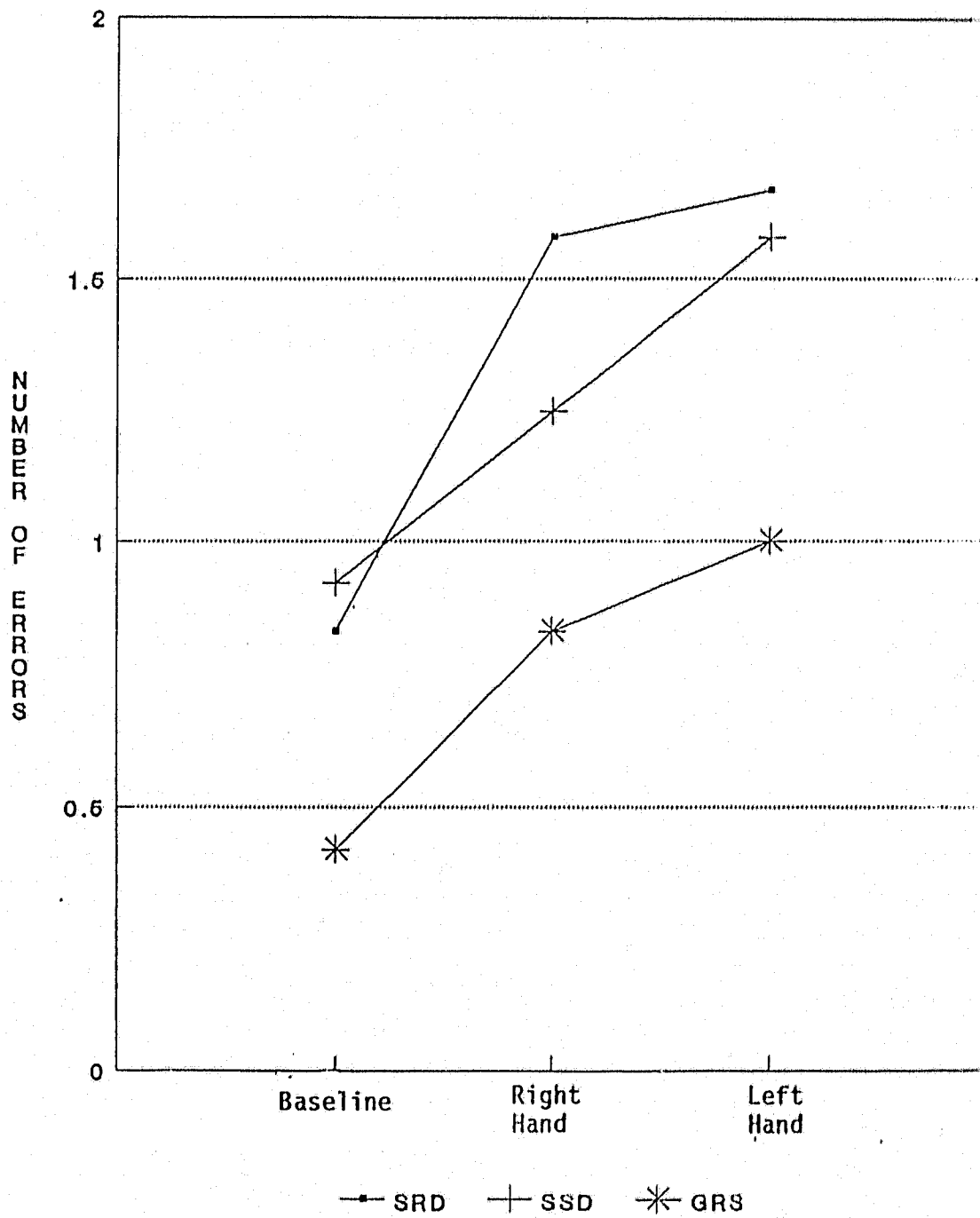
Summary of Analysis of Variance of Right- and Left-Hand Tapping Effects on Line Orientation Judgement (JLOT) Accuracy

Source	df	SS	MS	F
<u>Between Subjects</u>	35			
A (Groups)	2	7.63	3.82	3.45*
Within Groups	33	36.47	1.11	
<u>Within Subjects</u>	36			
B (JLOT Error)	2	9.24	4.62	8.14**
A x B	4	.65	.16	0.27
Error		37.44	.57	
<b>Total</b>	<b>71</b>	<b>91.44</b>		

\* p <.044

\*\* p <.001

**Figure 3:** JLOT Performance Errors Without Concurrent Tapping and With Left- and Right-Hand Tapping.



## Chapter IV

### DISCUSSION

The analysis of the test data supported the three research hypotheses:

1. Right hand tapping disruption, resulting from the concurrent JLOT activity, was significantly greater for SSD and SRD as compared to GRS.
2. SSD and SRD right hand performance was not significantly different on this task.
3. Group differences in right hand interference effects were unrelated to either rate or accuracy of JLOT performance.

However a post hoc analysis of left hand interference effects not only showed no group differences, but also found that only the SSD and SRD groups demonstrated a significant difference in interhand tapping disruption. Unexpectedly the GRS group showed no asymmetrical tapping decrement. To complicate matters further, analysis of the JLOT errors showed that, for all groups, only left hand concurrent tapping significantly affected performance accuracy. Thus the only effect which discriminated between poor and superior spellers was the contrast in right hand tapping disruption.

In brief review, the dual task paradigm infers hemispheric specialization from tapping interference during a concurrent task. It is assumed that the sharing of a hemisphere by two different processes is less efficient than the dedication of each hemisphere to one of the processes. Since finger movements appear to be

controlled by the contralateral hemisphere (Brinkman & Kuypers, 1972), it follows that disruption in tapping performance by a concurrent task indicates that both activities are controlled by the same cerebral hemisphere.

This model does not easily explain the present data. For example the JLOT accuracy data suggests right hemisphere specialization for all three groups. However, the tapping interference results for the poor spelling groups are incongruent with this inference. For these subjects, left hemisphere specialization is indicated by tapping rate asymmetry and right hemisphere specialization by JLOT accuracy asymmetry. In attempting to account for this apparent contradiction, it will be useful to begin with a consideration of variables intrinsic to the paradigm (i.e., conceptual and methodological problems) and those extrinsic to it (i.e., individual difference variables)

#### 4.1 Conceptual and Methodological Problems

The concurrent-task method is more complicated than it first appears to be. Its major ambiguities and complexities stem from the impossibility of measuring processing resources directly and, consequently, from lack of knowledge about the relationship between changes in task performance and changes in the allocation of resources to the task (Hiscock, 1986). Results may reflect the influence of the manual task on the cognitive task, the influence of the cognitive on the manual task, or a bidirectional influence. For example, for poor spellers in the present study, it appears that the JLOT task influences tapping rate in the right hand condition whereas tapping influences JLOT accuracy in the left hand condition. Unfortunately, in the study of Native Indian children (Stellern et al., 1986), JLOT

accuracy data were not obtained. Differences between the good and poor reader groups in the allocation of resources to JLOT processing accuracy could conceivably explain why the Native Indian good readers demonstrated an asymmetrical left hand tapping disruption not found in the present study with the GRS group. That is, the failure to find a GRS left hand tapping interference effect in the JLOT concurrent condition may have been because the GRS group, in contrast to the Native Indian good readers, may have sacrificed line orientation judgement accuracy for tapping speed. This possibility is suggested by evidence that Caucasian's may be less attentive than Native Indians on some visuospatial tasks. For example, McShane and Plas concluded that "the ability of WISC-R Performance subtests to predict [Native Indian] achievement gains in verbally oriented subject areas such as reading and language, may represent an over-utilization of spatial processing strengths...." (1984, p. 64).

Another difference between the present research and that of Stellern et al. (1986), involving allocation of attentional resources, was the use of naming instead of pointing to identify the two lines in the response - choice display that were oriented similarly to the two stimuli lines. While this was done to obtain accuracy data, it is possible that pointing with the left hand would have resulted in greater GRS right hand tapping interference. In addition the naming procedure involved left hemisphere language faculties in each hand condition. Thus the right hand conditions differed from the left in demanding both verbal and manual attentional resources. However right hand tapping disruption occurred with poor readers in both the present study and that by Stellern et al. despite the differences in identifying the pairs of lines (naming vs pointing), suggesting that this procedural

differences was not critical to the experimental outcomes. Further the JLOT validation tests with patients suffering from unilateral disease permitted either naming or pointing (Benton, Varney & Hamsher, 1978) and no differential effect was noted.

#### **4.2 Individual Differences**

Handedness, age, sex and bilingualism are variables which have commonly been found to influence performance in the concurrent activities paradigm (see Green & Vaid, 1986; Hellige & Kee, 1990, for reviews). The present experiment controlled for age, ethnic origin, handedness, but not for sex. The number of boys in each group numbered 12 SRD, 5 SSD and 3 GRS. However it is unlikely that this difference was a significant source of variation since the group contrasts in sex distribution predict that SSD performance should be more identical to that of GRS than that of SRD. That is, the SRD group consisted entirely of boys whereas a majority of girls were present in both SSD and GRS groups. Further, Hiscock et al. (1985) found, with good readers in grades 2 to 5, that boys performed more accurately than girls in a dual-task line orientation judgement experiment, and with significantly less disruption in tapping. These effects are in the opposite direction of those encountered in the present research.

By elimination, individual difference in spelling ability appears to be the most likely variable responsible for the contrast in right hand tapping interference. This hypothesis is reinforced by the replication of the result obtained by Stellern et al. (1986) with Native Indian poor readers (who would likely have been poor spellers). However the speculation that nonverbal spatial tasks, such as the JLOT,

may be late lateralized to the right hemisphere by "default" as language skills develop in the left hemisphere (Le Doux, Wilson & Gazzaniga, 1977). does not account for the apparent hemispheric dichotomy between tapping interference and line-judgement accuracy observed with poor spellers. It is as if these students switched hemispheres for judging line orientation when they switch hands for tapping and that accuracy in the right hand condition was achieved at a cost to tapping performance. In contrast, the inference which follows from the GRS data seems straightforward. Since the only asymmetrical effect was a decrement in accuracy in the left hand condition, it would appear, as expected, that superior spellers performed the JLOT task solely in the right hemisphere.

#### 4.3 Left Hemisphere Visuospatial Dysfunction

It would be easier to accept the idea that the two poor spelling groups switched hemispheres for solving the line orientation judgement tasks if they had shown a difference in either error or rate of line orientation processing between the two hand conditions. Instead, it becomes necessary to argue that the absence of evidence of left hemisphere line orientation processing in the error data represents a sacrifice of tapping rate for spatial accuracy. One problem with this hypothesis is the lack of any accompanying difference in the rate of line orientation processing. Improved accuracy without a reduction in processing rate is not an expected outcome (Hiscock, 1986). Further, it is not apparent why left hand tapping should force a more error-prone right hemisphere spatial processing strategy. Altogether it seems more parsimonious to suggest that the similarities between the three groups in the rate and accuracy of line orientation judgements,

indicates that the poor spellers as well as the good spellers processed this task in the right hemisphere under both right- and left-hand tapping conditions. That is, the SRD and SSD right hand tapping decrement with concurrent spatial processing, resulted from some other cause(s) unrelated to a competition for hemispheric resources.

This interpretation of the data does not negate the evidence brought together in the review of the literature that poor spelling may result from left hemisphere parietal system dysfunction for the spatial ordering of letters in words. It only denies the premise, developed from Witelson's dehaptic evidence (1976) and LeDoux, Wilson and Gazzaniga's (1977) lateralization by default speculation, that poor spellers may have a left hemisphere faculty for line orientation judgement as a consequence of their failure to develop visual-orthographic spelling. While SRD subjects may have a faculty for left hemisphere haptic processing of spatial shapes (Witelson, 1976), this interpretation of the present results indicates that such ability does not extend to visuospatial processing. There is some evidence, mainly in the SRD literature, that supports this re-thinking of the data.

#### **4.4 Specific Reading Disability and Visuomotor Anomalies**

Two studies suggest the possibility that, in specific reading disability, visuomotor coordination may not develop normally. Santostefano (1978) found evidence of deficient visuomotor programming in delayed readers, aged five to nine, when they performed a maze-tracing task. Normal readers discontinued a ballistic (visually unmonitored) strategy at age seven whereas the delayed readers did not do so until age eight (grade 2) at which point both their visual scanning and

manual activity slowed down to well below the level of typical readers. Similar differences were found by Wann (1987) in the motor patterns of good and poor writers in grades 4 and 5 (ages 9 and 10). Poorer writers continued to use a greater frequency of braking movements that appeared to result from a visually dependent strategy for making corrections to movement trajectories. Wann concluded that these writers had not yet made the transition to "planned" trajectories. This statement recalls Kimura's (1982) study, reviewed in Chapter 2, which found evidence that the pre-programming of manual movement sequences occurs in the left hemisphere parietal region. Poor writing and spelling may therefore represent a failure to develop programs which can then be run off without excessive visual monitoring. Evidence from brain-damaged patients who have no impairment in writing or spelling but who are unable to read their writing (Harris & Coltheart, 1986), may be illustrative of the non-visual nature of left hemisphere parietal pre-programming.

There is convergent evidence from another source which supports the concept that visual-orthographic accuracy in spelling may involve pre-programming of hand movement patterns. In the introduction (see Chapter 1), studies were cited which had found evidence for a transition in early adolescence to a visual-orthographic spelling strategy (Nolen & McCartin, 1984; Smith, 1992). Research which has studied the development of eye-hand coordination in the reaching movements of children aged 5 to 11, may provide some insight into this early adolescent transition. Hay (1979) observed that ballistic movements at age 5 were replaced by a predominance of visually guided movements at age 7. From ages 9 to 11 there was progressive integration of temporal (ballistic) and spatial

(visual) components of movements with mature reaching skills emerging at about the age of 12. In an analogous study Mounoud, Viviani, Hauert, & Guyon (1985) speculated that the pre-adolescent integration stage involved construction of representations appropriate to the fully developed (early adolescent) skill. It is tempting to speculate that visual-orthographic spelling patterns are similarly pre-programmed before adolescence and become fully available for use only after about age 10. Thus the continuation of a visually dependent strategy in poor writers, observed by Wann (1987), may indicate an arrest in this process.

It is not clear whether the results of these studies are relevant to specific spelling disability. However, since both SSD and SRD have been found to be associated with handwriting deficits (Share et al., 1987) this possibility cannot be readily dismissed. Perhaps the most significant result of the present experiment is to bring this question into focus as a significant research issue. Studies which have found visuomotor anomalies such as crossed eye-hand dominance to be associated but not predictive of reading disability (see Porac & Cohen, 1976, for a review) may have been addressing the wrong question. Such deficits may be a sufficient cause of spelling but not of reading disability.

#### 4.5    Summary

This chapter has considered various sources of influences which might account for the test data. Spelling ability appeared to be the most likely cause of variations in dual-task performance between the three early adolescent groups. Research, which examined the manual fine motor skills of children with learning problems, supported the hypothesis that poor spelling may be associated with

excessive committment of visual resources to the writing process. It was theorized that this may be a cause of spelling but not necessarily reading disability.

The following chapter presents an overview of this research project and considers directions for future study.

## Chapter V

### CONCLUSIONS AND IMPLICATIONS

This study was designed to contribute to an understanding of underlying cerebral strategies relating to spelling ability in early adolescent students who differ in reading and spelling abilities. The subjects performed a dual-task interference procedure which required solving spatial line orientation problems while simultaneously tapping the index finger of either the left or the right hand. Task interference was assessed from decrements in line orientation judgement rate, accuracy and/or tapping rate over single task baseline conditions. The data was analyzed to determine whether there was significantly greater interference in either the right or the left hand experimental conditions.

According to the dual-task paradigm, an asymmetrical decrement in performance supports the inference that the tapping and the spatial tasks are competing for resources from the same hemisphere. Because the finger-tapping movement of the hand is primarily controlled by the hemisphere on the opposite (contralateral) side of the body, greater interference between one hand and the spatial task suggests that these activities are primarily controlled by the contralateral hemisphere.

One aspect of this study was a partial replication of a study with Native Indian children (Stellern et al., 1986) using a Caucasian population. Stellern et al. employed verbal and line orientation judgement concurrent task procedures to

determine whether their Native Indians subjects were right hemisphere-dominant for language. This hypothesis was not supported, however post hoc analyses found that the spatial task discriminated between reading levels. Good readers experienced greater left hand tapping disruption and poor readers experienced greater right hand disruption. The basic premise of the present research was that this effect may have been a function of spelling rather than reading ability.

The project was also influenced by Frith's (1980, 1985) research with poor spellers who differ in reading ability and her general theoretical stance which argued for the need to consider both constitutional and environmental interactions involved in learning processes. Frith suggested that children with problems of spelling only and those with both reading and spelling problems may have experienced arrests at different stages in the development of mature reading-spelling skills. While a large volume of research has found that a lack of phonological awareness may arrest reading progress (Wagner & Torgesen, 1987), Frith's research stands virtually alone in its premise that there may be an analagous road-block to spelling skill.

Building upon other research (e.g. Bruck & Waters, 1988) which found that SSD and SRD spellers had greater difficulty with the ordering of the spatial rather than the phonological components of words, the present project was interested in finding similarities between SSD and SRD in spatial processing. The reasoning was quite simple: an arrest in a spatial component of spelling might be accompanied by differences in left hemispheric spatial processing of non-alphanumeric stimuli.

This hypothesis was encouraged by a review of research from neuropsychology and language arts which provided convergent support for a separation between

spelling and reading functions. A variety of evidence pointed to the involvement of the temporal lobe in direct phonological print decoding and the parietal lobe in a parallel, less direct process, involving grapheme phoneme conversion processes. The left hemisphere parietal system was identified as a likely locus for spelling functions from neuropsychological studies of brain injuries. Other research identified this as a site of possible dysfunction in SRD subjects. This data prompted the hypothesis that SSD and SRD may be similar with respect to parietal system deficits in the programming of spelling patterns but different in that reading disability may additionally involve temporal lobe problems with the phonological processing of print. The spatial dual-task procedure was used as an inferential test for parietal lobe function.

### **5.1 Findings Related to Existing Research**

An extensive literature search failed to turn up any studies which had compared the performance of SSD and SRD subjects on non-alphanumeric tasks. The existing research has concentrated on comparing differences in spelling patterns between the two groups and cannot be unambiguously interpreted since instructional emphases on phonics or sight-word strategies is not reported. A distinct advantage of the present methodology was the absence of this potential history confound.

Comparisons with other research is therefore limited to studies which have examined nonverbal processing in children with reading disabilities. The findings of the present research replicate those of Stellern et al. (1986) for Native Indian poor readers. However the GRS group in the present project did not demonstrate

the left hand disruption experienced by the good Native Indian readers. It was speculated that this difference may have been due to a greater attentiveness on the part of the Native Indian subjects to the visual rather than the motor requirements of the task.

Similarities between the good and poor spellers in the accuracy and rate of line orientation judgement, under right hand tapping conditions, prompted a theoretical shift in the interpretation of the right hand tapping disruption experienced by the SSD and SRD groups. Studies which had found inefficient visual control of fine motor manual activity in delayed readers (Santostefano, 1978; Wann, 1987) were cited in support of the hypothesis that this deficit, rather than hemispheric resource competition, was responsible for the right hand tapping interference effect.

## **5.2 Conclusions and Implications from this Study**

It can be concluded from this study that both good readers/poor spellers (SSD) and poor readers/poor spellers (SRD) differ from good readers/superior spellers (GRS) in demonstrating right hand interference in a concurrent tapping spatial orientation judgement task. It cannot be unambiguously inferred from these results that poor spellers process this spatial task in the left hemisphere whereas good spellers do not.

### **Theoretical Implications**

The major finding of this project was that spelling rather than reading ability predicted right hand tapping decrements in the concurrent task condition. Several studies with reading disabled populations have found bimanual coordination

deficits in tasks which require precision of timing between the two hand (see Gladstone et al., 1989, for a review). A question for future research is whether such deficits also accompany specific spelling disability.

The similarities between SSD and SRD in the dual-task experiment indicate that the two groups have in common a visuomotor anomaly that is not restricted to the processing of alphanumeric symbols. It remains an open question whether this anomaly is related to a left hemisphere parietal system motor programming deficit that affects the successful development of visual-orthographic skill in spelling. Regardless, future research into the cerebral origins of reading disorders may be informed by the use of SSD controls in order to differentiate factors specific to reading as distinguished from spelling disability.

#### **Instructional Implications**

Lamme (1982) stressed that some children are pushed into handwriting before they have acquired adequate pre-handwriting skills and that this may result in poor writing habits that are very difficult to correct later. In a similar vein, Kirk (1983) argued that learning to read precedes learning to spell and that spelling disability may result if insufficient time is allowed for consolidation of learning in one area before attempting to integrate a new set of rule systems. The results of the present study support the need to consider reading and writing as independent subjects in the primary grades. The dual-task procedure used in this project might serve as an appropriate normative means for determining writing readiness as it provides an indication of both hand dominance and perceptual-motor integration.

#### **Recommendations for Further Research**

Two general recommendations arise out of the findings of this study. First that research into the etiology of reading disorders would benefit from including SSD subjects as controls. This may provide an effective means of isolating the variables which are specific to reading disability. Second, that more research attention be allocated to the study of the visuomotor maturational prerequisites for learning to write. Simner (1981) has found that faulty letter stroke patterns, learned before entering school, are not only difficult to correct but also strongly predictive of school failure. Further, there is a large body of research which has found correlations between motor anomalies and reading disability (Gladstone et al., 1989). It is conceivable that some forms of reading and spelling disability are secondary manifestations of neuromotor disorders (e.g., crossed eye-hand dominance) resulting from premature writing. The equivocal support for the role of motor coordination as a predictor of reading difficulty (see Simner, 1983, for a review) may be due to the confounding presence of good readers/poor spellers.

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**Appendix A**

**Individual Subject Demographics and Test Scores**

**Poor Readers/Poor Spellers (SRD)**

Individual Subject Demographics and Test Scores

Poor Readers/Poor Spellers (SRD)

Age	GR	Rdg	Sp	Base Line Tapping Decrement		Concurrent Tapping Decrement		Concurrent JLOT rate		JLOT Number of Errors		
				RH	LH	RH	LH	RH	LH	Base	RH	LH
14.4	7.8	5.0	4.0	62	54	11	16	12	24	1	1	1
14.2	7.8	3.0	3.5	65	65	26	0	30	15	1	0	1
11.6	5.8	2.5	3.0	54	49	9	4	13	38	2	3	3
12.3	6.8	2.5	3.3	72	62	8	3	0	33	1	3	4
11.8	6.8	2.5	2.5	57	50	5	0	33	33	0	0	0
12.1	6.8	3.0	3.7	59	48	10	4	0	57	1	1	2
12.0	6.8	4.0	4.5	74	76	8	12	20	10	0	2	1
13.3	6.8	4.5	3.5	75	64	16	0	20	0	2	2	2
13.1	6.8	4.0	3.8	70	57	23	11	8	0	0	2	1
12.2	6.8	4.5	4.5	77	72	0	3	30	20	0	3	2
13.2	7.8	4.0	4.5	70	60	6	2	18	9	0	1	1
12.9	6.8	4.8	3.0	67	58	23	24	20	10	2	1	2

Good Readers/Poor Spellers (SSD)

13.8	7.8	7.0	5.0	60	58	8	0	75	25	0	2	0
12.9	6.8	12.9	6.0	75	72	8	0	20	0	1	1	1
13.4	6.8	12.9	6.0	76	63	5	8	9	18	1	2	2
13.8	7.8	9.0	4.5	68	54	9	2	10	20	1	1	1
12.6	6.8	7.0	4.0	63	62	9	2	13	13	2	1	3
12.1	5.9	8.0	4.5	51	52	9	2	28	0	1	0	1
12.9	6.8	10.0	6.0	77	56	9	2	0	18	1	1	1
12.8	7.8	11.0	6.5	72	46	18	2	10	20	2	2	2
13.7	7.8	11.0	7.0	66	62	8	10	20	0	1	0	2
12.8	6.8	9.0	6.0	73	63	10	3	8	0	1	2	4
13.1	7.8	11.0	3.5	74	63	22	16	13	10	0	1	1
12.9	6.8	8.0	6.0	70	53	3	4	16	10	0	2	1

Good Readers/Superior Spellers (GRS)

12.3	6.8	6.0	12.9	67	66	2	6	0	33	0	0	2
11.5	6.8	12.9	12.9	67	56	2	2	0	14	0	0	1
11.8	6.8	10.0	12.9	68	47	2	0	16	16	0	1	1
12.6	7.8	12.9	12.9	66	55	2	4	8	0	1	0	0
11.7	6.8	6.0	10.0	73	61	1	10	38	15	0	2	1
12.4	6.8	8.0	12.0	66	61	3	2	8	0	1	0	1
12.6	6.8	10.0	12.9	70	67	11	3	33	0	0	2	0
13.7	7.8	9.5	12.9	83	76	2	0	9	18	1	2	1
13.4	7.8	9.5	10.0	77	75	5	3	9	18	0	1	2
13.9	7.8	7.0	12.9	70	64	2	0	10	20	1	1	1
13.2	7.8	12.9	12.9	73	55	2	12	9	16	1	0	2
11.6	6.8	10.0	9.0	73	58	2	9	20	30	0	1	0

RH = Right Hand  
 Gr = Grade Placement  
 Rdg = Reading Grade Level

LH = Left Hand  
 Sp = Spelling Grade Level