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ABSTRACT

This study measured unilateral, tachistoscopic naming reaction times of 30 normal and 30 reading-disordered children (mean age of 9.3 years) to objects representing two levels of picture vocabulary age. Reading disabled subjects are enrolled in the Reading Center, a diagnostic and treatment program for disabled readers at Bowling Green State University (Ohio). Results of analysis of the latency data showed main effects for Group and Stimuli, but not for Visual Field. All interactions were nonsignificant. The latency results obtained for each group appear to be explained by an interhemispheric transfer theory which indicates that, although each hemisphere may be capable of performing a component of a given processing task, the stage of processing required to complete the operation is functionally localized to one hemisphere. Analysis of the error data showed that significant differences in error rate existed between groups as a function of each visual half field. Significant differences existed between the two visual fields for the reading-disordered group but not for the normal reading subjects. Findings suggest that the left hemisphere of the reading-disordered subjects experienced difficulties with the integration of local and global form discriminations when responding to visual information displayed within brief presentation windows, and suggest that interhemispheric transfer deficits may underlie certain types of reading disorders in children. The paper concludes that reading-disordered children evidence difficulties in lower or early level recognition of visual information and this problem is significantly compounded when visual images are forced to cross the corpus callosum from the right to left hemisphere. (Contains 17 references.) (JDD)

HEMISPHERIC OBJECT NAMING AND INTERHEMISPHERIC TRANSFER FUNCTIONS IN READING DISORDERED SUBJECTS

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Abstract

It has been proposed that anomalies in hemispheric processing asymmetry and interhemispheric transfer may be contributing factors underlying various types of reading disorders in children. It must be recognized, however, that the techniques employed in the past are capable of yielding data regarding relative processing efficiency or superiority of one hemisphere over the other only. They have been incapable of examining models of neurolinguistic organization that account for both left and right hemisphere processing, information essential to test the extent of dominance patterns and interhemispheric transfer functions. This study measured unilateral, tachistoscopic naming reaction times of normal and reading disordered children to objects representing two levels of picture vocabulary age. Results of an ANCOVA procedure on the latency data showed main effects for Group and Stimuli, but not for Visual Field. All interactions were nonsignificant. The latency results obtained for each group appear to be explained by an interhemispheric transfer theory which indicates that, although each hemisphere may be capable of performing a component of a given processing task, the stage of processing required to complete the operation is functionally localized to one hemisphere. An Arc Sine transformation was applied to the error data and submitted to an analysis of co-variance procedure. Findings showed a significant Stimuli x Group interaction. Post hoc tests showed that significant differences in error rate existed between groups as a function of each visual-half field. Additionally, significant differences existed between the two visual fields for the reading disordered group, but not for the normal reading subjects. Taken in concert with the error-type analysis, it is suggested that the left hemisphere of the RD

subjects experienced difficulties with the integration of local and global form discriminations when responding to visual information displayed within brief presentation windows. The remaining finding, that error rates increased significantly following left visual field stimulations for the reading disordered group, are consistent with a theoretical perspective suggesting interhemispheric transfer deficits may underlie certain types of reading disorders in children. Accelerated error rates following right hemispheric stimulation suggests anamalous interhemispheric transfer of visual images across the corpus callosum in the present group of reading disordered children. Clinical implications are discussed.

It has been proposed that anomalies in hemispheric processing asymmetry may be a contributing factor underlying various types of reading disorders in children (Mykelbust, 1968; Zangwill, 1960). However, studies investigating lateral asymmetries for linguistic processes in reading disordered populations have produced mixed findings. That is, while certain hemispheric specialization research has failed to produce left hemispheric advantages for linguistic information in reading disordered children (Leong, 1976; Thomson, 1976; Witelson, 1976), other literature has produced functional asymmetries consistent with or more robust than those obtained by normal readers (Bryden, 1970; Witelson, 1976; Yeni-Komshian, Isenberg, & Goldberg, 1975). Although such inconsistent findings may be attributed to differences in methodology in testing for hemispheric asymmetries, it must be recognized further that the techniques employed in the past are capable of yielding data regarding relative processing efficiency or superiority of one hemisphere over the other only. Because of this, past experiments have failed to produce cerebral lateralization data of the type that are capable of predicting models of hemispheric processing asymmetry that account for both left and right hemispheric language processing capacity.

As we have observed in past studies, information pertaining to the linguistic capacity of each hemisphere provides a broader picture of cerebral organization and interhemispheric interaction for language functions in both the pathological and normal intact brain (Rastatter, McGuire, & Scukanec, 1991; Rastatter, Watson, & Shulman, 1990). As such, issues pertaining to diffuse or incomplete language laterality patterns in reading disabled populations become readily apparent while theoretical positions regarding interhemispheric inhibition are directly testable.

Although a number of explanations have been forwarded to account for visual perceptual asymmetries in the intact brain (Moscovitch, 1986), the hemispheric processing models proposed by Zaidel (1983) are capable of yielding data pertaining to the analytic functions of each hemisphere. Zaidel indicates that each hemisphere maintains a separate processing style, language structure and memory capacity. Although based on data derived from disconnection syndromes, which may not be an adequate representation of normal function, Zaidel (1983) forwarded the position that both hemispheres in the intact brain may be relatively specialized for certain linguistic tasks in that each is capable of processing direct sensory input, but at different levels of efficiency or competence.

A method presented by Zaidel (1983) for testing the linguistic potential of each hemisphere involves varying the central processing task while employing a vocal reaction time procedure. He indicates that lateralization studies producing differential effects in the left versus right visual fields that employ lateralized verbal responses may imply right hemispheric linguistic processing. Specifically, when the left hemisphere is specialized for a given task (in this case, linguistic processing) and a varying (or increasing) processing load is presented to the minor right hemisphere, differential stimulus processing times occur as a function of each visual-half field. As a result, a significant stimulus (processing load) x visual field interaction is predicted for the latency data, indicating differential, right hemisphere processing. Alternately, symmetrical responses latencies for each stimulus load favoring the visual field contralateral to the dominant language hemisphere would infer left hemisphere processing only.

While it has been suggested that anomalies in hemispheric dominance characteristics may underly various learning difficulties, recent evidence has emerged indicating that abberations in interhemispheric transfer of information in reading disordered children may be influential in their disorder (Broman, Rudel, Helgotta, & Krieger, 1986; Davidson, Leslie, & Saron, 1990). Based on this literature two possible underlying mechanisms have been hypothesized related to interhemispheric transfer functions in reading disordered children. The first includes a signal processing time theory which indicates that the time associated with the exchange of stimuli from the right to left hemispheres may be too brief in reading disordered children, thereby encroaching on analytic, left hemispheric functions (Davidson et al., 1990). A second theory has been forwarded suggesting that the corpus callosum is inadequately developed in reading disordered children, resulting in pyschological noise occurring between the two hemispehres as a function of diminished interhemispheric inhibiting patterns (Broman, et al., 1986).

Such theoretical positions, however, were based on data derived from stimulus-response paradigms that required either simple signal-detection processing mechanisms or early-level linguistic subsystems incapable of assessing higher-ordered language processing events. As such, further research is called for investigating interhemispheric transfer and inhibition patterns in reading disordered children for language processing functions, events that may underly their primary reading disorder.

The purpose of the present study was to measure unilateral, tachistoscopic naming reaction times of normal and reading disordered children to objects representing different levels of picture vocabulary age. Such a paradigm has been shown to provide data relative to differential, hemispheric object naming functions while concurrently resolving issues pertaining to inter hemispheric inhibiting patterns in the intact brain (Rastatter et al., 1991).

Method

Subjects

Thirty reading disabled subjects (x age 9.3 yrs.) and a matched sample (age and sex) of normal subjects were administered the experimental procedures. Reading disabled subjects were selected by their referral to, and acceptance into, the Reading Center, a diagnostic and treatment program for disabled readers at Bowling Green State University. Children are enrolled in the Bowling Green State University Reading Center based on a diagnostic preassessment. This assessment includes the Woodcock Reading Mastery Test-Revised, (WRMT-R) and the Peabody Picture Vocabulary Test (PPVT). All children enrolled at the BGSU Reading Center perform below grade and age expectation on reading measures. The mean PPVT score obtained for the RD children proved to be 97.11 while the corresponding score for the normal reading children were 107.5. Word Identification Subtest score of the WRMT-R for the RD group was 44.5 in contrast to an average score of 64.4 for the control group. The mean score for the Word Attack Subtest was 11.24 for the RD children and 28.2 for the normal children. Normal subjects were randomly selected from a local elementary and middle school in Bowling Green, Ohio. All subjects were evaluated using the Classification of Hand Preferences by Association Analysis (Annett, 1970) and showed a right-hand preference.

Stimuli

Stimuli were a series of 16 line drawings representing picture vocabulary items taken from the Boston Naming Test (Goodglass & Kapplan, 1983). Items corresponded to picture vocabulary ages of 5.5 years (Level I) (bed; tree; pencil; house; whistle; scissors; flower; saw) and 10 years of age (Level II) (harp; hammock; pelican; pyramid; muzzle; unicorn; funnel; knocker). All pictures were hand sketched by a professionally trained artist. The drawings fit within a 1.5 cm square. The stimulus pictures were then affixed to an index card. All index cards were photographed and made into slides to fit the slide projector. The stimuli subtended visual angles between 3 and 4 from the central fixation point to the lateral periphery for pictures in both the left and right visual fields. All stimuli were presented unilaterally to both the left and right visual fields.

Instrumentation

The visual stimuli was presented unilaterally to both the right and left visual fields by a tachistoscope (Lafayette Model 42011-A) set at an exposure duration of 100 msec. Simultaneously with onset of illumination, the tachistoscope's presentation timer was activated by a second digital timer (CMV, Model 7078) accurate to 1 msec. The timer was stopped by a signal from a voice-operated relay (Grason-Stadler, Model E7300-1) activated by a microphone (Grason-Stadler, E7300A-2) after the subject responded to the picture stimulus. This gave a naming reaction-time value for that particular stimulus (see below).

Object Recognition Procedure

Each subject was instructed to focus on a circular fixation point presented under the constant illumination mode of the tachistoscope. It was explained that a series of line drawings would appear either to the right or left of the fixation circle. The subject's task was, as quickly and accurately as possible, to speak the name of the picture into the microphone (located approximately 10 cm from the subject's mouth). The order of stimulus presentation was randomized, using the criterion that identical pictures would not appear adjacent to each other in a direct sequence. The order of presentation was identical for all subjects.

Results

Reaction Time Data

The reaction time data were submitted to an analysis of covariance (ANCOVA) procedure in an attempt to adjust for the effects of PPVT average differences between the RD and normal children. Table 1 presents the adjusted means and standard deviations for each independent variable for the RD and normal children. Results of the ANCOVA showed that the covariate (x PPVT scores) did not account for a significant position of the variance ($p>.05$). After adjusting for the covariate, the analysis showed significant main effects for Group ($F(1, 57)=8.32$, $p=0.005$) and Stimuli ($F(1, 57)=1.38$, $p=0.0001$), but not for Visual Field ($F(1, 57)=1.38$, $p=0.244$). All interactions were nonsignificant ($p<.05$).

Error Data

An Arc Sine transformation was applied to the error data and submitted to an ANCOVA procedure to test the significant main effects and interactions among variables. The analysis showed a nonsignificant covariate ($p>.05$) and that the main effect for group ($F(1, 72)=41.24$, $p=0.0001$), stimuli ($F(1, 72)=42.30$, $p=0.0001$) and visual field (F(1, 72)=4.16, p=0.04) were significant. Additionally, the Stimuli x Group interaction was significant (F(1, 72)=6.20, p=0.0026), while remair 'ng interactions were nonsignificant (p>0.05). Figure 1 displays the Stimulus x Group interaction. Tukey post hoc tests showed that significant differences in error rate existed between groups as a function of each visual-half field (p<.01). Additionally, significant differences existed between the two visual fields for the reading disordered group (p<.01), but not for the normal reading subjects.

Error Type

Object naming errors for the current experiment were categorized into three classifications. These included errors of visual recognition where the line features of the object were confused (such as naming a pencil a line), semantic errors (naming confusion reflecting class/category substitutions-semantic paraphasias) and phonological errors (naming confusions reflecting either rhyming substitutions or literal paraphasias). Inspection of the naming error patterns revealed that both groups of subjects evidenced visual recognition confusions. Semantic and phonological naming errors did not occur in the data.

Discussion

The results of the current study showed that the visual field main effect for the latency data was nonsignificant and did not interact with the group variable. Given these findings differential right hemispheric processing is not predicted for either the normal or disordered readings groups. In order to predict minor hemispheric processing an interaction must occur between visual fields and stimuli, a condition necessary to fulfill the requirements of the direct access model (Rastatter, et al., 1991).

Rather, the current findings appear to be explained more completely by an interhemispheric transfer theory which indicates that, although each hemisphere may be capable of performing a component of a given processing task, the stage of processing required to complete the operation is functionally localized to one hemisphere (Moscovitch, 1986). Therefore, when stimuli are delivered to the hemisphere capable of partial processing only, the information must eventually be sent to the specialized hemisphere via a transcallosal route. As such, under conditions of interhemispheric transfer the processing resources of a single hemisphere are employed to completely analyze both right and left visual field signals. As a result, and as in the case of the current study, the latency of reaction time following stimulation of the unspecialized hemisphere was increased (by 24 msec.) as compared to responses following input to the dominant hemisphere.

Based on past literature, if the right hemisphere was capable of stimulus processing, left visual field signals would have been significantly degraded due to interhemispheric inhibiting effects. As a result, right hemispheric processing times would have been significantly augmented (Rastatter, Dell, McGuire, & Loren, 1987).

Based on these findings, it is suggested that hemispheric organization for those operations involved in object naming were parallel for each group and, therefore, cannot be considered an agent contributing to the current subject's reading disorders. That is, in both groups of subjects, the left hemisphere proved dominant for object naming functions with the right hemisphere serving primarily as an afferent channel sending the left visual-field signals to the dominant hemisphere for analysis.

The results showed further that the main effect for stimulus level (picture vocabulary-age) was significant. Stimuli corresponding to early levels of acquisition were named significantly faster than those acquired at a later age. The fact that the stimuli x group interaction was nonsignificant suggest that the two groups of subjects possessed similar hemispheric processing hierarchies for object naming functions.

It has been demonstrated that the recognition of visual information results from the operation or interaction of several subsystems or modules over a given period of time (Chiarello, Nuding, & Pollock, 1988; Riddoch & Humphreys, 1987). Riddoch and Humphreys (1987) forwarded a processing-stage model operationalizing the dynamics involved in picture-naming tasks. They argue that initially the image of a picture must access a lower-level perceptual processing stage where figure-ground discrimination and local and global form discriminations are integrated. Prior to naming, however, three additional, higher level representations must be accessed in a cascading manner to formulate a verbal response. These include a structural descriptive level where knowledge of object form (the object's parts relative to its major axis) is accessed, a semantic representation system concerned with functional and associative object characteristics, and finally, a phonological level responsible for output-naming functions.

The activation of the naming cascade, however, may be influenced by certain factors. That is, it has been demonstrated that name frequency (the frequency of occurrence in the language) influences naming reaction times to objects from structurally distinct categories (Riddoch and Humphreys, 1987). Objects with a high frequency of occurrence in the language are named significantly faster as compared to objects corresponding to lower frequencies. Since the vocabulary-age levels of our stimuli varied inversely with the frequency of the object names (Francis and Ducera, 1982), it is suggested that the left hemispheres of both groups performed the current naming task in a manner consistent with the neuropsychological principles defining the Cascade Model. Under normal conditions the time involved in performing structural description and semantic level resolution influences directly those variables impacting later stages of analysis, such as object-name frequency, or, for the current study, vocabulary-age level. Specifically, Riddoch and Humphreys (1987) indicate that structurally-distinct objects are capable of accessing structural and semantic information quite rapidly. Due to rapid access, there is less time for late representations to be partially activated through the cascade, resulting in marked effects of response latency. As such, based on the principles of the Cascade Model, it would appear that left-hemispheric verbal mediation processes of the disordered and normal readers were parallel.

While neurolinguistic organization and hemispheric processing hierarchies were functionally normal in the reading disordered children, the latency analysis showed that the time involved in performing naming cascades was significantly slower than the normal subjects. Such findings suggest that the modular interactions required to name objects are impeded at some level within the cascade. While tests of modular-related activity were not conducted directly in the current experiment, we postulate that the earlier levels of stimuli recognition may underlie the observed increased in the naming response times for the reading disorder subjects. It was demonstrated in the pretest that each child was capable of naming each object prior to receiving the experimental trials. Such findings indicate the presence of an intact structural descriptive, semantic and phonological interactive system. Under conditions of accelerated stimulus processing, however, naming error rates were significantly greater than the normal readers. Taken in concert with our descriptive data which showed that naming errors were based primarily on visual confusion points in the general direction of a low-level, perceptual processing stage aberration that served to degrade figure-ground discrimination abilities in the reading disordered children. Further testing these assumptions, however, is warranted to more fully respond to these issues.

As referred to above, results of the error analysis showed a significant interaction between the group and visual field variables (Figure 1). As the figure shows, the reading disordered children's error rates were significantly increased following right visual field input. While these data are consistent with the literature showing that reading disordered subjects experience elevated levels of naming errors, our findings suggest that the source of our sample's error patterns were visually based. Such a position runs counter to the common theme in the literature suggesting that error rates are a manifestation of phonological difficulties in reading disordered children. As discussed above, the current data reflected visually-based error patterns which is consistent with the position that the left hemisphere experienced difficulties with the integration of local and global form discriminations when responding to visual information displayed within brief presentation windows.

The remaining finding, that error rates increased significantly following left visual field stimulations for the reading disordered group, provides some interesting insights pertaining to right-to-left interhemispheric communication of visual information. Such findings are consistent with a theoretical perspective suggesting interhemispheric transfer deficits may underlie certain types of reading disorders in children (Davidson, et al., 1990). Zaidel (1983) has suggested that when visual information must cross the corpus callosum prior to analysis, as is in the case of the current interhemispheric transfer interpretation, signal fidelity may be altered resulting in a loss of certain features necessary to perform discriminations. Accelerated error rates following right hemispheric stimulation suggests anamalous interhemispheric transfer of visual images across the corpus callosum in the present group of reading disordered children. What is striking about the data is the fact that error rate was not affected in the normal children following left visual field input, suggesting efficient, nondegraded, transcollosal function for the current stimuli. While difficulties in interhemispheric transfer of various types of information have been reported in reading disordered samples (see Davidson et al., 1990), the present study provides additional information pertaining to the effect of transcallosal signal degrading on response characteristics of these children. Again error patterns suggested that the interhemispheric transfer required for a response to occur resulted in a distortion or loss of visual features necessary to perform early level discrimination functions.

In summary, the current results suggest that reading disordered children exhibit hemispheric processing characteristics for object naming functions similar to normal readers. As such, we do not believe that neurolinguistic organization serves as an underlying factor contributing to the disruption of reading processes. Rather, our data suggested that reading disordered children evidence difficulties in lower or early level recognition of visual information and this problem is significantly compounded when visual images are forced to cross the corpus collosum from the right to left hemisphere.

Clinically, our data would support the use of reading approaches such as rebus methods or the use of environmental print, that serve to increase the visual information that can be used by the disabled reader. These approaches can assist the child to overcome the initial visual decoding weaknesses and facilitate the transfer of the visual information into the semantic and phonological modules. Furthermore, we suggest that the tachistoscope could be used in a remedial fashion to increase collosal transfer of information.

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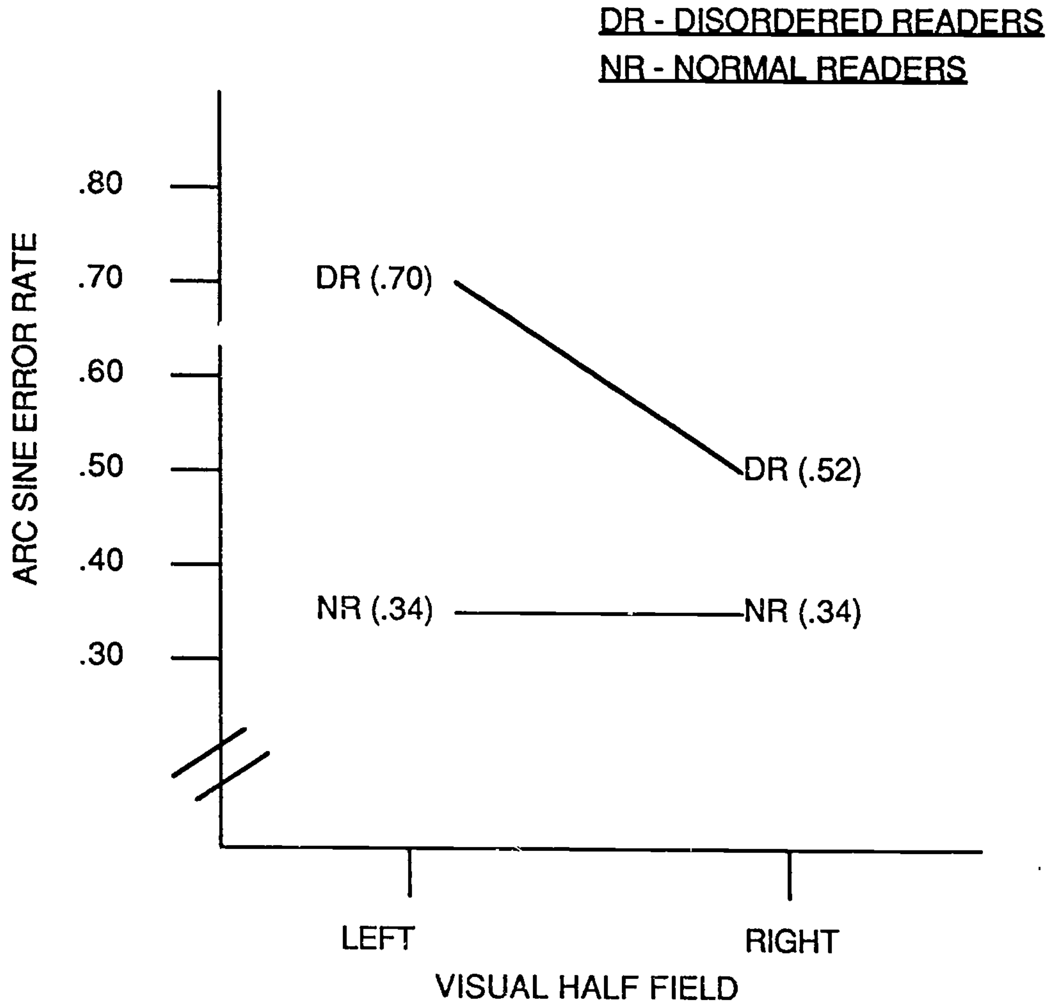
Table 1

Means and Standard Deviations for Naming Reaction Times as a Function of Group, Visual-Field and Picture Vocabulary-Age Level.

Variable	x	SD
Group*		
Disorders Readers	1.091	225
Normal Readers	933	164
Stimuli*		
Level I	890	191
Level II	1.135	201
Visual Field		
Left	1.024	221
Right	1.000	198

*Significantly Different ($p<.01$)

FIGURE 1



Significant Group x Visual Field Interaction