LAKEHEAD UNIVERSITY

A TACHISTOSCOPIC STUDY OF READING RELATED OPERATIONS IN AVERAGE READERS AND THOSE EXPERIENCING DIFFICULTY

by

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A THESIS

SUBMITTED TO THE FACULTY OF ARTS

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF ARTS

DEPARTMENT OF PSYCHOLOGY

THUNDER BAY, ONTARIO, CANADA

JUNE 1989

ISBN 0-315-55727-3

ABSTRACT

Thirty elementary school children were classified into equal groups of poor and average readers. In a series of four experiments, subjects were requested to provide vocal responses to tachistoscopically presented stimuli representing an array of reading related tasks. Poor readers maintained a performance throughout two experiments suggesting a left hemisphere deficit, and the persistence of a serial approach to verbal processing characteristic of right hemisphere stimulus entry in normals (Bub and Lewine, 1988). It was hypothesized that normal readers were induced to perform in a manner conforming to Kershner's (1983) model of learning disabilities, and the performance of poor readers in this study. The use of morphographic analysis (Dixon and Engelmann, 1979) and the exploration of prolonged stimulus exposure to individual hemispheres were proposed as novel methods of reading remediation. A tentative experiment on metacontrol revealed an inconsistency in structural and semantic preferences to a target word in the left visual field of poor readers.

ACKNOWLEDGEMENTS

The author would like to thank the following for their assistance and cooperation:

The Superintendent of Special Education, and the principals of the Lakehead District Catholic School Board, for allowing me into the Board's schools.

The parents who permitted their children to participate in the study, but especially the children themselves.

Dr. E. Bauman and Dr. M. Dilley, the former for his research supervision and the latter for her assistance over the last three years and two theses.

Dr. J. Jamieson, for his open door stats clinic.

Ms Rhonda Kelly, for her efficient manuscript preparation.

With my student status at Lakehead ending, I would like to thank all my professors and the departmental secretarial staff for their contributions to my education in Psychology.

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The notion that reading disability may be linked in someway to unusual hemispherical asymmetry surfaced in the 1930's (Orton, 1937). Orton's hypothesis has been construed as suggesting that deficits arise from insufficient acquisition of language specialization by the left hemisphere (Kershner, Henninger, and Cooke, 1984), or from a failure of both hemispheres to establish any dominance for a number of reputedly language associated behaviours (Naylor, 1980). In any case, the resulting "mixed" dominance is thought to promote interhemispherical competition, and thus poor language ability.

Orton's work preceded a period of visual lateralization research with normal and clinical populations that flourished in the 60's, 70's and early 80's, but whose intensity has now subsided. It wasn't until 1970, however, that normal and poor readers were compared on recognition of words presented simultaneously in both visual fields (McKeever and Huling, 1970). Olson (1973) was the first researcher to test average and poor readers for unilateral word recognition, although Forgays (1953) tested children reading normally for unilateral word recognition.

The accumulated results are not consistent, with many studies differing additionally in stimulus input factors, and stimulus and subject characteristics. Upon review, the literature has elicited comments that range from "unsatisfactory" (Young and Ellis, 1981, p. 188) to "meaningless" (Naylor, 1980, p. 543). Moscovitch (1986), breaking ranks with more stringent reviewers, was kinder in his judgement of visual laterality studies comparing normal and disabled readers. Adopting relatively more relaxed criteria for evaluation, he found evidence in studies meeting his criteria that word identification is as strongly lateralized in right-handed poor readers as in normals. That is, both groups show a right visual field (RVF) advantage in word identification.

Moscovitch's conclusion, the inconsistency of results in the literature, and the procedures used to obtain these results will be dealt with at length later in the paper.

The disparate findings obtained from the investigation of reading disability and laterality have spawned an array of theories, most of them clever, logically sound and rarely wholly refutable or defensible. Some of the theories, like Orton's hypothesis, are relevant to the present study and are outlined below.

Accentuating the developmental implications of Orton's work, Bender (1957) proposed a maturational lag hypothesis that defined reading problems in terms of retarded development of aptitudes relevant to good reading. Some considered the lag to be evident in delayed cerebral specialization of the hemispheres (Lenneberg, 1967), and others have postulated a delay in general development of the whole nervous system (Satz and Sparrow, 1970).

Kershner (1983) summarized another popular view, coined the transmission deficit hypothesis. Information shuttled across the corpus callosum and/or other commissures is thought to be degraded or delayed, resulting in various language processing deficits. Several variants of this hypothesis are extant: (a) the hemispheres cannot integrate late stage refined products of processing, (b) a respective hemisphere cannot discharge products of early stage elemental intrahemispherical processing to its analogue for further processing, and (c) the callosum interferes with complex inhibition/facilitation activity between the hemispheres.

A number of studies suggesting an unusual right hemisphere presence in task performance of the reading disabled were reviewed by Corballis (1983). Arguments supporting this possibility endorse (a) either a LVF advantage of poor readers over normal readers (Marcel, Katz, and Smith, 1974) and gifted normal readers (Kershner, 1977) in word recognition, or (b) the interpretation of dyslexic performance on lateralized and nonlateralized tests (that in normals would indicate abilities strongly associated with the right hemisphere) as suggesting the presence of hemispherically diffuse right hemisphere abilities (Gordon, 1980; Witelson, 1977). Corballis (1983) specified the latter observation not as an account of a LVF advantage, but as a description of processing locked into a right hemisphere mode, as if the dyslexic had two right hemispheres. Witelson speculated that bilateral engagement of what is considered a right hemisphere (RH) mode might negatively influence left hemisphere (LH) language processing.

Capacity and selective hemispherical activation are fundamental to two information processing based theories of interest. The dual processing, limited capacity model explains task performance asymmetry as "... an interaction between the distribution of task specific processing demands across hemispheres and the availability and efficiency of attentional resources drawn from anatomically separate left hemisphere and right hemisphere supply pools of limited quantity" (Kershner, 1983, p. 70). Reading impairment might arise from differential arousal of the two hemispheres (Posner, 1975), and/or overloading of a hemisphere through excessive processing demands or interference and subsequent engaging of the second hemisphere for ancillary processing (Hellige, Cox and Litvac, 1979). In average readers, this engagement may expedite language processing. In the reading disabled, however, a possible lack of interhemispheric integration of unilateral processing products, (ie. a lack of cooperation), may lead to reading deficits.

The second information processing based theory addresses selective activation of the hemispheres (Kinsbourne, 1975). Actual performance asymmetry is presumed to be small and constant, with increased magnitude and variability the result of differential attention. Attentional shifts can be "primed" by (a) stimulus location, (eg. RVF or LVF); (b) the knowledge or expectancy of a specific kind of stimulus; (c) practice; or (d) simultaneous performance of concurrent tasks. When attention is increased in a given hemisphere, a perceptual orientation advantage may result in that hemisphere for stimuli projecting contralaterally as opposed to ipsilaterally. For the reading impaired one might infer some kind of dysfunction in the dynamics of intra- and interhemispheric processing (Kershner, 1983).

Kershner's proposed hybrid model combines elements of the dual processing, limited capacity and selective activation models, and circumscribes dyslexic language deficits inside a perimeter of unilateral capacity limitations for the left hemisphere, selective overactivation of its analogue, and difficulty in coalescing the products of unilateral processing of verbal material.

The most important corroborating phenomenon for the information processing based theories is that of asymmetry reversal in task performance, although the perhaps less dramatic increments and reductions of asymmetry are also present in the literature, and fit into information processing models just as well. Asymmetric performance reduction, increase and reversal have been achieved in a number of dichotic and visual laterality studies with normals, and with dyslexics to the exclusion of normals in studies employing the same experimental manipulations. Such studies have deliberately altered the priming variables discussed above and/or subject strategy, with instructions in task execution. Thus, not only does performance asymmetry have an irregular pattern across the reading disability literature, it has also been directed successfully intra-experimentally.

The tachistoscopic technique for studying lateralization is based on the arrangement of neural pathways in the visual system. Optic fibres from the outer or temporal half of each retina extend to the ipsilateral lateral geniculate nuclei of the thalamus. Those fibres of the optic nerve originating at the inner or nasal half of each retina decussate (crossover) at the optic chiasm, and synapse with cells of the geniculate nuclei contralateral to the retina of origin. Travelling ipsilaterally, fibres from the thalamus connect with the visual cortex of each occipital lobe.

The effect of this neural wiring on information transmission is such that during tachistoscopic foveal point fixation, information from the right visual field (RVF) is routed to the left hemisphere. Transmission is accomplished via the temporal and nasal hemiretinae of the left and right eyes, respectively. Information concerning stimuli in the left visual field (LVF) travels to the visual cortex of the right hemisphere, the process initiating in the left nasal and right temporal hemiretinae. During a tachistoscopic trial, iinformation can be directed simultaneously to both hemispheres with bilateral visual field (BVF) stimulus exposure, or differentially with either LVF or RVF stimulus presentation.

The present tachistoscopic study is composed of four experiments that require subjects to execute (a) letter/letter, word/word and word/pseudoword stimuli same-different decisions based on shape and sound; (b) word/word and word/pseudoword identification with and without inspection fo stimuli prior to testing; (c) word/word same-different decisions dependent on semantic association, and (d) stimulus word/response item matching, the latter selected from an array of items providing for a visual, phonological, concrete semantic or abstract semantic match.

As mentioned above, reviewers of divided visual field research have not been hard pressed to find methodological irregularities with which to fuel their critiques. One of the papers reviewers regularly invoke is that of Young and Ellis (1981), who have specified what they consider the minimum methodological requirements of studies of proper design. The present study has tried to satisfy some of these criteria, additionally considering some of Moscovitch's (1986) and Naylor's (1980) and Naylor et al.'s (1980) suggestions. What follows directly below is s summary of methodological considerations.

1. Ensuring similarity of recognized stimuli.

Concern has been expressed over the random selection of words for use in identification and recognition procedures. There is some evidence that the processing of concrete imageable words produces smaller performance asymmetry than more abstract words (Ellis and Shepherd, 1974; Hines, 1977), the latter type being favoured in RVF exposure. Jorm (1979), in a paper on reading ability, stated that concrete imageable words are more easily recognized by poor readers. Results, so the argument goes, are suspect if hemisphere and/or group performance comparisons are made from tests using unidentified, mixed concrete and abstract stimuli.

The present study required all subjects to execute a semantic association task. Concrete and abstract words were used in construction of the task, and word identification was requested after every association trial for identified concrete and abstract stimuli.

2. Ensuring equivalence of cognitive processes.

Young and Ellis (1981) proposed that performance asymmetry differences between good and poor readers may reflect differences in reliance on lexical knowledge, or grapheme to phoneme conversion. They cited evidence that the latter reliance, if tapped, results in a larger RVF advantage (hence greater asymmetry) than a reliance on lexical knowledge, perhaps more bilateral in nature. Subjects in the present study were asked to match word/word and word/pseudoword pairs based on shape and sound. Additionally, identification was required for the above stimulus pairs (which were not semantically categorized). It was hoped this array of tasks would address the concerns of Young and Ellis regarding the use of naming tasks, as well as their comments on the possibility of naming/appearance strategy overlap in matching tasks.

3. Comparing readers matched on reading ability and age.

Controlling for chronological age may be necessary to avoid age related developmental differences in groups, but with good and poor readers an unwelcome result of equal ages may be groups differing in reading ability. Obviously, if the mismatch is too extreme, group differences would be suspect. The present study used words from reading and spelling material (Anderson and Groff, 1968) selected to be one year below actual grade levels for poor readers, while normal readers worked with words chosen from their actual grade levels.

Further, if any of the variants of the maturational lag hypothesis have credibility, balancing groups for age may be insufficient. Therefore, the present study used age as a covariate in statistical analysis.

4. Word identification.

Moscovitch (1986) commented that word or word-like letter string identification are the tasks most consistent in producing a RVF advantage. By restricting non-linguistic factors (which may involve bilateral or right hemisphere activity) to processing prior to specific linguistic processing, he thought results would be more likely to reflect differences in asymmetry with verbal material. Therefore, he recommended word and word-like letter string identification. As already discussed, the present study employs both matching and identification tasks.

5. Subjects must read at least at a grade 3 level. Citing studies of Israeli children, Moscovitch (1986) argued that normal children reach a level of proficiency in their native language around grade 3 that increases the probability of obtaining stable performance asymmetry, (ie. an RVF superiority). Subjects in the present study were required to correctly read word stimuli in two of four experiments. This identified all subjects as capable of reading aloud words selected at a grade 3 level or above.

6. (a) Full scale IQ should be within or above the normal range for both groups.

(b) A dyslexic subject is one who reads below grade level despite having the emotional and intellectual capacity to read normally.

It is unknown if Moscovitch's (1986) criterion (a) was met in the present study. Only a few of the below average reading group had received intelligence testing, and it was beyond the time resources of the experimenter to test all subjects. Naylor (1980) considers IQ a potentially confounding factor. Interestingly, in a study appearing in the same year as her reading disability/laterality review, groups were measured on age, hyperactivity and scores on the Peabody Individual Achievement Test, with no use of a formal IQ. McKeever and Van Deventer (1975) used IQ as a statistical covariate, but noted there was no significant correlation between IQ and any of their dependent measures. Similarly, Gross, Rothenberg, Schottenfeld and Drake (1978) found no significant correlations between WISC FIQ, VIQ and PIQ and stimulus duration thresholds for identification of lateralized visual letter stimuli by reading disabled and normal children. Kershner (1977) employed IQ as a covariate, but this procedure did not alter the significance of visual field differences in the word recognition performance of gifted children and poor readers. All subjects of the above studies, however, had IQ's in or above the normal range. In the present study, all subjects were evaluated by educators as being average or above average in aptitude in at least one academic subject (eg. social studies, science).

Moscovitch's criterion (b) for dyslexic membership may be considered by some to be generous. A significant number of reading disability/laterality studies have poor reading groups with a mean reading level at least two grades below their mean grade level or age expectancy (for example Gross, Rothenberg, Schottenfeld and Drake, 1978; McKeever and Van Deventer, 1975; McKeever and Huling, 1970; Pirozzolo and Rayner, 1979; and others). Subjects in the present study were identified by educators as average or poor readers, using reading performance relative to grade level as a criterion.

7. Stimulus pool, memory, and laterality.

Naylor, Lambert, Sassone, and Hardyck (1980) cited the experiments of Hardyck, Tzeng and Wang (1977; 1978), the latter team reporting (a) a gradual increase in performance asymmetry with a small pool of verbal stimuli used over many trials and (b) a decrease or disappearance in asymmetry with a large stimulus pool. Naylor et al. suggested that limited pairs of stimuli are quick to enter short term memory store and experimental results reflect lateralization of the memory store, not necessarily verbal or visuospatial processing. The present study employed a large stimulus pool, and items present study employed a large stimulus pool, and items that were used twice were exposed to subjects in two testing sessions six months apart. The semantic association experiment results, however, do reflect the influence of a memory component, because subjects were required to inspect an item list intermittently until all word pairs had been correctly identified during the semantic association tasks.

8. Word pair letter length.

In the attempt to control for differences in reading ability between the present study's two experimental groups, discussed above, a separate problem was created. Words selected at lower grade levels tended to be shorter in length than words selected at higher grade levels. Even though word pairs from any one grade level used in the various tasks of this study were carefully constructed to ensure uniformity, a problem with word pair letter length differences across grades remained. The very detailed work of Young and Ellis (1985) and Bub and Lewine (1988) strongly supported a differential effect of word length on word identification and lexical decision in the visual fields. Performance with LVF stimuli appears to decrease as a function of increasing word length, whereas RVF performance is affected negligibly.

This finding has two ramifications in the present experiment. First, within group hemispherical asymmetry results may have been maximized through the use of paired stimuli. Second, between group comparisons and group by field interactions may reflect the influence of differential item letter lengths. Although the latter point was initially accounted for with the use of letter length as a covariate, odd looking effects at the beginning of data analysis prompted a call to an SPSS statistician. The MANOVA programme is not capable of directing multiple varying covariates to specific target variables, but uses linear combinations of covariates. As this procedure was unsuitable, only the constant covariates age and sex were retained for mixed model analysis.

Following inspection of the descriptive statistics of Bub and Lewine (1988), it appeared that error rates and reaction times changed very little over a one letter difference in item length. In the present study, the range of mean pair letter length differences in any one experiment over groups, visual fields and tasks is less than one letter.

There was no difficulty completing ANOVA's of same hemisphere accuracy and response latency differences between groups, using age, sex and mean pair letter length as covariates.

9. Fixation Control.

A regular observation made by reviewers of tachistoscopic laterality research is the number of studies lacking a formal method of fixation control (see almost any review, except Moscovitch, 1986). Central fixation prior to stimulus exposure has been monitored with electro-ocular devices, or confirmed by requiring a subject to correctly report a centrally placed stimulus in addition to the target stimulus. The former were not available to the experimenter, and there is sufficient evidence of asymmetry induction by the latter method to warrant its avoidance (Beaton, 1985; Kershner, Thomae, and Calloway, 1977; Sergent and Hellige, 1986; and others). Given the right proximity and seating height of the experimenter, experimenter controlled stimulus exposure, mixed visual field exposures (LVF, RVF, BVF), and consistent testing of a subject for gaze alignment, all but a few stimulus exposures should coincide with correct gaze alignment in tachistoscopic studies.

10. Sex differences.

After reviewing the developmental literature for sex differences in asymmetry, Bryden (1982) concluded that laterality effects are weaker in children than adults, but there was nevertheless an indication of greater bilaterality for both language and spatial processes in female children. In the general population of poor readers, male children appear to occur with greater frequency. With unequal numbers of each sex within and across groups, the removal of seven female subjects from this study would have achieved sex homogeneity. The consequences of such an adjustment would have been a loss of power in analyses, and unequal group sizes. It was decided to use sex as a covariate in ANOVA and mixed model analyses.

The following experiments were conducted with the hope of acquiring insight into reading ability within the context of asymmetry patterns, utilizing diverse data collected from the same experimental subjects. From a student's perspective, the study seemed to be an excellent vehicle for a general introduction to visual laterality research, and an opportunity to achieve a broader perspective into a very pressing problem, learning disabilities.

For clarity of exposition, the order of experimental report differs from the actual sequence of performance, which was 1-4-2-3. Experiment 1 inquires into the letter matching abilities of average and poor readers, who were instructed to use the physical and phonological characteristics of letter pairs as criteria for matching.

Experiment 1

Experimental results in letter identification and letter pair matching with normal children are less stable than asymmetry findings in studies employing words, according to Beaumont (1982), presumably because letters can be processed as physical or nominal stimuli, ie.

coded spatially or phonologically. Beaumont's literature review summarized accumulated results as unclear, letter stimuli producing a modestly superior number of RVF effects along with some LVF effects and neutral results.

Similarly, findings with reading disabled subjects are mixed. For example, McKeever and VanDeventer (1975) obtained nonsignificant group by field interactions in vocal reaction times to unilaterally presented letters at two different exposure speeds, with normal and poor readers. Bouma and Legein (1980), in a correlational study, did not demonstrate any relation between exposure field and group, using fraction correct and latency of correct responses as measures in letter identification. Utilizing duration thresholds of letters to obtain a predetermined correct percent of trials in letter identification, Gross et al. (1978) did obtain significantly longer mean thresholds in the LVF than the RVF for poor readers, but not in normal readers.

Outcomes in studies using adult subjects, as reviewed by Beaton (1985) and Beaumont (1982), have been less equivocal. Physically identical letters (AA), the above reviewers concur, produce superior LVF accuracy and reaction times in matching tasks. Nominal identity pairs

(Aa), elicit a RVF advantage.

Boles (1981), however, has effectively challenged the veracity of these reviews. Conducting a comprehensive multi-experiment study that manipulated stimulus input and response mode factors, he reported what were for him perplexing results. Boles obtained a RVF advantage in latency times and error rates for "same" physical matching trials in about half of his experiments, and no asymmetric results for same nominal matching. In one of six experiments there was a significant RVF superiority for "different" responses.

Dogged by these results, Boles plunged into the literature, commenting after his review, "... what has not been recognized is that the literature is by no means in complete agreement on the direction of asymmetry in letter matching" (p. 287). He concluded letter matching must be viewed as highly variable.

Experiment 1 of the present study is essentially a duplication of letter matching investigations, however it does differ in some respects from the majority of earlier studies. First, it has far fewer trials, the tasks thereby retaining their novelty for the subject. Second, the two matching tasks, ie. by shape and by sound, are kept separate, and not mixed into one block. Third, subjects receive explicit instructions on when to make discriminations visually, or phonologically. The presumed influence of stimulus type is supplemented with experimenter directed processing guidelines.

Of interest here are patterns of performance within and between groups, and any relationships emerging between consistency (or inconsistency) in field advantages and performance across the two tasks.

METHOD

Subjects

The following text describing the selection and grouping of subjects is pertinent to all experiments, because the same subjects were used throughout the study.

Subjects were recruited from the Lakehead District Catholic School Board, after receiving permission to conduct research from the Superintendent of Special Education, permission from principals to enter their respective schools, and parental consent for each subject.

Educators (principals, classroom teachers and special education teachers) were requested to recommend right handed elementary school pupils between the ages of 9-12 who were considered average or below average readers, using general reading performance relative to grade level as a criterion. Handedness was determined during the study by instructing each student to write his/her name, and inquiring about the hand used to bounce and throw a ball, hold a knife without a fork, and hold a fork without a knife. None of the students used an inverted hand posture to write their names. Below average readers, at the time of the study, were demonstrating average or above average performance in at least one academic subject, as evaluated by classroom teachers.

All students were screened for (a) uncorrected visual and auditory problems, (b) irregular school attendance (c) ingestion of psychotropic drugs, and (d) serious behaviourial problems and medical disorders.

Data were collected over two sessions separated by about a six month period. Initially, nineteen average and twenty-three below average readers were tested. However, only fifteen of the poor readers were successfully recruited for participation in the second testing period. It was decide to maintain the number of average readers at fifteen too, therefore the testing of average readers was terminated after fifteen had been processed. A drop out rate of about 35% was calculated for the poor reading group.

The subjects were all Caucasian except for one Chinese-Canadian female in the average reading group. This group ultimately consisted of thirteen boys and two girls, with a mean age of 11.33 yrs., SD = .46. The poor reading group was composed of five girls and ten boys, with a mean age of 11.39 yrs., SD = .88.

Apparatus and Material

The subjects viewed stimuli through a Polymetric tachistoscope, model number U-0959. This instrument has a 10.16 cm x 12.7 cm stimulus card aperture, an image distance of 44.45 cm, an exposure time range of 10 ms to 10 sec and operates silently. The preset exposure time for all stimuli of all experiments was 175 ms.

All letters and word stimuli were printed by the experimenter horizontally on white file cards trimmed to 10 cm x 12.5 cm, using the same fine point black felt pen. Upper case letters were 10 mm in size, as were lower case letters with extensions below the printing line. Lower case letters occupying space above the line without extensions were 5 mm in size, while those with extensions were 10 mm in size. The above description of apparatus and material is true for all experiments in the study.

In experiment 1, letter members of visual pairs either were identical, eg. ff, or similar, eg. PR. Phonological pairs were formulated in one of three ways: (a) to sound the same but look different, eg. dD; (b) to sound different but look similar, eg. VW; and (c) to look and sound different, eg. Bz. See appendix A for a list of letter pair stimuli.

Design and Procedure

During the tachistoscopic procedure of all experiments, a subject was first required to direct her/his attention toward a central dot, which served as a focus point. The experimenter, seated directly in front of the tachistoscope and subject at a height permitting inspection of the subject's eyes, then requested the subject to look a little to the left of the dot, look directly at the dot, look a little to the right of the dot, and finally look directly at the dot again. This exercise gave the experimenter some idea of where the subject's eyes would be located in their orbits if she/he was focused directly on the dot.

A hockey goalie analogy was used with subjects to impress upon them the importance of focusing on the dot. The subjects had to be in the centre of the net to be ready to react to any fast shots (stimuli) coming from either side. They were told that if they happened to be looking the wrong way, they would never see a word or letter appearing on the opposite side. Subjects were reminded to focus on the dot before every trial. The above description of the tachistoscopic procedure applies to all experiments in the study.

In addition to task performance, latency to vocal response times were recorded in centiseconds using a hand held digital stopwatch, for three of the four experiments. The watch was activated simultaneously with depression of the tachistoscope's stimulus trigger, and stopped by the experimenter when a subject made a response. Accuracy was stressed over speed when subjects were given instructions.

In experiment 1, each subject was tachistoscopically presented with a total of thirty letter pairs, ten in the LVF, ten in the RVF, and ten flashed bilaterally. Letter pairs requiring same-different discrimination based on shape (visual identity) were exposed successively in one block, separate from pairs requiring same-different discriminations based on sound (phonological identity). Visual and phonological stimuli blocks were counter-balanced for each group.

Subjects were shown on paper the relationship between members of different types of pairs, and instructed in appropriate responses, for each of the visual and phonological discrimination tasks. Five practise stimulus cards were exposed to each of the subjects for each of the tasks prior to actual testing. See appendix A to inspect the subjects' instructions.

Results

Each subject contributed a percent correct score for each of the left, right, and bilateral fields of exposure, and attendant median latency to response times. See Table 1 for group descriptive statistics, and Tables 2 and 3 for a summary of results.

Group main effects, although reported in the text, do not appear in the tables of this study, because of the MANOVA package problem discussed above. However, significant effects are tabled from ANOVAS on same hemisphere data between groups.

Table 1

Group Accuracy and Latency Times In Same-Different Discriminations: Letter Pairs

	Average Readers		Poor Readers	
Variable	M	SD	M	SD
LVF				
Percent correct visual pairs	76.00	11.20	74.90	17.70
Latency (cs) visual pairs	123.47	35.62	139.93	27.51
Percent correct phonological pairs	92.00	10.10	70.70	18.30
Latency (cs) Phonological pairs	126.27	50.23	102.00	24.46
RVF				
Percent correct visual pairs	89.30	12.80	78.70	16.00
Latency (c) visual pairs	119.47	25.41	110.93	21.54
Percent correct phonological pairs	86.70	16.30	84.00	15.50
Latency (cs) phonological pairs	124.73	29.53	101.13	21.81

Table 2

Summary of Significant Effects for Experiment 1: Visual Discrimination of Letters

Within Group Asymmetry Analyses

Variable	Average Readers		Poor Readers	
	LVF	RVF	LVF	RVF
Visual discrimination - percent correct				
Response latency (cs)			-	+

Between Group Asymmetry Differences and Visual Field Effects[a]

Variable	Average Readers	Poor Readers
RVF visual discrimination -percent correct	+	+
RVF response latency (cs)	-	-

Between Group Visual Field Differences

No significant effects (see text for marginally nonsignificant effect)

[a] two identical signs indicates a field effect, different signs group asymmetry differences. A negative sign for response latency indicates significantly less elapsed time.

Table 3

Summary of Significant Effects for Experiment 1: Phonological Discrimination of Letters

Within Group Asymmetry Analyses

Variable	Average Readers LVF	Average Readers RVF	Poor Readers LVF	Poor Readers RVF
Phonological discrimination -percent correct			-	+

Between Group Asymmetry Differences and Visual Field Effects[a]

Variable	Average Readers	Poor Readers
LVF-RVF differences -percent correct	-	+

Between Group Visual Field Differences

Variable	Average Readers LVF	Average Readers RVF	Poor Readers LVF	Poor Readers RVF
LVF phonological discrimination -percent correct	+		-	
RVF response latency (cs)				

two identical signs indicates a field effect, different signs group asymmetry differences. A negative sign for response latency indicates significantly less elapsed time.

Within group repeated measures ANOVAS with Field (left vs right) as the within subject factor were computed for visual and phonological letter pair scores and their accompanying latency times. Average readers were significantly more accurate in making visual discriminations between letter in the RVF compared to the LVF (89.30% vs 76.00%), F (1, 14) = 12.73, p = .003. Poor readers were significantly more accurate in making correct phonological discriminations between letters in the RVF compared to the LVF (84.00% vs 70.70%, F (1, 14) = 5.38, p = .036. Poor readers also took significantly longer to make correct visual discriminations between letters in the LVF than the RVF (139.93 vs 110.93 cs), F = (1, 14) = 7.61, p = .015.

Following the within group tests, a series of Group (average vs poor readers) by Field (left vs right) analyses of covariance were performed with repeated measures on Field, and Sex and Age as covariates, for all visual and phonological letter pairs and latency times. The Field effect for visual discrimination of letters was significant, with subjects making more correct discriminations in the RVF than the LVF (84.00 % vs 75.3%), F (1, 28) = 5.30, p = .029, regardless of group membership. Subjects also took significantly less time to make those RVF visual discriminations (115.20 cs vs. 131.70 cs), compared to their LVF latency time, *F* (1, 28) = 4.90, *p* = .035.

The ANCOVA for correct phonological discriminations produced a significant Group effect, *F* (1, 26) = 7.09, *p* = .013, and Group by Field interaction, *F* (1, 28) = 5.34, *p* = .028. Average readers made significantly more correct phonological discriminations across visual fields (89.35% vs 77.35%). Poor readers' LVF-RVF difference in phonological discrimination scores was significantly larger than that of average readers (13.3% vs 5.3%). Other unreported effects were not significant.

To complete letter pairs analysis, ANOVAS were computed with Group (poor vs average readers) as a between subjects factor, Sex and Age as covariates, and percent correct visual and phonological letter pairs and their respective latency times as dependent variables. Poor readers scored significantly less than average readers when making phonological discriminations with LVF items (70.70% vs 92.00%), F (1, 26) = 10.26, *p* =.004. Poor readers also took significantly less time to make phonological discriminations with RVF items (101.13 cs vs. 124.73 cs), F (1, 26) = 5.65, p = .025. A nonsignificant trend was that of good readers outperforming poor readers in RVF visual discrimination (89.30 vs 78.70), F (1, 26) = 3.23, p = 0.84. Remaining unreported effects were nonsignificant.

BVF accuracy and response latency were not included in this analysis, or any other experimental analyses, for a number of reasons. It was decided to keep the contrasts utilized in mixed model analysis orthogonal, and to control the experiment-wise probability of type I errors. Analysis of results from tasks involving word stimuli would have posed an additional problem. Because word pairs are split in BVF exposure, letter length in any one visual field would have been about half that of unilateral exposures. However, the above considerations did not preclude testing for between group BVF differences, and these are reported near the end of the study.

Discussion

Average readers demonstrated a significant RVF over LVF superiority in visual discrimination, while the performance of poor readers was in the same direction, but nonsignificant. Together, respective group performances produced significantly higher accuracy and shorter times in the RVF. The general direction in performance of poor readers approximated that of average readers, differing in degree. Asymmetry, and accuracy with RVF stimuli of the poor readers trailed that of average readers.

With instructions to discriminate letters using a sound criterion, poor readers exhibited a significant RVF over LVF superiority, while average readers produced a nonsignificant trend in the opposite direction. Subsequently, there was no significant field effect. The poor readers' asymmetry was significantly larger, primarily because of their significantly worse performance with LVF stimuli.

Although the results for average readers are very similar to those obtained by Boles (1981), they do not alter the inconsistency found in the literature. Boles and Eveland (1983), after completion of a follow up study to Boles' 1981 work, concluded that a phonetic or name code is not active in letter matching tasks. Rather, direct visual coding is used in physically identical matches, or a visual generation of one member of a nominal pair, once the other member is perceived.

The above authors' further conclusion that coding used in letter matching is likely bilaterally represented is especially germane. Where dual processing of a verbal stimulus is possible, it is not sufficient to argue for differential hemispherical processing abilities, as if that stimulus is most efficiently coded in one way within one hemisphere. Rather, it is more reasonable to state that initial exposure of a stimulus to a specific hemisphere may expedite the performance of certain tasks, retard that of others, or have no differential impact. Perhaps even the sequence of hemispherical activation is critical; certainly, selective activation can alter asymmetry patterns measured with task performance (Kershner, 1983).

The accuracy results of Experiment 1 demonstrate the transience of performance asymmetry across two simple reading related tasks for both average and poor readers. Assuming the Boles and Eveland (1983) hypothesis is correct, it is unclear why performance asymmetry should appear at all in average readers with such uniform inconsistency in the literature unless dual processing and/or selective (perhaps sequential) activation are operative. Attempting to interpret the results within a more conservative laterality model yields the same conclusion. If more efficient visual discrimination between letters is predicted in the LVF, and a significant RVF effect is obtained, then an advantageous summation of LH and RH processing is strongly suggested.

Similarly, expectations of a significant RVF effect with phonological discrimination followed by nonasymmetry results implies the interplay of attentional/arousal dynamics and dual processing.

Poor readers exhibited different performance patterns than average readers in the experiment. The field effect and general directional similarity in visual discrimination performance of the two groups, combined with the nonasymmetric results of poor readers, may indicate the latter group was performing to capacity. However, the significant RVF effect arising from poor readers' phonological discrimination demonstrated that under certain experimental conditions task performance can be maximized. This raises the intriguing possibility that perhaps patterns of asymmetry can be exploited to make various remedial reading methods more effective.

Control of initial hemispherical stimulus exposure, particularly for extended periods of time, may be worthy of future investigation to determine its potential as a remediation technique.

Response latency is used as a measure of asymmetry in many laterality experiments (see most experiments referenced in this study for RT use or discussion of its use), either together with task accuracy or by itself. Results from this experiment underline the pitfalls of using RT alone. Response latency effects here fall into three categories: (a) shorter time accompanied by superior accuracy, eg. the visual discrimination field effect; (b) shorter/longer times without superior accuracy, eg. average readers' longer processing time with RVF items compared to poor readers' time in phonological discrimination did not produce superior accuracy; and (c) a nonsignificant RT effect paired with superior accuracy, eg. LVF vs RVF phonological discrimination in poor readers.

Categories (a) and (c) above are the most compelling for the detection of performance differences, and four effects falling into (c) would have been missed if RT alone had been employed. It is tempting to interpret the category (b) effect as evidence of a task superiority for poor readers because ability differences are often pinpointed as an inherent weakness of asymmetry studies with good and poor readers (Bryden, 1982). However, it can be argued the effect identifies a more conservative processing style of the average readers.

Experiment 2 continues the use of visual and phonological matching, as well as a "mixed" matching task that presumably involves both types of discrimination. Word/word and word/pseudoword pairs are employed as items. An additional item identification task is nested between matching trials.

Experiment 2

Mention has been made of the division in the reading disability/asymmetry literature, and its reviewers, over the evaluation of findings. Considering six reviews published between 1980 and 1987, two found a lack of evidence for asymmetry differences in poor and good readers (Moscovitch, 1986; Naylor, 1980), two considered accumulated results more or less unclear (Beaton, 1985; Young and Ellis, 1981) and two gave guarded support for further research (Beaumont, 1982; Bryden, 1982).

Moscovitch (1986) limited his comments to research employing word identification. He reasoned that dyslexic children, perhaps weak in verbal coding, might fall back on pictorial strategies during matching tasks and recognition exercises (exclusive to identification), putatively a right hemisphere strength. This comment was followed by a list of cited studies with normal adults demonstrating alteration of the RVF advantage for words when non-identification response modes were used. The inference here not reported by Moscovitch is that obviously normal readers have also performed equally or better with right hemisphere stimulus entry trials compared to left hemisphere stimulus entry trials in word matching tasks.

Pirozzolo and Rayner (1979) required normal and poor readers to select a target word from an array of visual and phonetic foils after tachistoscopic exposure of the target word. Normal readers showed greater asymmetry (from superior RVF performance). Naylor et al. (1980) obtained an RVF advantage for reading disabled but not for normals in a matching task using 6-12 letter word pairs. Witelson's (1976) study employing a word matching task produced no asymmetry in dyslexic or normal reading boys.

A concern over the fluctuation in the use of visual vs phonetic coding is valid if interest in reading group ability goes beyond asymmetry patterns. One way to force the use of grapheme-phoneme conversion is to employ word/pseudoword matching, where the latter component of the pair is orthographically different, but phonetically similar. Such a phonetically regular letter string that has no assigned meaning is sometimes called a pseudohomophone (eg. rose-rowz). It can be seen that visual coding would produce a different response, and phonetic coding is necessary to produce a same response. Although a reading disability literature search did not reveal a study utilizing pseudohomophones (the literature is vast), in normals it takes longer to correctly reject pseudohomophones as real words than dissimilar letter strings in both visual fields (Barry, cited in Bryden, 1982).

A further possible variant of matching tasks would involve pairing real words and words altered to be orthographically and phonetically irregular. If trials with "mixed" (ie. doubly irregular) pair exposures were to be blended with trials using word and word/pseudohomophone pairs, correct decisions should demand visual and phonetic analysis, because a subject would not know from trial to trial whether visual analysis alone would provide sufficient information for a decision. Beaumont (1982) considered letter string matching tasks to produce an RVF advantage, although very short strings could effect a LVF advantage. The normal subjects of Bradshaw, Gates and Nettleton (1977) exhibited LVF superiority in a lexical decision task when the first or last letters of words were altered.

Experiment 2 employed the three matching tasks described above. As in experiment 1, of main interest was performance within and between groups in hemisphere of entry comparisons. Additionally, subjects were required to report their perceptions after every trial. The number of correct pairs seen, and the number of incorrect pairs seen were tallied, while pair letter fragments were not. It was hoped this would provide some idea of how stimuli were processed. That is, would subjects have to rely less on (incomplete) perceptual information and more on their knowledge and skills of linguistics in making decisions, or could they simply report what they saw?

Method

Subjects

See experiment 1

Apparatus and Material

See experiment 1

Design and Procedure

See experiment 1 for a description of the tachistoscopic procedure. Each subject was tachistoscopically presented with a total of forty-five word/word or word/pseudoword pairs, fifteen in the LVF, fifteen in the RVF, and fifteen flashed bilaterally.

Stimulus offset began at 20 mm and ended at 57 mm ($2^{\circ}30'$to $7^{\circ}15'$) depending on stimulus length. An effort was made to keep stimulus letter lengths uniform between the visual fields and stimulus type of each grade; mean differences amounted to fractions of a letter. Below average readers were given stimuli rated one grade below their actual grade levels.

In all visual field presentations, a subject was required to make a same or different response to three types of item pairs. These types were considered visual, phonological, and mixed. Visual pairs contained two real words, orthographically and hence phonetically equivalent, (eg. bottle-bottle). Acoustic pairs were composed of one real word, always on the left, and one pseudoword phonetically matching the real word, but orthographically different (eg. cream-kreem). Mixed pairs had one real word, always on the left, and a variant of the real word that was orthographically and phonetically different, (eg. grown-growm). The guideline for altering words of mixed pairs was to have as few words as possible with more than two letter changes. The majority of alterations were made using one letter change. Please see appendix B for a list of stimuli used in experiment 2.

Three procedures were employed to familiarize subjects with same or different responding prior to actual testing. First subjects were shown on paper the relationship between items in each type of pair and instructed as to what response (same or different) should follow their perception of a particular word pair type. If words looked the same, a "same" response was appropriate. If words looked different but sounded the same, again a "same" response would be correct. Finally, if words looked different and sounded different, a "different" response should follow. See appendix B for verbatim instructions.

After this introduction, a sample of ten stimulus cards from another grade were viewed under normal (non-tachistoscopic) conditions by a subject. These cards were used to familiarize a subject with the deployment of stimuli in the visual fields, and to request same or different responses in order to corroborate a subject's understanding of the introduction described above. The third and final familiarization procedure was a short practice session using nine stimulus cards and the tachistoscope. Words for this session were the same for all subjects, selected from a Grade 2 spelling list.

After a same or different response and a latency time was recorded, a subject was required to report what stimulus pair, or what portion of a pair was seen, and this was also recorded. Each subject was given two examples of how a same or different response could be arrived at after perception of only a portion of a stimulus pair. One example illustrated how a visual comparison could be made, and the other example how a phonetic comparison was possible. Subjects were encouraged to use their word skills.

Results

For each type of stimulus pair in each of the left and right visual fields, a subject provided a score (percent correct), and a median latency to response time in centiseconds. See Table 4 for group descriptive statistics of average and poor readers, and Table 5 for summarized effects from mixed pair matching.

Within group repeated measures ANOVAS with Field (left vs right) as the within subject factor were computed for visual, phonological, and mixed pair types and their respective latency times for each group. None of the effects in this series were significant. Average and poor readers do not exhibit significant asymmetry in times or accuracy in correctly discriminating between word/word and word/pseudoword members of visual, acoustic and mixed pairs.

There were three marginally nonsignificant trends identified. Average readers performed differentially in making correct same-different responses to visual pairs (a 16.00% differences in favour of the RVF); $\underline{F}$ (1, 14) = 4.42, $\underline{p}$ = .054. Poor readers tended to be more accurate with LVF presentations of mixed pairs (a 9.33% visual field difference), $\underline{F}$ (1.14) = 3.90, $\underline{p}$ = .068, and to be faster (72 cs), F (1, 10) = 4.06, p = .072.

Next, a series of Group (average vs. poor readers) by Field (left vs. right) analyses of covariance were performed with repeated measures on Field, with Sex and Age as covariates, for all visual, phonological, and mixed pair types and their respective latency times. ANCOVA using correct responses to visual pairs produced a significant Group X Field interaction; $\underline{F}$ (1, 28) =

Table 4

Group Accuracy and Latency Times In Same-Different Discrimination: Structural Pairs

	Average Readers			Poor Readers		
Variable	M	SD	Mean Letter Length	M	SD	Mean Letter Length
LVF						
Percent correct visual pairs	70.70	21.20	10.32	82.70	16.70	9.69
Latency (cs) correct visual pairs	134.90	34.10		180.93	43.58	
Percent correct phonological pairs	72.00	23.70	10.16	64.00	27.50	9.56
Latency (cs) correct acoustic pairs	179.50	49.18		194.20	56.19	
Percent correct mixed pairs	41.30	14.10	10.24	33.33	25.80	9.56
Latency(c) correct mixed pairs	204.47	59.23		161.27	73.09	
RVF						
Percent correct visual pairs	86.70	14.50	10.48	73.33	22.30	9.65
Latency (cs) correct visual pairs	144.26	48.85		162.67	61.00	
Percent correct phonological pairs	68.00	16.60	10.40	60.00	25.10	9.65
Latency (cs) correct visual pairs	168.00	48.01		209.33	72.48	
Percent correct mixed pairs	36.00	17.20	10.44	24.00	18.80	9.60
Latency (cs) correct mixed pairs	182.60	74.48		233.46	113.15	

Table 5

Summary of Significant Effects for Experiment 2: Discrimination of Mixed Words-Pseudowords

Within Group Asymmetry Analysis

No significant effects (see text for two marginally nonsignificant effects)

Between Group Asymmetry Differences and Field Effects[a]

Variable	Average Readers	Poor Readers
LVF discrimination -percent correct	+	+
LVF-RVF differences -response latency (cs)	-	+

Between Group Visual Field Differences

Variable	Average Readers		Poor Readers	
	LVF	RVF	LVF	RVF
Response latency	+			

[a] two identical signs indicates a field effect, different signs group asymmetry differences. A negative sign for response latency indicates significantly less elapsed time.

6.46, p = .017. Average readers demonstrated a 16.00% performance difference (in favour of the RVF), significantly higher than the 9.39% performance difference for poor readers, which reflected better performance with pairs initially received in the LVF.

An analysis of covariance using correct responses to mixed pairs resulted in a significant Field effect; F (1, 28) = 4.23, p = .049. Subjects responded significantly more accurately (7.00%) when mixed pairs were presented initially to the LVF and not the RVF. There was also a significant Group X Field interaction in the ANCOVA employing latency times for correct responses to mixed pairs. Differences in visual field latency times were significantly greater for poor readers than for average readers; F (1, 24) = 5.06, p = .034. There were four poor readers who did not contribute correct latency times. Differential latency times amounted to 72.18 cs for poor readers, with RVF items eliciting longer times. This can be compared to a 21.87 cs differential latency time for average readers, with LVF items eliciting longer times. Good readers tended to outperform poor readers in the mixed matching task, as was evidenced by a marginally nonsignificant Group effect; F (1, 26) = 4.03, p = .055.

To conclude the analysis of structural pairs, ANOVAS were run with Group (poor vs average readers) as a between subjects factor, Sex and Age and mean pair letter length as covariates, and performance in discrimination and latency times for the three types of pairs as dependent variables. For example, an ANOVA testing for group differences in latency times for mixed pairs presented in the LVF used Group as the BS factor, latency times as the dependent variable, and controlled for differences in Sex, Age, and the letter length of mixed pairs. This analysis was in fact the only significant test; $\underline{F}$ (1, 22) = 4.31, $\underline{p}$ = .050. Average readers took a significant average of 43.39 cs longer to make correct discriminations with mixed pairs presented to the right hemisphere. There were also three marginally nonsignificant effects. Good readers tended to outperform poor readers in RVF visual pair matching, F (1, 25) = 3.25, $\underline{p}$ = .083. There was also a trend for good readers to respond faster with LVF visual pairs, F (1, 25) = 3.88, $\underline{p}$ = .060. Finally, there was a nonsignificant tendency for good readers to be more accurate in the matching of RVF phonological pairs, F (1, 25) = 3.91, $\underline{p}$ = .059. Unreported effects were not significant.

As mentioned in the Design and Procedure section, a subject was asked, after making a response to an item, exactly what was seen. Subjects' descriptions were divided into pairs seen correctly or incorrectly, and their respective latency times compiled. Letters, however many, not reported as components of complete pairs were not considered to form pairs, and were excluded from the analyses reported below. Each subject contributed a sum of pairs seen correctly, and a sum of pairs seen incorrectly, and attendant median latency times, from the left, right and bilateral visual fields. See Table 6 for group descriptive statistics of average and poor readers and Table 7 for a summary of significant effects.

Within group repeated measures analyses of variance with Field (left vs right) as the within subject factor were computed for number of pairs seen correctly and incorrectly, and their respective mean latency times. Poor readers were significantly faster in correctly seeing stimuli in the LVF, compared to stimuli seen correctly in the RVF, by 33.8 cs, F (1, 14) = 8.34, p = .012. Average readers saw significantly more incorrect pairs when processing stimuli exposed in the LVF, rather than the RVF (5.13 vs 2.73), F (1, 14) = 19.64, p = .001. All other effects were nonsignificant.

Group (average vs. poor readers) by Field (left vs. right) analyses of covariance was executed with repeated measures on Field, and Sex and Age as covariates, for number of pairs seen incorrectly and correctly, and accompanying latency times. Average readers saw

Table 6

Group Statistics of Pairs Seen and Latency Times Over All Structural Pairs

	Average Readers		Poor Readers	
Variable	M	SD	M	SD
Pairs LVF				
Seen Correctly	6.13	1.41	4.13	1.89
Latency (cs)	149.40	36.33	168.40	35.84
Seen Incorrectly	5.13	1.24	3.07	1.75
Latency (cs)	152.13	30.41	211.79	73.35
Pairs RVF				
Seen Correctly	6.60	1.40	4.00	1.73
Latency (c)	150.33	33.55	202.20	57.38
Seen Incorrectly	2.73	1.34	3.10	1.87
Latency (cs)	141.93	30.82	203.13	78.42

Table 7

Summary of Significant Effects for Experiment 2: Correct and Incorrect Pairs Perceived

Within Group Asymmetry Analysis

Variable	Average Readers LVF	Average Readers RVF	Poor Readers LVF	Poor Readers RVF
Correct pairs -response latency			-	+
Incorrect pairs -mean number	+	-		

Between Group Asymmetry Differences and Field Effects[a]

Variable	Average Readers	Poor Readers
LVF correct pairs - response latency	+	+
LVF-RVF correct pair differences -response latency		+
LVF incorrect pairs -mean number	+	+
LVF-RVF incorrect pair differences -mean number	+	-

Between Group Visual Field Differences

Variable	Average Readers LVF	Average Readers RVF	Poor Readers LVF	Poor Readers RVF
RVF correct pairs -means number		+		
LVF incorrect pairs -mean number				
LVF incorrect pairs -response latency				
RVF incorrect pairs -response latency		+		-

[a] two identical signs indicates a field effect, different signs group asymmetry differences. A negative sign for response latency indicates significantly less elapsed time.

significantly more pairs correctly than poor readers (6.37 vs 4.07) regardless of field of exposure of stimuli, as evidenced by a significant Group effect, F (1, 26) = 10.59, p .003. The Group effect for latency time for correctly seen pairs was significant, F(1, 26) = 6.93, p = .014, as was the Field effect, F (1, 28) = 5.42, p = .027, and the Group X Field interaction, F (1, 28) = 4.85, p = .036. Overall mean latency time was significantly shorter in the average group (149.87 cs) than the poor readers (185.3 cs). Subjects saw stimulus pairs correctly significantly faster in the LVF (158.9 cs) than the RVF (176.27 cs). LVF-RVF latency time differences for poor readers, however, were significantly longer than differences for average readers (33.80 cs vs. 1.33 cs), and account for the Field effect.

The ANCOVA for stimulus pairs seen incorrectly produced a significant Field effect, F (1, 28) = 12.39, p = .001, and Group X Field interaction, F (1, 28) = 12.39, p = .001. Subjects saw significantly more incorrect pairs in the LVF than the RVF, (4.10 vs 2.90), but this effect is accounted for by the number of LVF incorrect pairs seen by average readers. The latter group had a significantly greater visual field difference in pairs seen incorrectly than poor readers (2.4 vs 0). The last significant effect in this series was found in the ANCOVA for latency times for pairs seen incorrectly.

Overall mean latency time for average readers was significantly shorter than the latency time for poor readers (147.03 cs vs. 209.04 cs), F (1, 25) = 14.87, p = .001. One below average reader reported no incorrect word pairs per se, just letters.

To conclude analysis, a series of ANOVAS was run with Group (poor vs. average readers) as a between subject factor, Sex and Age and mean pairs letter length as covariates, and pairs seen correctly and incorrectly and their respective latency times as dependent variables. The covariate letter length was an average of letter lengths of all pair types in any one visual field. The ANOVA testing for group differences in pairs seen correctly in the RVF was significant, F (1, 25) = 10.75, p = .003, with poor readers seeing significantly fewer pairs correctly than average readers (4.00 vs 6.00). Poor readers also saw fewer pairs incorrectly in the LVF (3.07 vs 5.13), F (1, 24) = 7.756, p = .010, and took longer to see those pairs (211.79 cs vs. 152.13 cs), F (1, 24) = 6.630, p = .017. One poor reader was excluded from the two ANOVAS immediately above because no incorrect words were reported in the left visual field, only letters. Finally, poor readers had a longer response latency with incorrect pairs in the RVF (203.13 cs vs. 141.93 cs), F (1, 25) = 12.15, p = .002. Unreported effects were nonsignificant.

<u>Discussion</u>

In visual pair matching, normal readers showed a trend toward an RVF advantage, corresponding to the significant effect for letters in experiment 1. This was accompanied by a trend to outperform poor readers in the same visual field. Their trend to respond faster in the LVF than poor readers, however, was not an indication of superior processing; they were actually (nonsignificantly) less accurate. When the performance asymmetry of both groups was compared, that of the good readers' was significantly larger. There is reasonable evidence here that left hemisphere stimulus entry is conducive to better performance in good readers compared to poor readers. Perhaps this effect has not been stable in previous studies because most have not included specific instructions for visual matching.

Rather surprising was a lack of significant differences in phonological matching. There was a trend observable for good readers to outperform poor readers during RVF presentations, and their mean latency times were also faster, but not significantly so. The overall lack of within and between group asymmetry suggests there must be another important component present in word identification, and perhaps normal reading, beyond visual and phonetic coding that creates group differences. The results also show that right hemisphere stimulus entry is almost as effective for task accuracy as left hemisphere stimulus entry. This in turn implies (a) that under some circumstances hemispherical cooperation is maximized regardless of hemisphere of entry for both groups, or (b) the right hemisphere has a capacity (if not dominance) for phonetic analysis that equals that of the left hemisphere when each hemisphere is required to sequentially (as opposed to simultaneously) visually and then phonetically process stimuli.

Perhaps the right hemisphere benefits from a task requiring radically sequential verbal processing (visual - phonological), and/or the left hemisphere does not. Normal reading may involve simultaneous visual and phonological processing. Approaching the results from another tack and recalling Kershner's (1983) hybrid model, the left hemisphere (if sequentially processing) of good readers may experience the capacity overloading hypothesized in poor readers. The activation of right hemisphere processing may follow, which either directly hurts LH performance, or the overloaded LH cannot efficiently integrate potentially beneficial RH processing products. This explanation doesn't account for equal performance in both groups, however; if the performance of normals was depressed in the above fashion, it is unclear why poor readers' performance wouldn't drop proportionately.

The matching task involving pairs composed of one word and one orthographically and phonetically altered word proved to be very difficult for both groups, the poor readers in particular. The latter group tended to perform worse than the normals regardless of field of exposure. There was also a clear trend present for poor readers to be faster and more accurate with LVF items compared to RVF items. In fact, subjects handled the task significantly better in the LVF. The response latency asymmetry of poor readers was significantly larger than that of good readers, and their LVF latency time was significantly faster. In general, the poor readers seemed far more dependent on right hemisphere stimulus entry to maximize their performance than good readers were.

If it is correct to assume that visual and phonetic analyses were involved in the mixed pairs matching task and the phonological matching task, a question arises concerning what could provoke (a) a drop in performance with the former task for both groups, and (b) a proportionately greater drop for poor readers. Four of this latter group supplied only incorrect responses to their groups' tally, and for subjects as a whole a significant LVF field effect appeared during mixed matching.

Because stimulus configuration so directly reflects presumed task demands in both types of matches, an appropriate area to look for differences is stimulus structure. Phonological pair pseudohomophones were constructed to appear as different as possible from their real word analogues, while retaining the same sound. Following processing of the real word component in a pair, its trace or STM form is probably retained while processing of the next component commences. The greater the dissimilarity of the last component, as with a pseudohomophone, the easier it is to visually process, and the less it interferes with phonetic analysis. Greater similarity, like that found in a mixed pair results in a more difficult and extended visual analysis, perhaps serially letter by letter. Poor readers must be particularly susceptible to interference from this kind of analysis when phonetic analysis is also required in a task.

Right hemisphere stimulus entry (eg. the LVF significant field effect) seems to expedite the processing required for matching of mixed pairs, especially for poor readers. The above proposed visual serial processing is not usually considered to be enhanced with right hemisphere stimulus entry, but rather left hemisphere entry, ie. the traditional left/serial, right/parallel distinction. In this experiment the distinction does not seem to hold. Other researchers have compiled results that also question the validity of the above dichotomy. Young and Ellis (1985), in a series of experiments on performance asymmetry with nonwords and words that varied in length, frequency and imageability, arrived at two conclusions relevant to this study. The first was that RVF performance asymmetry results from characteristics of processing found in the normal (foveal) reading system. It is RVF stimulus exposure that enhances parallel processing; in a sense, information is processed in small numbers of dense chunks. Young and Ellis also said that in the LVF lexical access is accomplished with short-term graphemic storage, ie. serial visual processing, a method "used only with unusual formats in the normal [foveal] reading system" (Young and Ellis, 1985, p. 353).

After a similar series of experiments, Bub and Lewine (1988) drew similar, but not identical conclusions. Recognition of words in the LVF is accomplished with a sequential analysis of individual letters, whereas RVF performance involves the simultaneous processing of multiple letters. LVF exposure, then, seems to imply the processing of larger numbers of less dense bits of information. Unlike Young and Ellis (1985), however, Bub and Lewine did not dismiss the possibility that the serial analysis apparent following LVF stimulus exposure serves to facilitate interhemispheric transfer of information to the RVF for further processing.

The correct pair seen, incorrect pair seen paradigm results of the last part of this experiment generally support the above remarks. Good readers saw more incorrect pairs in the LVF than the RVF. This produced significantly greater asymmetry for incorrect pairs in good readers relative to poor readers. Good readers saw significantly more correct pairs in the RVF than poor readers, and significantly more incorrect pairs in the LVF. It is clear that average readers, even when making incorrect responses, reported more complete pair units, while poor readers reported pair fragments more frequently. Although not documented, it was observed that poor readers often reported most of the letters of a pair, and then interrupted themselves to blurt out the complete pair unit, as if they were assembling pair units concurrently with their report of its letter components.

LVF correct pairs were reported faster than RVF pairs by poor readers, while there was no difference in processing time for good readers. The poor readers' response latency was chiefly responsible for a significant (LVF) Field effect for response latency for correct pairs. Similarly, the (LVF) Field effect for incorrect pairs seen was a direct result of the good readers' performance. When poor readers reported incorrect pairs, their processing time was significantly longer than that of good readers, in both visual fields.

The traditional significant RVF advantage for normals in pairs seen is missing here. Its absence may be explained by the lumping together of all three types of pairs for data analysis. Therefore, the results reflect an average of the matching trends for an RVF advantage with visual pairs, equal asymmetry with phonological pairs, and a LVF advantage with mixed pairs. The variety of individual matching trends and the indistinct overall identification results seriously challenge the traditional verbal/RVF, non-verbal/LVF polarization.

In the above discussion, it was postulated that the mixed pair matching task may have been successful in inducing maximal performance in both reading groups (to a lesser extent for good readers) through a serial method of visual analysis via right hemisphere stimulus exposure. Results from the pairs seen data demonstrate that poor readers were working in their tasks with pair fragments to a greater extent than good readers. For example, with LVF exposure good and poor readers reported similar numbers of correct pairs seen, but good readers reported significantly more incorrect pairs seen. Even during their reports of complete pairs, poor readers would often begin with letters and end with a pair.

The serial processing perhaps characterizing letter reporting was described above as involving greater numbers of information chunks relatively poor in content. Unlike good readers, poor readers apparently struggle when attempting to capitalize on the advantages inherent in phonetic grouping. An alternative for poor readers (and spellers) can be found in morphographic analysis (Dixon and Engelman, 1979). Morphographs, defined by the authors as the smallest units of identifiable meaning in written English, are initially introduced to a student independent of their presence in complete words. Following semantic and spelling mastery of a pool of morphographs, a student is instructed in the assembly of word units.

Morphographic analysis was originated as a method of spelling remediation, and the meaning of many morphographs are not taught. An application in reading remediation would exploit the full semantic potential of morphographs. Conceptually, such an application is not far removed from that of ideographic scripts, where ideas are denoted by symbols. The idea here is that training in units of meaning instead of units of sound may assist the processing of information in larger chunks.

In the matching task with pseudohomophones, poor readers demonstrated a knowledge of and skill in phonetics allowing for same-different discrimination about equivalent to good readers. Results from the mixed pairs task and from the pairs seen data suggest a persistence in serial processing of small units of information. But it remains unclear if problems in phonetic analysis would determine this type of visual analysis, or if the latter disrupts the former. The two are closely related, and are part of the basis of Boder's (1973) taxonomy of poor spellers. Investigation into the differential effects of morphographic training on poor readers divided into her subtypes might be pursued.

Reiterating a portion of the discussion of experiment 1, perhaps an iniquiry into the remedial potential of prolonged unilateral presentation of language skill exercises (or reading itself) would prove rewarding. It is difficult to speculate whether a hemisphere of stimulus entry would be selected so as to train-to-strength, or the hemisphere of entry that maximizes the performance of good readers. In any case, hemisphere of entry could serve as an experimental variable for manipulation.

Experiment 3 continues the use of the matching task, utilizing decision making in presumably "higher-order" operations associated with semantic associations. As in experiment 2, subjects are required to report stimulus items after a matching task trial. However, unlike the second experiment, subjects are allowed to inspect an items list both prior to the initiation of testing, and in between blocks composed of trials of items that were not perceived in the previous block.

Experiment 3

Paivio's (1969) dual-coding hypothesis of long term memory processes has received strong support in the literature. Briefly, Paivio has argued that pictures, objects and concrete words amenable to visual coding are also verbally coded. Abstract words and concepts do not readily lend themselves to imagery, and hence are only verbally coded. Because concrete words have two memory traces and abstract words or concepts just one, the probability of recall is greater for concrete words.

Several tachistoscopic studies claim to have demonstrated a relationship between the right hemisphere and nonverbal coding, and the left hemisphere and verbal coding. After explicitly instructing normal subjects to use verbal rehearsal or visual imagery to memorize word pairs, Seaman and Gazzaniga (1973) flashed probe pictures unilaterally. When subjects indicated whether or not the probe matched a memorized word pair, an RVF advantage emerged for matches based on verbally rehearsed pairs, and a LVF advantage for pairs memorized with visual imagery.

Interestingly, there have also been interactions of degree of concreteness/imageability and visual field in some studies with normals where stimulus exposure was not preceded by rehearsal. Concrete words have produced neutral or nonsignificant asymmetry effects in word identification and lexical decision tasks, while abstract words have led to an RVF advantage (Ellis and Shepherd, 1974; Day, 1977; Hines, 1977), though the literature is not unanimous regarding this phenomenon. The above results reflect dual coding rather nicely, as the verbal and nonverbal traces of a concrete word should produce little performance asymmetry. They also suggest the operation of semantic/activation factors, as if a subject begins deeper processing without conscious effort.

Most asymmetry experiments with a more formal presence of memory factors require subjects to hold a set of items in memory while probe stimuli are exposed, and generally, superior RVF performance is obtained (Beaumont, 1982). Zaidel (1978) stated that short term memory is phonetically based, and that the right hemisphere has a severely limited STM. The present experiment is somewhat novel in that subjects must report following a same-different semantic association trial. Subjects are not just identifying words with ascribed degrees of concreteness/imageability characteristics, but actually making semantic decisions. The performance of both poor and good readers, then, can be measured not only on word identification but also on semantic decision making itself. Of interest here is within group and between group performance in both tasks, and differential performance between tasks. Specifically, will the loading demands of a memory component and a "deep processing" component alter the asymmetry reported above for concrete and abstract stimuli?

METHOD

Subjects

See experiment 1

Apparatus and Material

See experiment 1

Design and Procedure

See experiment 1 for a description of the tachistoscopic procedure. Each subject was tachistoscopically presented with a total of thirty-six word pairs, twelve in the LVF, twelve in the RVF, and twelve in the BVF. As in all experiments involving words and pseudowords, the stimulus offset range was 2°30' to 7°15', depending on word length. Once again stimulus letter lengths were controlled to avoid disparities in visual fields and stimulus types of each grade. Below average readers were tested with words rated one grade below their actual grade levels.

For all visual field exposures, a subject was required to make a same or different response to two types of item pairs. Nomenclature assigned to these types was concrete and abstract, and both types contained two real words. Concrete pairs contained one or two words that provided a subject the opportunity to test an association within the pair using sensorial imagery and memory, ie. an association was accessible through sensory experience. For example, a correct response to the pair call-yell would be same, and a correct response to the pair hot-ice would be different.

Abstract pairs contained one or two words that allowed for an association made by categorical generalization, eg. knife-weapons, or dealt with nonspecific abstractions that required a conceptual association, eg. cream-speed. A correct response to the first pair above would be same, and the second pair would require a different response. Please see appendix C for a list of stimuli used in experiment 3.

A subject was initially introduced to the association task with an explanation of how the meanings of words in a pair were to be used together to see how well they could form a single idea or thought that made sense to her/him. It was explained that some words in a pair would not mix together well, while others would but not very strongly, and some would mix very strongly.

Next, a sample of ten cards was observed nontachistoscopically by a subject, and the experimenter requested same or different responses to check a subject's understanding of the task; both correct and incorrect responses were discussed. The only form of item that created confusion was opposites - subjects tended to generalize opposites into commonalities. For instance, first-last as a stimulus usually elicited a same response initially, the subject explaining that both words were positions. Once subjects were informed that although opposites could be generalized, when considered simultaneously they were different examples of generalizations, subjects had little problem during actual testing in avoiding mistakes with opposites. See appendix C for actual instructions used in this experiment.

Before testing began, each subject engaged in a tachistoscopic session employing nine practise cards. Prior to exposure, the subject inspected a list of word pairs corresponding to word pairs printed on stimulus cards, but with their order of presentation changed. Subjects were told that any stimulus pairs not perceived during the first presentation would be exposed again following a second inspection of the list. The same procedure was followed during actual testing, utilizing however many list inspections were necessary.

In addition to the recording of same and different responses and latency times, the number of repetitions, if any, for each item were also recorded.

Results

For each type of stimulus word pair in each of the left and right visual fields, a subject provided a score (percent correct), and a median latency to response time in centiseconds. Refer to Table 8 for group statistics of average and poor readers, and Table 9 for summarized significant effects from abstract semantic association.

Within Group reported measures analyses of variance with Field (left vs right) as the within subject factor were computed for the number of correct associations and mean latency times. Average readers scored significantly higher in making abstract associations with items exposed to the RVF compared to the LVF (92.10% vs 64.50%), F (1, 14) = 29.72, $\underline{p}$ = .000. Poor readers took considerably longer to make concrete associations with RVF items than with LVF items (224 cs vs 198 cs), but the effect was marginally nonsignificant, F (1, 14) = 4.54, $\underline{p}$ = .051.

Table 8

Group Accuracy and Latency Times in Same-Different Associations: Semantic Pairs

	Average Readers			Poor Readers		
Variable	M	SD	Mean Letter Length	M	SD	Mean Letter Length
LVF						
Percent correct concrete pairs	82.20	15.90	9.80	73.50	16.30	9.41
Latency (cs) concrete pairs	180.40	44.56		198.93	51.97	
Percent correct abstract pairs	64.50	16.50	9.96	64.50	22.70	9.51
Latency (cs) abstract pairs	198.60	64.61		237.60	91.09	
RVF						
Percent correct concrete pairs	83.10	12.60	9.96	81.10	15.10	9.56
Latency (cs) concrete pairs	183.73	42.78		224.40	85.89	
Percent correct abstract pairs	92.10	10.70	9.96	67.80	20.20	9.41
Latency (cs) abstract pairs	207.33	67.29		199.47	68.08	

Table 9

Summary of Significant Effects for Experiment 3: Same-Different Associations with Abstract Semantic Word Pairs

Within Group Asymmetry Analyses

Variable	Average Readers		Poor Readers	
	LVF	RVF	LVF	RVF
Abstract associations -percent correct	-	+		

Between Group Asymmetry Difference and Visual Field Effects[a]

	Average Readers	Poor Readers
RVF abstract associations -percent correct	+	
RVF-LVF differences -percent correct	+	-

Between Group Visual Field Differences

Variable	Average Readers		Poor Readers	
	LVF	RVF	LVF	RVF
RVF abstract associations -percent correct		+		-

two identical signs indicates a field effect, different signs group asymmetry differences. A negative sign for response latency indicates significantly less elapsed time.

The next step in data analysis was to run Group (average vs poor readers) by Field (left vs right) analyses of covariance with repeated measures on Field, and Sex and Age as covariates, for percent of associations made correctly and accompanying latency times. The ANCOVA for percent correct abstract associations had a significant Group effect, F (1, 26) = 7.83, p = .010, Field effect, F (1, 28) = 14.62, p = .001, and Group X Field interaction, F (1, 28) = 9.01, p = .006. Poor readers' overall percent correct was significantly lower than percent correct for average readers (66.2% vs 78.30%). The disparity is fully accounted for in the interaction. LVF-RVF performance differences were significantly lower in the below average reading group than the average readers (3.30% vs 27.60%). It was superior RVF performance by the average readers that inflated their average performance, because both groups were equal in LVF performance. Subjects scored significantly higher with items presented in the RVF (80.00%) compared to the LVF (64.50%) regardless of group membership. However, poor readers contributed only a small (3.3%) RVF advantage to the Field effect. Remaining unreported effects were nonsignificant.

Utilizing Group (poor vs average readers) as a between subjects factor, Sex and Age and mean pair letter length as covariates, and percent correct associations and attendant latency times as dependent variables, ANOVAS were computed to compare group performance. The only significant effect occurred for percent correct abstract associations with items presented in the RVF, $F(1, 25) = 13.084$, $p = .001$. Average readers scored significantly higher than poor readers (92.10% vs 67.8%).

The number of exposure repetitions required by subjects to perceive stimuli were tallied for each visual field. See Table 10 for group descriptive statistics.

Within group repeated measures analyses of variance with Field (left vs right) as the within subject factor using required repetitions as the dependent variable were both nonsignificant.

Table 10

Group Statistics for Required Repetitions Over All Semantic Pairs

	Average Readers		Poor Readers	
Variable	M	SD	M	SD
LVF required repetitions	1.73	1.48	6.20	4.84
RVF required repetitions	1.40	1.12	5.33	3.61

A Group (poor vs average readers) by Field (left vs right) ANCOVA with repeated measures on Field, and Sex and age as covariates, was executed for repetitions required, producing a significant Group effect. Poor readers required significantly more repetitions of stimuli compared to average readers, regardless of field of exposure (5.77 vs 1.57), F (1, 26) = 48.58, p = .000.

Two ANOVAS were run with Group (poor vs average readers) as a between subjects factor, Sex and Age and mean pair letter length as covariates, and LVF and RVF required repetitions as dependent variables. As might be expected, both were significant. Poor readers required more repetitions of stimuli exposed in the RVF than average readers (6.20 vs 1.73), F (1, 25) = 30.69, p = .000. The same result was also true for the LVF (5.33 vs 1.40), F (1, 25) = 14.95, p = .001.

Discussion

The semantic association results for good readers correspond to results from other studies reported above requiring recognition only, but interestingly the repetitions required data do not, at least as a function of hemisphere of stimulus entry. Considering results within the context of Kershner's (1983) hybrid dual-processing model, it would seem that memory demands on the left hemisphere initiated a distribution of attention and resources to facilitate right hemisphere processing, which in turn preserved LH capacity for the semantic association task. Conservation of LH capacity and increased RH participation in lexical access would explain the disparity for normals between semantic association results and the lack of asymmetry for repetitions required. It would have been more prudent, however, to have analyzed repetitions required as a function of stimulus type, instead of assuming repetitions required would reflect only differences with abstract pairs.

The results presented here suggest a very rapid deployment of interhemispherical attention and resources dependent upon the nature of processing required, which is presumably a function of stimulus type, how a subject evaluates a stimulus, and of course a subjects' inherent ability (perhaps involuntary but not necessarily untrainable) to deploy attention and resources for maximum performance. Therefore, it is difficult to identify the performance of poor readers in abstract association as stemming from an interference effect (memory, perception, association), or as a deficit that would have resulted regardless of degree of perceptual difficulty. The association task is somewhat like Wechsler's (1981) similarities subtest found in his intelligence tests, and the thought that the study's informal control of IQ was inadequate is unavoidable.

The relatively large standard deviations for repetitions required within both groups probably can be attributed to the memory component of the experiment, illustrating individual differences in capacity. These standard deviations can be compared to those obtained in the pairs seen data of experiment 2, where no formal memory load was used. The large difference in repetitions required between groups, regardless of visual field, can be compared to the consistent reporting of letter fragments by poor readers in experiment 2. Despite their access to an item list in this experiment, poor readers could not improve upon their perceptual performance. Although no formal memory testing was done on either group, it was directly observable during the course of the experiment that the poor readers required repetitions of stimuli even when the number of remaining unperceived stimuli was very low. They also offered incorrect word pairs they had memorized when requested to report items. It is reasonably clear that poor readers process words in a fragmented manner, a process identified as characteristic of the right hemisphere of normals (Bub and Lewine, 1988; Young and Ellis, 1985). This was evident in experiment 2, when poor readers were observed to report large letter strings and convert them to words, and in the present experiment, where they could not easily convert letters perceived to whole words held in memory store.

Comments directed toward the use of response latency as a tool in asymmetry measurement made in previous experiments are also relevant here. In average readers, greater accuracy in abstract association was accompanied by a nonsignificant processing time difference in the RVF compared to the LVF. Poor readers, however, took significantly longer to process LVF abstract pairs than RVF pairs, without any increase in accuracy. Task engagement as a function of time may or may not result in increased performance.

A few remarks on the quality of the items used in this experiment are appropriate. Although the writer spent many hours in designing items, they were never validated with children, and therefore reflect what one adult thinks might be considered concrete or abstract by a child. Unfortunately, it was not until well into testing that the writer became aware of the compendium of Paivio, Yuille, and Madigan (1968) containing words evaluated for concreteness and imagery. Whether or not the use of this compendium would have led to different results with children is not known.

Finally, it is appropriate to clarify that the perceptual asymmetric shift reported here has not been demonstrated, but is hypothesized. The argument is based on evidence that (a) normals have shown an RVF advantage in recognizing abstract words (Ellis and Shepherd, 1974;

Day, 1977), and (b) short term memory tasks seem particularly suited for LH stimulus entry processing (Zaidel, 1978).

Experiment 4

This study has proposed that several of the asymmetry patterns demonstrated by poor or normal readers can be interpreted within the framework of Kershner's hybrid model of learning disabilities. Some of the questions that might follow from these results, and the findings of other studies cited above, should address how an asymmetry shift is generated. Why should significant asymmetry effects ever be observable if a mechanism or switch of some kind facilitates dual processing, assuming that two way interhemispherical transfer of processing products does not result in degradation of those products? Should not the right hemisphere, apparently much easier to overwhelm with many "verbal" tasks utilized in tachistoscopic research, also have its processing supplemented through left hemisphere engagement?

The asymmetry shift as a phenomenon may not only appear as a direct response to changes in stimulus characteristics, or other manipulations. Reconsidering the abstract semantic association and repetitions required data for normals of the third experiment, it is evident that Kershner's (1983) model can not account for the performance pattern of normals unless right hemisphere activation and resource allocation was an experimental phenomenon, and not a trial response to RVF stimuli. That perceptual asymmetry was absent and the abstract association asymmetry effect significant suggests attention and resource allocation for dual processing <u>prior</u> to item exposure, because task trials were mixed.

J. Levy and associates have conducted several experiments with split-brain patients that shed some light on the disposition of a hemisphere to engage or complete a task. The variable being measured is hypothesized to be hemispherical dominance, as opposed to capacity. For example, Levy (1974) presented subjects with printed instructions to either (a) perform a task, (b) point to a task being performed, or (c) retrieve an object associated with the task. Subjects were most successful at following the latter set of instructions, could sometimes point to a picture of task performance, but rarely could they perform a task during right hemisphere exposure. Levy suggested that ipsilateral neural pathways from the left hemisphere to the left hand allowed the LH to interfere with attempts to follow "perform" and "point to performance" instructions. Presumably the LH, not having viewed the instructions itself, disrupted left hand performance. During retrieval, however, the fine motor movements used would enhance RH control, so the task could be accomplished.

In another experiment, Levy, Nebes and Sperry (1971) requested subjects to write (with their left hand) the names of objects placed in their left hands. Curiously, only the first two or three written letters of object names were correct, while an attendant vocal response produced words resembling the written response only in the middle and end letters. Levy et al. argued that the LH struggled for motor control with the RH, ruining the written response. This struggle was further revealed by the similarity of the tail end of written and vocalized response words.

As a final example of the phenomenon Levy has termed metacontrol, consider the Levy and Trevarthen (1976) experiment employing chimerical stimuli. The experimenters presented a half of an object in each visual field simultaneously, and then asked split-brain subjects to choose an object from an array that went with the "one" that was flashed. Instructions requesting an appearance match usually resulted in a choice similar to LVF stimuli, while instructions to "choose one that you could use with the one just seen" functionally matched RVF stimuli.

Nevertheless, Levy and Trevarthen were perplexed by the number of functional matches with LVF stimuli that followed appearance instructions, and the number of appearance matches with RVF stimuli that followed function instructions. They concluded that there is "...little doubt that metacontrol systems exist, that these systems activate that hemisphere which is appropriate for some task...on some occasions, however, the metacontrol system can fail to arouse the appropriately specialized hemisphere, in spite of the fact that the other one must then proceed to perform in a cognitively inappropriate mode..." (p. 310).

After reflecting on the experiments of Levy and associates, and on the fact that right hemisphere stimulus entry does not seem to expedite left hemisphere activation (using accuracy as a measure), it seemed reasonable that a left hemisphere based language metacontrol system is functional in language processing. Moscovitch's (1986) model of functional localization is perhaps the most extreme example of metacontrol, stating that left hemisphere inhibition of right hemisphere language capabilities, via interhemispheric pathways, effectively localizes language processing in the left hemisphere. Moscovitch's model clearly receives little support from the present study, however the idea of some left hemisphere mediation of attention and resource allocation in dual processing seemed worth exploring with good readers and poor readers.

A task was devised wherein a subject could indicate a preference for a visual, phonological, concrete semantic or abstract semantic match to a word flashed to the right or left visual field. It was reasoned that, with the removal of all time and accuracy constraints, an autonomous and properly functioning metacontrol system would direct either a consistent pattern, or no pattern at all across visual fields.

METHOD

Subjects

See experiment 1

Apparatus and Material

See experiment 1

Design and Procedure

Each subject was tachistoscopically presented with a total of twenty words, ten in the LVF and ten in the RVF. Stimuli were offset 20 mm to 57 mm from the fixation point, occupying an eccentricity range of $2^{\circ}30'$ to $7^{\circ}15'$, depending upon their letter length. Below average readers were flashed stimulus words one grade lower in difficulty than their grade levels, while average readers saw words selected directly from their actual grade levels.

After each word exposure, subjects were asked to select one of four response items that most closely matched the stimulus word. Four types of response items were offered on each trial; visual, acoustic, concrete and abstract. For example, in response to a tachistoscopic presentation of the word roses, a subject could choose the structural visual match robes, or the structural acoustic match rowzez, or the associative concrete match red, or the associative abstract match plant. Encouragement was given to choose whatever item was preferred, and it was made clear there were no right or wrong answers. Please see appendix D for a list of stimuli and their respective response choices, and instructions used.

After making a selection, each subject was asked what the stimulus word was. Incorrect identification resulted in the stimulus being flashed again during the stimulus presentation process until the word was correctly identified.

Results

Each subject's scores were divided into two preference types, structural and semantic. The structural type was computed by tallying the sums of visual and acoustic matches, while the semantic type represented the sum of the sums of concrete and abstract matches. See Table 11 for group descriptive statistics of average and poor readers.

Within group repeated measures ANOVAS with Field (left vs right) as the within subject factor were executed for structural and semantic preferences for each group. Poor readers had significantly more structural preferences in the RVF than the LVF (6.47 vs 5.47), F (1, 14) = 13.13, p = .003, and therefore significantly more semantic preferences in the LVF than the RVF (4.53 vs 3.53), F (1, 14) = 13.13, p = .003.

Two Group (poor vs average readers) by Field (left vs right) ANCOVAS, with repeated measures on Field, and Sex and Age as covariates, were computed for mean number of structural and semantic preferences. The Group X Field interaction was significant [F (1, 28) = 6.12, p = .020] for structural preferences. Poor readers had a significantly larger visual field difference, than average readers (1.00 vs .67). The interaction of the ANCOVA using semantic preferences was also significant, F (1, 28) = 6.94, p = .014. Again, poor readers had a significantly larger LVF-RVF difference (1.00 vs .73) in the opposite direction to that of average readers.

Analysis was concluded with a series of ANOVAS with

Table 11

Group preferences for structural and semantic matches

	Average Readers		Poor Readers	
Variable	M	SD	M	SD
LVF				
Structural preferences	7.47	2.57	5.47	3.66
Semantic preferences	2.53	2.50	4.53	3.16
RVF				
Structural preferences	6.80	3.02	6.47	2.39
Semantic preferences	3.20	3.23	3.53	3.40

Group (poor vs average readers) as a between subjects factor, left and right visual field structural and semantic preferences as dependent variables, and Age and Sex as covariates. None of the resulting effects were significant.

DISCUSSION

In left versus right visual field within group comparisons, as well as in relative comparisons of group asymmetry, poor readers exhibited significantly more inconsistency in the matching of stimulus and response items. These results were obtained by independently comparing structural and semantic preferences within and between groups, and differences are quantitative. Additionally, the results should not be interpreted as suggesting hemispherical preferences for types of processing. The fact that poor readers had a greater preference for structural items in the RVF than the LVF, and a larger preference for semantic items in the LVF than the RVF, cannot be construed as an indication of processing preference. Because the task was designed so a subject had to choose A or B, and not A and B, a significant effect with one stimulus type guaranteed a significant effect from comparisons with the other stimulus type. The task's purpose was to reveal differences between groups in preferences for response items, which it did.

The data are perhaps more persuasive when patterns of preference across stimulus type are observed, rather than group differences in each stimulus type. Note in Table 11 that the predominance of structural preferences over semantic preferences is remarkably uniform in the RVF and LVF of average readers, and the RVF of poor readers (approximately 50-70% more structural than semantic preferences), but not in the LVF of poor readers. If it is assumed that the left hemisphere exercises metacontrol over language processing, then a similar pattern of preferences should appear in each field of exposure. This effect has occurred for normal readers. Further, RVF exposure produced similar patterns of preference in both good and poor readers, but results with LVF exposure are markedly different, even without formal testing. A 50-70% structural-semantic preference difference when compared to a 17% difference will produce a significant effect.

From a dual processing perspective, weak left hemisphere metacontrol of language processing could produce severe problems in efficient allocation of attention and resources, and the evaluation and integration of processing products from both hemispheres. However, it is quite a conceptual leap from the results of this experiment to the above speculation. The large standard deviations cannot be ignored, and the results may be unreliable. Conversely, it may be the design at fault, perhaps simply too crude to cleanly separate a metacontrol effect from unwanted variance. There must be some effect on preference from the very act of perceptual processing. In addition, stimulus words are probably going to be differentially processed by individuals because of a specific meaning or appeal the stimulus possesses. It is unclear if the present design could ever be refined to deal with these problems, and the writer hopes another researcher will be stimulated enough by the results obtained here to pursue metacontrol with a more sophisticated design.

Comments on BVF effects

BVF results were not incorporated into this paper for reasons discussed in the general introduction. However, ANOVAS were computed to test for group differences in latency times and performance involving all structural and semantic pairs, correct and incorrect stimulus pairs seen, and required repetitions of word pairs. Group (poor vs average readers) was the between subject factor in these tests, and Sex and Age and mean pair letter length served as covariates.

Only two of these ANOVAS were significant, while one was marginally nonsignificant. In experiment 2, poor readers took significantly longer to report incorrect pairs seen than good readers (198.48 cs vs. 143.20 cs), F (1, 25) = 4.93, p = .036. This can be compared to significantly faster reporting of incorrect pairs for poor readers in the LVF, and significantly slower reporting of incorrect pairs in the RVF.

In experiment 3, poor readers required significantly more repetitions of semantic pairs (4.80 vs 1.87) than good readers, F (1,2 5) = 5.72, p = .025. The same effect held for their performance with both LVF and RVF stimuli. Finally, poor readers tended to perform worse than average readers when making same/different responses to phonological pairs in experiment 2 (70.10% vs 87.60%), F (1, 25) = 4.22, p = .051. This parallels another marginally nonsignificant effect of good readers' superiority with phonological pairs in the RVF.

In many tachistoscopic studies employing BVF exposure, fields are compared in the accuracy data they produce; in turn, these results are used for group comparison. Here, groups comparisons were restricted to BVF reports only. It is interesting to note that for those tasks <u>demanding</u> hemispherical transmission of information (ie. all matching tasks) for response integration, no significant effects are evident. This can be compared to a fair number of significant effects involving LVF stimulus entry where callosal transfer would imply either (a) complete processing products transferred for the purpose of vocal response, or (b) earlier stage processing products transferred for further LH processing. Weighing these two points, one might infer that it is unlikely that degradation of elemental information or early stage products during transfer is a factor in between group or within group differences. Beaumont (1982), in his summary of tachistoscopic findings in the decade 1971-1981, concluded that the traditional RVF advantage is not dependent upon a vocal or right-hand response. In sum, it appears there is little evidence here to support studies suggesting delay of myelination of callosal fibres as a (broad) factor in the performance of reading disabled subjects (for example, Gross et al., 1978) compared to good readers.

General Discussion

Experiments conducted in this study have demonstrated the mutability of accuracy and response latency asymmetry within and between poor and average reading groups, across an array of reading related tasks. In general, the study reflects the state of tachistoscopic laterality/reading disability research. A common remark appearing in most of the reviews cited in this study can be paraphrased "the presumed asymmetry effect for normals was not obtained, therefore the results for the reading disabled group can also be dismissed". Given the heterogeneity of results in the literature, it may be indeed be presumptuous to assume that a particular effect's occurrence for any one group warrants the acceptance or dismissal of another experimental group's results.

Typically, the text of a review will also focus on perceived weaknesses in methodology potentially contributing to the appearance of unstable (or unacceptable) results. The inference seems to be that following the rationalization of a host of experimental concerns, effects will be duly sorted into a conformity revealing the relationship of functional asymmetry and reading disability. Asymmetry effects are sensitive to stimulus input factors (Sergeant and Hellige, 1986) and the characteristics of stimuli and procedures designed to constrain a subject to a specified "function". Although standardization of such variables are desirable for replication purposes, this experimental sensitivity to variables that are not stable in a normal reading environment seriously undermines the validity of models presenting dichotomous explanations of language processing ex vitreo.

An important question, infrequently addressed, concerns the possibility that inconsistent findings will persist despite the adoption of recommendations leading to the standardization of experimental methods. In this situation, attempts to protect the integrity of functional models would require the disassembly of broad functional categories into fractions that would be assigned unilaterally or bilaterally to the hemispheres. The results would be analogous to the efforts of early instinct theorists who observed behaviours and compiled long lists of discrete instincts. Proponents of structural models directly relating structure to function would be left in an even more tenuous position. Ojemann's (1983) cortical stimulus mapping of behaviours such as reading, naming, phonemic identification, and semantic association produced patterns of disruption in the left hemisphere of patients tested prior to neurosurgery. Electrical stimulation of complementary areas of the right hemisphere produced no disruptions. Apparently complementary structural representation of such activities in the hemispheres is not necessary for their performance.

Although this study has addressed some methodological issues found in the literature and discussed in the general introduction, undoubtedly it will be challenged on one point or another. Nevertheless, within and between group diversity in performance asymmetry as well as some consistent findings remain distinctive and require further consideration.

Evidence of intra- and interexperimental asymmetric shifts cited from the literature and speculated upon in this study conform to both static and dynamic models of dual processing.

A proposed static model identifies relatively inflexible processing circuits in each hemisphere with partially overlapping abilities. Inflexible here means a limited number of modes of processing. Abilities overlap either because of duplicated modes, or divergent modes that ultimately compute a similar processing product. In tachistoscopic research, circuits are activated with differential visual field stimulus exposure, and produce a response consisting of autonomous processing products from one hemisphere. Such a model explains all types of asymmetry effects because it assumes the hemispheres have some identical and some unique processing modes, and field of stimulus exposure determines hemisphere of response. In normal language processing, some kind of metacontrol unit would operate to determine hemisphere of response.

A problem with this static model is that it cannot account for evidence that left hemisphere lesions can result in a greater disruption of (receptive and expressive) language processing than left hemispherectomy (Smith, cited in Beaton, 1985). This phenomenon suggests some type of interaction between the hemispheres, rather than two independent processing circuits.

The alternate dynamic model of dual processing also postulates similar but not identical processing circuitry. Tachistoscopically presented stimuli would produce asymmetry effects equivalent to those in the static model, except under one condition. An overloading of the left hemisphere with excessive task demands (eg. number of required operations or divergency in kinds of operations) would result in a metacontrolled activation of right hemisphere circuitry and therefore a distribution of task demands. Activation does not imply an inactive right hemisphere, but rather an activation of increased processing from whatever level of processing existed prior to task demand redistribution. Additionally, if metacontrol can be conceived as a vector, it would originate in the left hemisphere and be unidirectional. Therefore, in either of the processing environments described above, an RVF item would produce a response reflecting the integration of dual processing products.

A problem with this model, at least in the present experiment, is demonstrating a shift instead of speculating an occurrence. Kershner and associates, however, have successfully demonstrated shifts (1977; 1984), and the dynamic model is more or less his model of learning disabilities. The dynamic model proposes shifts for both normal and learning disabled subjects, with shifts happening much more frequently for the latter group because of their performance deficits with RVF stimuli demonstrated here and elsewhere (see any of the referenced reviews).

The results of experiment 1, and the work of Boles (1981) and Boles and Eveland (1983) were used to present a case for dual processing and selection activation in the intact brain. This was done within the framework of the Boles and Eveland hypothesis and the more conventional LH/nominal match and RH/visual match. It was argued that the latter model, confronted with asymmetry effects conflicting with its position would either have to acknowledge the possibility of a summation of processing products or nonintegrative dual processing.

Instructions to visually match letters in experiment 1 produced a significant RVF over LVF accuracy advantage for normal readers. Poor readers also showed on unreliable RVF advantage for visual matching, which combined with the results of good readers into a significant (RVF) Field effect. This was accompanied by a significant Field effect for response latency, with RVF items eliciting shorter times. Results for visual letter matching generally reveal an enhancement of performance with left hemisphere stimulus entry for both groups, with good readers displaying an unreliable RVF accuracy superiority over poor readers. The overall RVF advantage with letters falls in line with Beaumont's (1982) summary of results in the literature, when the nominal/physical dichotomy is ignored.

The results of normal readers in letter matching using sound and shape criteria were very similar to those obtained by Boles (1981). No visual field advantage emerged with sound criteria, and an RVF advantage was clear with shape criteria. The pattern of poor readers over the two tasks was exactly the opposite, with a significant RVF over LVF advantage for phonological matching, and neutral asymmetry (a nonsignificant RVF advantage) in visual matching. The respective performances of the reading groups in letter matching seems to be maximized with the same (left) hemisphere but for different tasks.

In experiment 2, good readers' visual matching in word pairs produced a marginally nonsignificant RVF over LVF advantage, which corresponds to their significant RVF advantage in the visual matching of letters. The former effect contributed to the significantly larger asymmetry for good readers relative to poor readers, who exhibited an unreliable trend in the opposite direction. Superior performance in the RVF of good readers compared to poor readers approached significance. Poor readers actually outperformed good readers in the visual discrimination of LVF items, through not significantly so.

The effects present in the visual matching of words are essentially marginally nonsignificant trends. Though conclusions cannot be formulated on unreliable test results, it is nonetheless noteworthy that the trends for the two groups are in opposing directions, with good readers showing a relative strength with RVF items, and poor readers a relative weakness with RVF items and a relative strength with LVF items. The one distinct effect, the greater accuracy asymmetry of good readers relative to poor readers stands in contrast to the nonsignificant results of Naylor et al. (1980b) and Witelson (1976) who also used matching tasks. Kershner (1977) obtained a similar effect, though he employed bilateral visual field word identification. In the present experiment, the correct matching of identical words proved to be the easiest task for both groups, producing the highest accuracy scores and the fastest times.

There were no significant within or between group differences in the matching of words and pseudohomophones comprising phonological pairs, although a nonsignificant trend for good readers to outperform poor readers with RVF items emerged. It was hypothesized that the nature of the tasks and the mixing of trials for the three types of tasks effectively separated processing into two steps:

visual inspection for orthographic differences followed by phonetic analysis. This sequence of processing may enhance right hemisphere stimulus entry processing and/or retard left entry processing. Normal reading for average readers, it was argued, could involve parallel visual and phonetic processing. Normal reading refers to the reading of text comprised of words already in the reader's lexicon. The results with phonological pairs suggest a right hemisphere presence of at least some phonetic skills, as well as the possession of roughly equivalent skills by the reading groups, within the limitations of the task.

In an alternative explanation of the lack of an RVF advantage for phonological pairs, the data was compressed into Kershner's model of learning disabilities in an effort to explain the dynamics of a shift. Such a shift is difficult to empirically demonstrate with unilateral stimulus exposure. The required procedure would involve BVF exposure so that an asymmetrical shift could be directly measured. However, it is unlikely a tachistoscopic measurement could work, because of the volume of information (one stimulus pair in each field) and the short stimulus times most experiments employ. Although Zaidel's (1975) Z-lens system of prolonging stimulus exposure might prove to be unwieldy, Bradshaw, Nettleton, Wilson and Nathan (1984) have devised an electronic system that could prove useful for BVF experimental demonstrations of asymmetric shifts. In the present experiment, notwithstanding that the data can fit Kershner's model and LH stimulus entry does seem to initiate rapid multiple letter processing and not sequential processing (Bub and Lewine, 1988) it would be rash to assume the LH would not sequentially process in the phonological task as it seems to do with unusual formats like vertical or staggered stimuli (Young and Ellis, 1985). Given sequential processing with LH stimulus entry, it was not accomplished any better in either group than with RH stimulus entry.

The performance of the matching task, using one word and one orthographically and phonetically altered complement, seemed to be expedited by RH stimulus entry, as evidenced by a significant Field effect. The poor readers appeared to be proportionately more successful with LVF items, with trends for greater LVF over RVF accuracy and faster processing time both approaching significance. Good readers, however, showed a marginally nonsignificant trend to greater overall accuracy with the mixed pairs task.

The visual similarity between pair members, it was reasoned, brought about a more extended visual analysis, probably serial in nature, which created the greatest interference with phonetic analysis in any of the tasks.

LVF stimulus entry apparently enhanced processing for both groups, particularly poor readers. These results were compared to those of Bub and Lewine (1988) and Young and Ellis (1985) who have found evidence of serial processing in the LVF with normals. Right visual field item exposure created the most difficulty for poor readers, continuing a pattern of weak RVF performance, except for phonological matching of letters.

In the letter matching experiment, there was no response latency pattern between tasks and across groups that might suggest processing differences in visual and phonological matching. In experiment 2, there was a consistent progression in processing time between tasks in both visual fields of both groups, with one exception. Visual matching prompted the shortest processing effort, then phonological matching, followed by mixed pair matching. The one exception out of twelve cells (3 tasks x 2 groups x 2 fields) is found in the LVF performance of poor readers.

This data, obtained in mixed trials, provides some confidence that the tasks were indeed not testing the same language processes. That phonological pairs seem to have a similar effect in both visual fields hints at the provocation of phonetic analysis by both RVF and LVF items, concurring with Barry's (1981) work.

Results from the correct pairs seen, incorrect pairs seen data of experiment 2 revealed that poor readers had to work with pair fragments in the three tasks to a greater extent than good readers. The latter group, even when making incorrect responses to LVF items, reported significantly more incorrect pairs than poor readers. Though the groups were equal in RVF incorrect pairs seen, good readers saw these pairs significantly faster. Good readers also saw significantly more RVF pairs correctly than poor readers.

The absence of a significant RVF over LVF effect for normals in pairs seen correctly was explained by the inadvertent collapsing of data across the three types of pairs. Results of experiment 2 can be summarized as follows:

1. (a) trends of a RVF advantage for normals and a LVF advantage for poor readers in visual matching.

   (b) significantly greater accuracy asymmetry for normal readers, principally because of poor readers' weak RVF performance.

2. (a) no significant within group or between group differences in phonological matching.

   (b) a hypothesized separation of visual and phonetic processing because of the nature of the task, depressing LH stimulus entry processing and/or expediting RH stimulus entry processing, thereby enhancing the performance of poor readers compared to normals.

3. (a) a significant (LVF) Field effect in mixed pairs matching, with the poor reading group benefiting more from LVF stimulus exposure than good readers.

   (b) a hypothesized greater reliance on serial processing, because of the nature of the task, and a positive comparison of results with research employing normal adults (Bub and Lewine, 1988; Young and Ellis, 1985) showing serial processing of verbal material presented to the left visual field.

4. (a) significantly more pairs seen correctly in the RVF by good readers, continuing a pattern of weak RVF performance by poor readers.

   (b) significantly more pairs seen incorrectly in the LVF by good readers than poor readers, across all pair types. Good readers also more frequently reported complete (albeit incorrect) pairs in the LVF compared to their own RVF responses.

   (c) the reporting of pair fragments by poor readers to a greater extent than good readers, and an observed tendency to initiate reports of complete pairs with letters and finish with a complete unit.

Over all tasks, poor readers showed a trend to an LVF advantage, neutral asymmetry, contributed more strongly than good readers to a (LVF) significant Field effect, exhibited a tendency to report pair fragments, and maintained a pattern of weak RVF performance. Good readers, after completing tasks that were hypothesized to be increasingly expedited by processing associated with LVF stimulus entry, went from significantly greater performance asymmetry relative to poor readers (chiefly from strong RVF performance) to neutral asymmetry, to participation in a significant (LVF) Field effect.

Considering (a) the relative stability of the performance pattern of poor readers across tasks and their weak RVF performance, and (b) the relative sensitivity of good readers to task demands initiating a rightword shift in their performance patterns, there appears to be sufficient evidence to endorse Kershner's (1977) argument for weak [performance] lateralization in poor readers. Bub and Lewine (1988) challenged Kershner, remarking the most convincing outcome would require equal RVF performance for good and poor readers, and superior LVF performance for poor readers.

This particular result is not necessary to demonstrate performance asymmetry differences between groups. Weak RVF performance for poor readers relative to good readers, accompanied by a within group asymmetry pattern favouring LVF stimulus exposure for poor readers across tasks (versus the task sensitivity of good readers) is sufficient.

Poor readers appeared to process the verbal stimuli in this experiment in a fragmented manner. In order to reduce the number of bits of information processed and increase the content of each bit, morphographic analysis was recommended as a potential method of remediation in reading.

In experiment 3, a semantic association task was performed by subjects concurrent with a (presumably LH) memory load and item identification. The results are summarized as follows.

1. average readers showed a significant RVF over LVF

advantage in abstract association, and superior RVF performance relative to poor readers with abstract items.

2. there were no significant within or between group effects with concrete items.
3. there was a significant (RVF) Field effect for abstract association, principally because of the significant asymmetry exhibited by good readers in the task.
4. poor readers required more item inspections than good readers, regardless of visual field. Both reading groups had no significant differences between RVF and LVF required repetitions.

It was hypothesized that in normal readers, memory demands on the left hemisphere resulted in a facilitation of right hemisphere perceptual processing, bringing about the loss of the presumed RVF advantage for abstract words (Ellis and Shepherd, 1974; and others) and a further conservation of capacity for the semantic association task. It could be argued that the results simply reflect a loss of efficiency by normals in perceiving RVF items, however the fact remains that a significant RVF advantage was maintained by this group in the abstract association task.

It is difficult to analyze the performance pattern for poor readers, because no data on tachistoscopic performance with concrete and abstract words was found performance with concrete and abstract words was found for them, although Jorm (1979) said poor readers recognize concrete words easier than abstract words in nontachistoscopic presentation. However, it was obvious that poor readers were not capable of improving on their item identification performance in experiment 2, even when periodically presented with an item list. Their performance in this experiment is considered further evidence of a tendency to process verbal stimuli in a fragmented serial manner, similar to the processing by normals of LVF word stimuli (Bub and Lewine, 1988; Young and Ellis, 1985). Witelson's (1977) comments concerning poor readers' two right hemispheres, none left, seem particularly apposite.

Experiment 4 was an exploration of possible differences between groups in making matches between a target word presented in either visual field and an array of visually, phonologically and semantically similar response items. Following a direction taken by Levy and associates (1971; 1974; 1976), it was hypothesized that with time and performance constraints removed, a left hemisphere metacontrol mechanism would establish a pattern of preference for structural and semantic items that would remain consistent regardless of field of item exposure. Results are summarized below.

1. In left versus right visual field within group

comparisons, as well as in relative comparisons of group asymmetry, poor readers exhibited significantly more inconsistency in the matching of stimulus and response items.

2. A non statistical comparison of the preference patterns of the two groups produced a uniform predominance of structural preferences in all visual fields except the LVF of poor readers.

Although the results are interesting, it was concluded that the large standard deviations identify the task as perhaps too coarse to separate the influence of individual word processing from preference selection.

Comments were made earlier in the study regarding the apparent sensitivity of effects to stimulus input factors, stimulus characteristics and mode of response. It was remarked that if each of the effects produced by nuances in the above factors was interpreted as an example of functional asymmetry, then not only would an alarming number of "functions" accumulate, but the relevance of experimental results to performance in a normal reading environment would be suspect. This writer, although disinclined to wholly endorse some of the reviewers' arguments, agrees with the general consensus that researchers may not be (directly) measuring functional asymmetry differences between good and poor readers, or even within group independent hemispherical differences on all occasions.

Throughout the study, the term functional asymmetry has been avoided and supplanted with the phrase performance asymmetry. It has not been satisfactorily established in the literature that the hemisphere of stimulus entry provides autonomous processing products as a response in the intact brain. If the notion of hemispherical collusion in processing has any credibility, then responses to tachistoscopic stimuli in at least some instances must represent processes and not wholly lateralized functions. Young and Ellis (1981) commented that only confusion can result from the free use of terms like hemispherical specialization (of function) when differences between strategies or processes and functions are not understood.

These strategies or processes appear to be involuntary. Individuals may be constrained to particular processes because of attendant deficits, or the processes may reflect unique adaptation to deficits. The present study has proposed that researchers consider some of the methods of prolonged hemifield stimulus exposure for the delivery of remediation material (including reading itself), to investigate the possibility that hemispherical processes might be altered or enhanced. The idea, perhaps novel, has not proven to be unique. Green and Josey (in press) have demonstrated substantial improvement in speech comprehension and academic performance in a subgroup of LD children following insertion of one earplug. The use of a subgroup by the above authors draws attention to the present study, which employed a heterogeneous sample, and it is regretted that time did not allow the division of the poor readers into Boder's (1973) subgroups.

A final comment might be directed to the diversity of tasks used in this study. Children are challenged daily to (a) master new words initially appearing unusual, (b) improve spelling skills, (c) integrate new material with learned material in reading exercises, and (d) manipulate semantic relationships to gain access to a greater number of concepts, and more complex concepts. It is suggested that the task array used in the study provides a more realistic measure of performance asymmetry found in the normal reading environment than any one task like word identification.

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APPENDIX A

Experiment 1

1. Task Directions

The machine you're sitting in front of is called a T-scope. If you look inside, you'll see a back dot in the middle of a white screen. The metal bar is for you to lean against, so you don't get too close or too far away from the screen. Look at the dot on the screen. Now look just a little bit to the right of the screen; now look back at the dot; now look a little to the left of the dot; and now back to the dot again [subject's height adjusted if necessary].

This machine can flash letter or words on the screen very fast. Watch, the dot will disappear and a word will come on the screen. That's fast, isn't it? Now, sometimes letters or words will come on the screen to one side, the other side, or one on each side of the dot. What do you think would happen if you were looking on one side of the screen, and a word was flashed on the other side? Do you think it would be easy to see? Probably not.

Imagine that you are a goalie and someone is rushing down the ice to take a shot at you. A good goalie would stand in the middle of the net, ready to move to one side or the other if the shot was headed that way. That's what you have to do. If you're always looking at the dot in the centre of the screen, you'll be ready for any letter or word. I'm going to be reminding you a lot about looking at the dot, so please don't get angry at me if I repeat myself.

The first two sets of cards have letters on them. I'm going to show them to you in the machine, and ask you if they look the same or sound the same. If they look the same, then you tell me "same", but if they look different, you tell me "different". For example, if I show you ff, do they look the same? Yes, and your answer would be same. What about Aa, do they look the same? No, and your answer would be different. After we are done this pile, then I'll show you another set and ask you if the letters sound the same. For instance, do Aa sound the same? Yes, and your answer would be same. What about BV? They don't sound the same, do they. So your answer would be different. I'm also going to be timing how long it takes for you to answer, using this stopwatch. But what I'm really interested in is seeing you get as many correct answers as possible, so please don't give answers to show how fast you are before you're really ready to give a good answer. Now we get to practice before your answers count.

2. ITEMS

(a) VISUAL MATCH

	LVF	BVF	RVF
1.			JJ
2.		ij	
3.			rr
4.			VW
5.	GC		
6.			qp
7.	RR		
8.	BB		
9.	ff		
10.		vw	
11.	yg		
12.			uw
13.		PR	
14.		rr	
15.		AA	

(b) PHONOLOGICAL MATCH

	LVF	BVF	RVF
1.			PF
2.			AP
3.		Nr	
4.		nM	
5.	bB		
6.	Bz		
7.		eE	
8.	hb		
9.	Hh		
10.			vw
11.			Qq
12.		WV	
13.		GC	
14.	BF		
15.			dD

APPENDIX B

Experiment 2

1. Task Directions

This set of cards has pairs of words written on each card, some on the left, some on the right and some one on each side, just like the cards with letters. Some of the words in the pairs will look the same, some will look different but sound the same, and some will look and sound different. If the words look the same, then after you see them, you will say "same". If the words sound the same but look different, you will say "same". But if the words look different and sound different, you will say "different".

Watch [series of words printed]. Suppose I show you the word clock with this, "clock". What do you notice about these two? That's right, they are exactly the same two words. So clock and clock look alike, and your answer would be same.

Now what if I show you clock with "kulok". They sure look different, don't they? Sound out "kulok" for me, and tell me what it sounds like. Like clock, right? So clock and kulok look different but sound the same, and your answer would be same.

What if I show you clock and "clod". Do they look the same? No, they don't, even though they are a bit alike because they both start with clo. Do they sound the same? No, even though they are similar because they have the same sound at the beginning. So if two words look different and sound different, your answer will be different.

After you say same or different, I'm going to ask you to tell me what you saw. If you saw words, or almost-words tell me the words you saw. If you see letters, tell me each letter you saw. And if you see one word and some letters, tell me those too. Sometimes you won't see everything, but you can still say same or different using your word skills. For instance, if I show you bog-bawg, but you only see bog-baw*, and you're not sure what the last letter was, a good guess would be that they're the same. Of if the words were teach.preach, and you saw teach.p***ch, you could say different, because you know the words have different starting letters.

I'm going to be using the stopwatch with this, but like I told you with the letters, it is much more important to try and be correct than to be fast. Let's practise before we start the real thing.

2. ITEMS

Grade 3

Visual Pairs	Phonological Pairs	Mixed Pairs
LVF		
best-best	care-kair	call-cal*
much-much	eight-ate*	done-donet*
only-only*	cars-carz*	draw-braw
here-here		
RVF		
skis-skis*	year-yeer	dead-pead
been-been	lake-layc*	road-roud*
side-side*	days-daiz	want-wunt*
	half-haff	
BVF		
soon-soon	clean-kleen*	sky-sby
even-even	light-lite*	draw-drow
sing-sing*	any-eny	sings-sengs
hot-hot		fire-fir
		hand-tand

* used in each of two sessions

Grade 4

Visual Pairs	Phonological Pairs	Mixed Pairs
LVF		
shark-shark	suits-sootz*	mouth-nouth
wrong-wrong	laughs-laffs*	whale-whalc
power-power	kids-cidz	wrote-wrate*
close-close*		stick-steck
RVF		
uncle-uncle*	couple-kupul*	score-scora
early-early*	drive-dryv	mount-moont*
month-month	apple-apul	places-ploces
	cloud-klowd	club-dub
BVF		
boats-boats	cherry-chery*	woods-voods
teach-teach	roses-rowzez*	thirty-thinty
cute-cute*	say-sez	ground-groond
plates-plates		guy-gug
		cage-cuge

Grade 5

Visual Pairs	Phonological Pairs	Mixed Pairs
LVF		
bottle-bottle	either-eethr	radio-radic
phone-phone*	mile-meyel*	sports-sparts
middle-middle	reason-reezun	large-lange*
lion-lion	worked-werct	size-stize
RVF		
captain-captain	pocket-pokit*	grown-growm
anyone-anyone	yelled-yeld	lion-lian
future-future	fought-fot	reward-remard
tiny-tiny	scary-skeree	knife-koife
cool-cool		bottle-buttle
BVF		
pilot-pilot	village-vilij	hurry-harry*
scream-scream	grabbed-grabd	factory-fatory
hands-hands	cream-kreem*	kinds-linds
short-short*	July-Jooly	quite-quita

Grade 6

Visual Pairs	Phonological Pairs	Mixed Pairs
LVF		
brook-brook*	glove-gluv	crew-crcw*
prize-prize*	tripped-tript	plastic-plostic
Hawaii-Hawaii	canoe-kanoo*	trains-traims
	clear-kleer	crazy-erazy
RVF		
hobby-hobby*	cottage-kotij	door-deors
escape-escape	mystery-mistree	nature-natare*
choice-choice	cents-sens	rifle-rifte
rough-rough	clawz-kloz*	nearly-mearly
BVF		
series-series	pause-paws*	guards-guarda
knock-knock	bullet-bulit*	block-blook
poison-poison	stomach-stumuk	knock-knoek
calm-calm		hopped-kopped*
ninety-ninety		

APPENDIX C

Experiment 3

1. Task Directions

We're going to keep working with words, but I think you'll have more fun with this set than the last one. I'm going to show you two words in the T-scope, and then you are going to tell me if the two words go together to make an idea or thought that makes sense to you. If the words do go together, you tell me "same", and if they don't, you say "different". For example, if you saw this pair, "drive-carrot", would you say same or different? That's right, most carrots don't come with handlebars or steering wheels. What about "calm-lake"? Yes, they could go together.

After you give me your answer, then I'm going to ask you what words you saw. But don't tell me until I ask you, okay? We have a problem on this one that maybe you already have thought of. Remember the last time I asked you what you saw, there were times you didn't see a word? Well, if that happened here you wouldn't be able to decide if the words go together or not, would you? So I'm going to give you a list with the words written on it, so you can use your memory to help you. And if you don't see the words, tell me right away, and I'll put the card to the side, you can look at the list again after we go through the set, and then I'll show you the cards you missed again. You don't have to pretend you saw the words, because you get to see the list again, and anyways I'll know when I ask you what you saw. Now let's practise. I'll be using the stopwatch with this bunch too, but it's still more important to be right than to be fast.

2. ITEMS

Grade 3

CONCRETE			ABSTRACT	
Same	Different		Same	Different
		LVF		
call-yell*	right-X		air-lives*	space-sad
tune-sing	donuts-ship*		cars-travel	iron-like
				side-silly
		RVF		
grass-green*	year-soft*		hours-time*	lands-mad*
care-hug	sky-pencil		best-good	route-art
		BVF		
talks-mouth	hot-ice		world-planet	dead-life*
high-jump	every-blue*		much-amount	start-over
lake-swim			car-play	

* used in each of the two sessions

Grade 4

CONCRETE			ABSTRACT	
Same	Different		Same	Different
		LVF		
uncle-man*	months-fork*		racing-risk	whale-pet*
thirty-count	suit-bath		score-games	songs-math
			poem-pretty	
		RVF		
flew-wing*	drive-carrot*		chief-power*	easy-hard*
orange-eat	rose-cat		shark-live	candy-scare
		BVF		
kid-bike	apple-frog		cloud-area	tea-sad
apple-skin	rocket-sock*		cherry-fruit	cage-nature
laugh-smile			place-area	easy-evils

Grade 5

CONCRETE Same	CONCRETE Different		ABSTRACT Same	ABSTRACT Different
		LVF		
lion-teeth*	phone-drink*		tiny-danger*	dirty-clean*
screamed-loud	July-freeze		support-work	cream-speed
		RVF		
cool-chilly	sports-sleep*		hurry-speed	hands-space
yelled-loud*	cool-burn		scary-fears*	hurry-wait
				future-funny
		BVF		
quickly-run*	bottle-noses		knife-weapon*	pocket-plant
large-whale	mile-spoon		grow-size	radio-fruit
				reward-old

Grade 6

CONCRETE			ABSTRACT	
Same	Different		Same	Different
		LVF		
clear-window*	cents-paper*		crew-effort*	rifle-peace
brook-wet	crook-pillow		bullet-enemy	saucer-enjoy
		RVF		
ninety-count*	rough-smooth*		vampire-fear	monster-share
doors-knobs	lake-dry		poison-death*	claw-time
		BVF		
calm-oceans*	Hawaii-snow*		prize-reward	series-love*
knocks-bangs	canoe-wings		hobby-enjoy	glove-young
			kinds-types	

APPENDIX D

Experiment 4

1. Task Directions

Now we are going to work with words. I'm going to show you a word in the machine, and then I want you to pick out a word or almost-word from a card that matches the word in the machine. You can pick any one you want, because there are no right or wrong answers. Just pick the one you think goes best with the word in the machine, and take as much time as you want.

Some of the choices will look a lot like the word. For instance, if I show you "clock" in the machine, then you might pick dock as a good match [word printed] because the c and k make a d when pushed together. You might also want to choose this one [word printed], "kulok"... because why? That's right, it sound the same. Or you could choose "tick", because ... clocks tick. You might feel like choosing this one, "time" [word printed]. Why? That's right, because clocks tell us the time.

If you don't see a word in the machine, that's okay. Just tell me right away and I'll show it to you again later. But if you do see the word, don't tell me until after you pick out one of these off the card that matches it best.

Grade 3

VField		Stimulus	Structural		Semantic	
		word	visual	acoustic	concrete	abstract
1.	R	talk	tak	tok	word	speech
2.	R	draw	drag	dro	pencil	art
3.	L	space	spice	spays	stars	far
4.	L	sky	ski	skeye	blue	space
5.	R	wound	woand	whoond	bleed	injury
6.	R	tune	tume	toon	loud	music
7.	R	route	raute	root	bumpy	travel
8.	L	world	would	wild	round	place
9.	R	rage	roge	raij	hit	anger
10.	L	days	dags	daiz	week	time
11.	L	here	herc	heer	me	place
12.	R	high	hagh	heye	up	distance
13.	R	cars	curs	karz	tires	travel
14.	L	right	rjght	rite	✓	good
15.	L	best	beast	bezt	medal	good
16.	L	grass	gross	guras	green	plant
17.	R	chose	chase	choez	point	judge
18.	R	iron	iran	eyern	car	metal
19.	L	eight	fight	ayt	number	amount
20.	L	clean	clan	kleen	bath	health

Grade 4

VField		Stimulus word	Response Items: Structural visual	Structural acoustic	Semantic concrete	Semantic abstract
1.	R	tea	teu	tuhee	wet	liquid
2.	R	roses	robes	rowzez	red	plant
3.	R	easy	eary	eezy	simple	effort
4.	L	rocket	racket	rohcet	blast	space
5.	L	racing	ricing	raysn	cars	sport
6.	L	early	eerly	urlee	sunrise	time
7.	L	places	pluces	playsez	city	area
8.	R	score	scare	skoar	shoot	game
9.	L	whale	whole	wayl	flipper	mammal
10.	L	poem	boem	pohem	words	pretty
11.	R	orange	range	ornj	peel	fruit
12.	L	kids	kils	ciz	girls	young
13.	L	clothes	cloths	klowz	buttons	cover
14.	R	trout	troot	tarout	fin	fish
15.	L	uncle	ancle	unkel	man	family
16.	R	own	gown	ohn	mine	belong
17.	L	says	sags	saiz	speak	language
18.	R	mountain	moontain	mounten	tall	nature
19.	R	months	moths	munthz	calendar	time
20.	R	thirty	thirsty	thrtee	count	math

Grade 5

			Response Items			
VField		Stimulus	Structural		Semantic	
		word	visual	acoustic	concrete	abstract
1.	R	radio	rodio	radeeyo	listen	machine
2.	R	village	villaye	vilij	house	shelter
3.	R	mile	mjle	meyel	walk	distance
4.	R	hands	hards	hanz	fingers	tool
5.	L	size	seize	seyez	elephant	compare
6.	R	July	Julg	Juleye	calendar	time
7.	R	grown	brown	geroan	man	size
8.	L	receive	rcceive	reeceev	gift	given
9.	L	kinds	kids	kyanz	size	types
10.	L	factory	factory	faktree	smoke	work
11.	L	sports	spurts	spoartz	ball	contest
12.	R	phone	phine	foan	ring	distance
13.	L	bottle	battle	botel	glass	container
14.	R	scary	scarry	skeree	face	afraid
15.	L	quickly	quicklg	kwiklee	run	speed
16.	L	screamed	scceamed	skreemd	loud	afraid
17.	L	captain	cartain	kapten	uniform	power
18.	L	cool	coal	kooel	chilly	feeling
19.	R	middle	muddle	midel	centre	place
20.	R	tiny	tinny	tynee	mouse	size

Grade 6

VField		Stimulus	Structural		Semantic	
		word	visual	acoustic	concrete	abstract
1.	R	hobby	bobby	hawbee	bicycle	enjoy
2.	R	Hawaii	Hawaji	Hawhyee	beach	place
3.	L	lakes	takes	laycs	swim	waterbody
4.	R	calm	caln	kom	lake	peaceful
5.	L	nature	natare	naycher	camping	life
6.	L	saucer	saccer	sosr	flat	manners
7.	R	knock	knack	nok	door	announce
8.	L	plastic	elastic	pulaztic	light	protection
9.	L	tripped	trapped	teript	fall	accident
10.	R	prize	price	preyez	medal	reward
11.	L	hopped	bopped	hopt	knees	motion
12.	R	fright	bright	fureyet	scream	feeling
13.	R	completely	conpletely	kumpleetlee	full	everything
14.	L	questions	qucstions	kwestyunz	?	wonder
15.	L	doors	moors	doarz	wood	privacy
16.	L	glove	love	gluv	cloth	protect
17.	L	mini-bike	mini-bike	minee-beyek	small	travel
18.	R	canoe	canoc	kanoo	paddle	travel
19.	R	rough	rougb	ruf	bumpy	surface
20.	R	crew	crcw	keroo	people	teamwork