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ABSTRACT

Neuropsychological research can provide a basis for learning how to interpret test data to help solve the problem of how to teach children who fail to read. Insights from brain research can be joined with diagnostic efforts and cognitive, language-based models of reading processes in order to move toward individual assessment and away from "group" or "subtype" classifications. Individual case studies are a promising research strategy for researchers and practitioners who attempt to blend neuropsychology with efforts in remedial reading, but additional research methodologies using advanced psychological measures that link psychological behaviors to organic brain functioning need to be employed as well. A case study demonstrated the dependence of diagnostic processes, remedial strategies, and the outcome on a reading specialist's understanding of how the brain contributes to reading and how this knowledge can be used in remediation. A remedial reading program was designed for the subject of the case study, a third-grader reading at the 1.5 grade level, based on his performance on the Wechsler Intelligence Scale for Children-Revised (WISC-R) and various qualitative neuropsychological measures. The subject's reading level increased almost 3 years in 3 months of intervention, and his reading fluency and confidence increased. (Two figures are included and 36 references are attached.) (RS)

Brain Functioning and Reading Remediation:

Progress in Research and Practice

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SUMMARY: Brain-behavior research (neuropsychology) which focuses on reading remediation fits within Mosenthal's (1985, 1987) definition of progress in educational research. Reading specialists and educators are asked to consider the value of an assessment/treatment model based on neuropsychological and cognitive, language-based views of the reading process. After objections and confusions related to neuropsychological views are discussed, cortical and subcortical areas are described in light of their known contributions to the complex act of reading. A case study presents assessment/remediation procedures as well as quantitative and qualitative data pertaining to the brain's "interactive axes." Remedial strategies bypass possible weaknesses in brain functioning and rely, instead, on language and neuropsychological strengths. Readers are urged to avoid a "gatekeeper's" mentality and to stay abreast of developments from neuropsychological research and medical technologies using computerized scanners.

Brain Functioning and Reading Remediation:

Progress in Research and Practice

Many reading specialists, teachers, and teacher trainers feel that they lack sufficient background to understand how brain functioning relates to the reading process. Our goal here is to provide in plain language the information practitioners need to make sense of this topic.

It is not uncommon to find skepticism about the applications of brain research to education in general and to reading problems in particular. This hesitation is likely due to two opposing problems. On the one hand, brain research presented by some educators is often far too simplistic. The "checklist" mania of right brained-left brained qualities serves as a good example (Shook, 1986). If a person does this or this, he is "right-brained"; if she does this and this, she is "left-brained." The popularity of Betty Edwards (1972)[2] Drawing on the Right Side of the Brain may even lead some to consider reading as a right or left brain dichotomy when in fact the reading process involves many areas of the brain. Edward's excellent best seller deals with creativity and artistic confidence, but has little to do with learning to read or reading to learn. On the other hand, brain research reported by the medical community is quite technical, frequently confusing, and, more often than not, difficult to distill into the form of educational practice.

As a result, most teachers tend to feel that brain-based information is not very helpful or relevant to the challenge of helping children overcome reading difficulties. Our purpose is to focus attention on research in the field of neuropsychology (the study of brain-related behavior) and to suggest to reading specialists and educators how this research can help children with reading difficulties. Currently, formal training and coursework in the field of neuropsychology is primarily offered to clinical psychologists. Unfortunately, brain-based explanations of behavior presented to educators are often simplistic.

Occasionally, as Shook (1986) explained, teachers and specialists are offered erroneous "right brain-left brain" dichotomies followed by unsubstantiated instructional/remedial recommendations. Based upon our knowledge of the research we applaud the fact that most teachers intuitively reject recommendations to use visual-spatial exercises that are supposedly "brain-based".

We believe that educators need more knowledge and better insights in neurological perspectives and that these can lead to substantial progress in reading remediation. In the Educational Researcher, Mosenthal (1985) pointed out that there are "three classes of critical definitions of progress in educational research." He concluded that progress must be literal (based upon quantitative validation of variables), interpretive (providing a view of how learning occurs) and evaluative (resulting in a judgement about the merit of investigations in light of how well they fit within various schemata of knowledge).

Neuropsychological insights related to reading remediation can be derived from each of these specifications of progress in educational research. To demonstrate this contention, we will explain first how the brain functions as an organized system in the reading process. Secondly, we will present a case study to describe how neuropsychological insights can provide effective clues for teaching remedial readers.

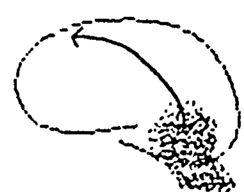
Understanding Brain Processes in Reading

In order to accomplish the complex cognitive act of reading, many systems in the brain work together. The act of reading does not take place in a single "cubby hole" in the filing system of the brain. Recent work regarding brain-based correlates of reading suggests that the higher level cognitive processes of reading take place through the interaction of many cortical and subcortical areas of the brain. The interaction of these areas forms a cognitive system (Luria, 1973). Luria's model for the child's brain is dynamic. He felt the young brain grows and changes just as the child grows and changes as a result of environmental interactions.

Until recently, brain-damaged adults often served as subjects for researchers who were trying to explain brain functioning. In these studies the function of a brain structure was inferred from behaviors that were lost or impaired. More recently, research efforts have tended to focus on brain metabolism or electrical activity in undamaged brains during complex behaviors. Using measures of cerebral blood flow, Lassen, Ingvar, and Skinhoj (1979) found at least 14 cortical areas (7 in each hemisphere) active during oral reading in normal adults. (See Figure 1.) This finding helped validate Luria's view of the cortical behaviors and relationships as complex, interconnected, and interactive.

Meier (1974) and Horton and Wedding (1984) described the brain system as having three dimensions that could be visualized as three axes. These axes serve as team players during the act of reading. (see Figure 2 next page) These axes accommodate 1) bottom to top, 2) back to front, and 3) left to right interactions. Each axis works as a reverberating, two-way system in coordination with the other axes. We will discuss each of these in light of their known contributions to reading. Although there is some overlap, none of them operate independently of each other.

THE BOTTOM OF THE TOP-BOTTOM AXIS


side view

Located in the limbic area at the bottom of the brain are the controls for regulating the arousal mechanisms of attention. These subcortical areas act as filters for the sensory data of letters and language. Once the incoming sensory messages of print are sent through the attention setting gates in the brain stem, they travel up to the cortical regions as electrical and chemical messengers to

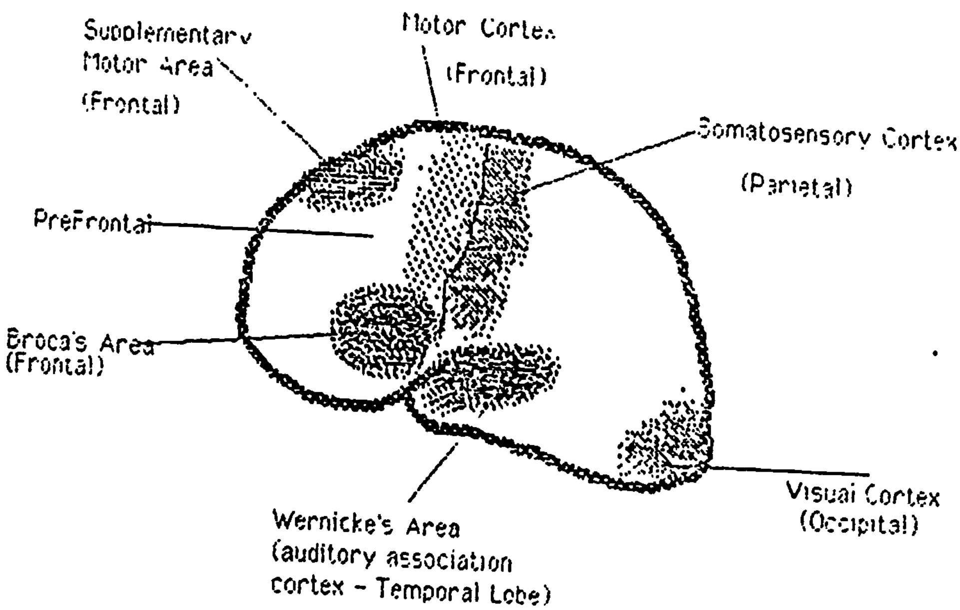


Fig. 1. Seven Cortical Areas Involved in Reading Performance

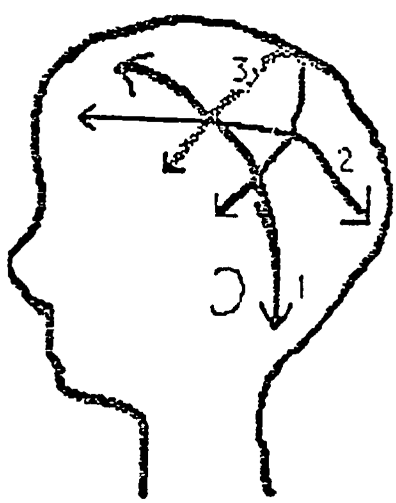
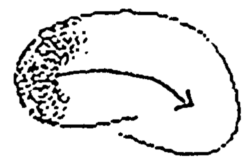


Fig 2 Three Brain Axes Active during Reading

<u>Bottom</u> arousal, attention	<u>Top</u> selection, organization, monitoring, evaluating
<u>Back</u> receives, processes, stores	<u>Front</u> motor output speech, hands
<u>Left</u> sequential, critical features	<u>Right</u> configurational, spatial, contour

be recognized and acted upon. At this point they are traveling towards the top of the top-bottom axis.

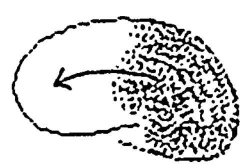
THE TOP OF THE TOP-BOTTOM AXIS



side view

The top axis of the brain is represented by the foremost areas of the frontal lobes. This area acts much like an orchestra conductor in calling forward information from the various rear regions of the brain. Its contribution to reading involves selecting, organizing, monitoring, and evaluating attempts at word recognition and comprehension. One specific job is to let us know if what we have predicted while reading is correct or makes sense (Denckla, 1983).

THE BACK OF THE BACK-FRONT AXIS



side view

The back of the brain perceives, processes, and stores all the data about what and where we see the orthographic information and what it means. It is composed of the occipital, parietal and temporal lobes which receive, encode and store information coming in through the senses of sight, touch/movement, and sound. The contributions from these lobes will be discussed under the left-right axis.

THE FRONT OF THE BACK-FRONT AXIS

side view

The front axis also resides in the frontal lobes and is located about where a headband would sit. It facilitates knowledge gained through movement or speech. Reading aloud, as most beginning readers are required to do, involves speech/motor processes. The forming of sequences of sounds for articulation, intonation, and rhythm depend upon this area. Another part of the frontal area is responsible for fluent speech. Children with oral reading difficulties may be impaired or behind in the development of this executor area of the brain.

THE LEFT OF THE LEFT-RIGHT AXIS

top view

The left-right axis is composed of the three major information processing lobes (occipital, parietal, temporal) and the relatively huge frontal lobes.

Left Occipital Lobe

The left occipital lobe handles information coming from the right visual field of each eye. This information is registered as waves of chemical and electrical messages which represent in a point-by-point way what is being seen. The left occipital lobe is best able to detect angular differences in lines, corners, and sequences of details such as are in the alphabet (Bogen and Gazzaniga, 1965), and they contribute to efficient eye movement and scanning which affect fluency in reading (Luria, 1973). Problems in this area inevitably lead to slow, effortful, word by word reading.

Left Temporal Lobe

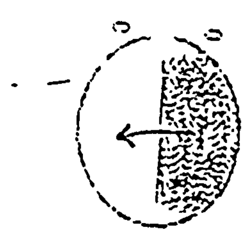
Part of the information which registers in the occipital lobes travels forward to the temporal lobes where an identification is made of which letter or word is seen (Yingling, 1986). The left temporal lobe handles linguistic-semantic information about words, enabling the recall of the sounds of the separate phonemes and phonemic sequences (Galaburda, LeMay, Kemper, and Geschwind, 1978). Deficits in this area have been associated with readers making meaningful substitutions (Benson, 1979).

Left Parietal Lobe

The left parietal lobe helps readers keep track of where to look while reading. An area within the left parietal lobe is used both for decoding speech and sequencing motor movements necessary for articulation (Ojemann, 1983). A localized strip of the left parietal lobe receives sensation from the right side of the body (Golden, 1981).

In the areas where the three information processing lobes border each other, the integration and association of what is seen is made with what is said.

THE RIGHT OF THE LEFT-RIGHT AXIS



top view

Right Occipital

The right occipital lobe receives all the information coming from the left visual field of both eyes. The right occipital area contributes greatly to the ability to glance at words and know what they mean without analysis. When this cortical area is functioning improperly, readers have trouble building a sight word vocabulary, processing clumps of letters, and may rotate letters. As Bakker (1976) has observed, they often over depend on phonic cues.

Right Temporal

The right temporal lobe shares the load of language in a supportive way. It contributes to a reader's ability to match letters and letter strings, in recognizing unusual scripts, and in housing a large repertoire of semantic terms (Geffen et. al. 1972; Gazzangia 1970). The right hemisphere facilitates the reading words "ideographically," without a middle translation step into a phonological code. Consequently, right temporal lobe processes enable meaning to be accessed directly from the orthography (Zaidel, 1985).

Right Parietal

These areas are also involved in recognizing words "instantly" through contour rather than through the mediation of phonics. An example of the contour, global aspects of spatial processing is seen in normal face recognition, at which the right hemisphere (left visual fields) usually excels (Bever, 1983). A strip of the right parietal lobe receives sensation from the left side of the body and provides an indication of right parietal functioning to examiners.

The bordering areas between these three information processing lobes serve an association function for integrating what is seen and said.

A Case Study: Assessment and Remediation

In the case study of Scott that follows, we have laid out the neuroanatomical constructs of the axes of the brain and their interactions in order to show how neuropsychological perspectives can serve the cause of reading assessment and remediation. We were interested not only in his scores or his number of right answers (quantitative data), but also, in keeping with Mosenthal (1986) and Luria (1973), in how he arrived at his answers (qualitative data) and how his performance conforms with neuropsychological and other research perspectives. Because the aim of neuropsychology is to investigate the functional status of brain systems which mediate mental processes, a broad range of behaviors were sampled. Scott is only one, individual child - not necessarily exactly like any other child in his interactive neuropsychological status. The description of his performance shows how diagnostic processes, remedial strategies, and the outcome are dependent upon a reading specialist's understanding of how the brain contributes to reading and how this knowledge can facilitate Scott's progress.

Referral Background:

Scott was referred by his teachers and parents because he had difficulty learning to read despite acceptable performance in arithmetic. He was eight years old and in the third grade. His parents reported that he had been read to "since he was small." They reported that he loved books, but was greatly frustrated by his difficulty with learning to read. During the evaluation he was cooperative and friendly, but showed his frustration easily, commenting frequently about his "stupidity."

Medical History:

Scott's medical history revealed no head injuries, high fevers, or serious health problems. Scott's Family Physician could find no reasons to recommend a neurological evaluation with such measures as a CAT scan (computerized axial tomography) or a MRI (magnetic resonance imaging). The neuropsychological assessment which follows detected no reasons for such examination, either.

Assessment Perspectives:

In the analysis that follows, Scott's inferred brain functioning is assessed from several perspectives:

...the Bottom of the top-bottom axis

...the Top of the top-bottom axis

...the Back of the front-back axis

- ...from the left and right parietal lobes
- ...from the left and right occipital-parietal lobes
- ...from the left and right temporal-occipital-parietal lobes
- ...from the left and right temporal lobes

...the Front of the front-back axis

- ...from the left and right frontal lobes

Analyses of left and right lobes have been incorporated into discussion of the front-back axis because each lobe lies within these areas. In keeping with the advice in Searls' (1985) How to Use WISC Scores in Reading/Learning Disability Diagnosis, the assessment included Scott's performance on the WISC-R and how it is related to his performances on the various neuropsychological measures

...the BOTTOM OF THE TOP-BOTTOM AXIS:

***LIMBIC SUBCORTICAL AREAS:

ATTENTION and CONCENTRATION

There was no evidence to support problems with his being able to attend to the materials of the test. Scott was not distractable and concentrated well. Thus, in light of this qualitative assessment, the limbic and other subcortical brain stem areas appear to be contributing properly to Scott's performance.

...THE TOP OF THE TOP - BOTTOM AXIS:

***FRONTAL LOBES: SELECTING, ORGANIZING, MONITORING, EVALUATING

Scott demonstrated skill in organizing his problem solving on various tests. He was able to self-direct, correct, and change his approach when needed. During drawing/copying tasks he was aware that his reproductions were not correct, but he was unable to fix them. When he was reading orally, he was aware of his difficulties and defined his problem as "I just can't remember what the words say, but I know what they are supposed to mean." This qualitative analysis of his ability to monitor and evaluate his performance suggests that his frontal lobe processing was functioning adequately.

...THE BACK OF THE FRONT - BACK AXIS:

***LEFT-RIGHT PARIETAL LOBES:

SENSORY FINDINGS

On certain sensory measures, Scott could not recognize simple shapes drawn on his fingertips. With his eyes averted, he had some difficulty naming which of his fingers was being touched or naming objects felt with his left hand. His difficulty accessing contour and spatial information might be associated with his problems in recognizing whole word patterns easily. The sensory tests on his fingers compared the performance of the left and right sides of his body, represented by the left and right parietal areas. A qualitative neuropsychological interpretation of his unilaterally weaker performance on the left side of his body implicates possible difficulties within his right parietal areas (Golden, 1981).

***LEFT-RIGHT OCCIPITAL-PARIETAL LOBES:

VISUAL-SPATIAL PROCESSING

Scott scored far below the level expected for his age on a number of the visual-spatial tests. For example, on a simple copy designs test (Beery 1982), his raw score of 9 indicated an age equivalence of 5-3; 1 % ile. The separate parts of his reproductions were usually correct, but the way in which they fit together was often wrong. Even when the fine-motor element of drawing was removed in a spatial reasoning test (Raven Colored Progressive Matrices, Raven, 1977), he did poorly. His errors were due to rotations of the correct answer or to only partially correct answers. On a complex figure drawing test (Osterreith, 1944), he was able to copy individual pieces but could not fit them together in relationship to the whole design. On the memory drawing of this complex figure, he drew most of the details, but his rendering of constructional organization and shape were inaccurate. His performance on these visual-spatial tasks offered some evidence for stronger left occipital-parietal functioning.

***LEFT-RIGHT TEMPORAL-PARIETAL-OCCIPITAL

LOBES: INTERRATIVE-ASSOCIATIVE FUNCTIONING

Scott was able to associate sounds of letters with their forms on a test of pronouncing nonsense syllables, scoring at the 2.8 grade level/40% ile (word attack subtest, Woodcock Reading Mastery Test, 1973) However, his oral reading score for real words in isolation or in context on both the Woodcock (word identification subtest, 1.5, 2 % ile; passage comprehension subtest, 9 % ile) and the Silvaroli Informal Reading Inventory (1973) were below grade level norms. On the Silvaroli his frustration reading level was grade 2, while his instructional reading level was grade 1.

***LEFT-RIGHT TEMPORAL LOBES:

AUDITORY-VERBAL-LANGUAGE PROCESSING

Scott did well, scoring at an age equivalence of 9.5—72 % ile on the Peabody Picture Vocabulary Test (Dunn and Dunn, 1981), which measures receptive vocabulary knowledge of the meanings of words. He had no difficulty understanding and following complex directions involved in parts of this evaluation. He did well also on a test of recognizing tone and pitch differences developed by Golden, Hammake, and Purisch (1987). His conversational speech reflected this ability. Both his quantitative performance on the PPVT and his qualitative pitch and tone performances offered no indications of difficulties within the left and right temporal areas.

...THE FRONT OF THE FRONT - BACK AXIS BY LEFT RIGHT AXIS

***LEFT-RIGHT FRONTAL LOBES:

MOTOR FINDINGS

Scott was right handed, but had mixed eye preference. He had trouble alternately looking at two objects and needed to self correct several times before fixating on them. When he read simple material, he had difficulty keeping track of his place. He also had problems with making shifts in on-going, coordinated fine motor movements with his hands and his mouth, sometimes mispronouncing words in conversational speech. "Clumsy-eye" difficulties are associated with the frontal motor mechanisms and their connections with the cerebellum for smooth efficient eye movements. These findings suggest difficulties with sequencing fine motor movement, perhaps contributing to his lack of fluency in reading.

***LEFT-RIGHT FRONTAL LOBES: LANGUAGE

Scott's highest scores were on measures where he could use language to work his way to solutions. His scores on the WISC-R expressive vocabulary subtests (Wechsler, 1974) were in the average range for scaled scores (Similarities 12; Vocabulary, 13; Comprehension 10).

On other qualitative measures, he had some difficulty with articulation when reading, although his intonational patterns and rhythm in oral speech seemed normal. On the California Verbal Learning Test (Delis, 1985), he was able to recall only 5 of the 16 words after 3 practice trials. He did not use categories to help organize his recall. Consequently, after a planned interruption, he could only recall short, serial strings of words. But, overall, his functioning was adequate in these frontal motor and expressive language areas.

***All Brain Areas: Overall WISC-R Performance

His scores on the WISC-R placed Scott in the average range. However, there was a noticeably wide difference between his Verbal (109) and Performance (88) scores, giving support for the strengths and weaknesses seen elsewhere in his evaluation. He did considerably better with tasks that lent themselves tolanguage or verbal, analytical reasoning. When the task presented was more spatial and it was not apparent to him how to use language, he had more difficulty.

His performance on sensory and visual-spatial measures suggested that Scott has real difficulty with processing global information presented in spatial formats. He did not seem to use configuration cues or the overall shapes of words in order to be able to recognize them quickly and consistently. As noted, he also had trouble keeping his place while reading and showed a slight difficulty in smoothly pronouncing words. Yet, he could slowly sound out many letter sequences accurately.

Matching Remediation to Neuropsychological Assessment

Scott was tested as reading at a 1.5 grade level at the middle of his 3rd grade year (Woodcock Reading Mastery Test, 1973). He tended to "guess" real words for unknown ones (e.g. air for are; ring for rug) when they were presented in isolation. Beyond that, he responded by uttering nonsense syllables. Perhaps because Scott had shown difficulty with working on spatial wholes and contours or perhaps because his previous instruction had emphasized "sounding out," he attempted to read using a piece by piece, phonic strategy. Since he was not incorporating what he knew about language, his attempts often resulted in nonsense words.

Building upon his verbal skills and strengths, it was decided that the major emphasis in his reading remediation program should be a combination of language prediction and anticipation used in conjunction with a letter-cluster phonetic approach. Sounding out two and three letter groups, especially at the beginning of words, and using his language and prediction skills (in keeping with Goodman, 1967; Smith, 1978), Scott ought to be able to predict more meaningful words. To compensate for his eye tracking problems, he should be encouraged to use a marker or his finger to keep place while reading.

Scott's district-adopted reading text was maintained as a major part of his remedial program. However, stories in the basal reader were tape recorded for Scott, first by his teacher, and then alternately by his mother and father. His parents were eager to help and appreciated this involvement. Scott was instructed to do three things with the tape of "modeled reading." He was first told to listen the tape and to use his finger as a marker to help keep his eyes on the words he heard being read. Scott's second step was to read along with the tape. These beginning steps required no supervision, simply Scott, his tape recorder, and book. Finally, he was to go to one of his parents and read the selection without the tape. Eventually, he took the tape to his classroom and used a set of headphones to work on these steps at school. The purpose of this activity was to create a reading environment for Scott that would encourage him to anticipate and predict meaningful words. Any meaningful substitution that phonetically started with the same letter(s) was accepted and praised as "good thinking." He was also encouraged to read the selection to a friend in a process called "buddy reading." He was kept "one story ahead" of his reading group at school so that he was prepared and confident when the group read and discussed the story in class.

In order to increase his ability to sound out words, children's tradebooks written at the 3rd-4th grade level were used in a special way. The short vowels in these books were marked with highlighter pen, a different color for each sound. Long vowel and vowel combinations were not marked at this time. Gradually, some words with short vowel sounds were not marked so as to phase out the color cueing. At the beginning, these materials were also taped for Scott, following the same steps used for his basal reader text. In order to measure if the strategy of predicting real words and consequently improving fluency was transferring to his reading of nonmodeled material, a technique described by Samuels and Eisenberg (1981) was used. Reading rate and number of errors were graphed for baselines in modelled and nonmodeled materials.

Scott was also taught the Glass Sound Clusters (Glass, 1985) which contain common groups of vowel-consonant letters found in Standard American English. He wrote them from dictation and they were pointed out to him while he was reading, both by his parents and his teacher.

Outcome:

A re-evaluation of Scott's reading three months later showed a Total Reading score of 4.2 (78 % ile) on the Woodcock Reading Mastery Test (1973), an increase of almost 3 years in three months of intervention. His reading fluency at the time of retesting averaged 82 words per minute, still quite slow because of his eye-tracking difficulties. He continued to make meaningful "miscues" on some content words (e.g. he read pastel for pale, mom for mother, and gleamed for glinted), but he was praised rather than criticized for these efforts to make meaning. His confidence improved, although he recognized that he needed to work harder at reading than most of his friends. His parents were proud of his efforts and were pleased with their contributions to his improvement. They were particularly happy about his improved attitude toward himself and his eagerness for school and new learning.

Concluding Remarks

Neuropsychological research can provide a basis for learning how to interpret test data to help solve the problem of how to teach children who fail to learn to read. Insights from brain research can be joined with diagnostic efforts and cognitive, language-based models of reading processes in order to move toward individual assessment and away from "group" or " subtype" classifications. In any developing child, it is the particular brain of that child which functions in the child's life and not "an average brain" of a group (Valsiner, 1983). Hence, individual case studies are a promising research strategy for researchers and practitioners who attempt to blend neuropsychology with efforts in remedial reading. Much more research, however, needs to be carried out. Additional research methodologies using advanced physiological measures that link psychological behaviors to organic brain functioning need to be employed as well. Magnetic resonance imagings (MRI's), digital subtraction angiographies (DSA's), and positron emission tomographies (PET's), as described by Howard Sochurek in the January 1987 issue of National Geographic, may help provide more explanations of reading, thinking, and language processes vis a vis brain functioning.

In his "Research Views" contribution in The Reading Teacher, Mosenthal (1987) has expressed his concern that there may be too many "gatekeepers" in the field of reading whose thoughts and practices are limiting progress. We feel it is time for reading specialists and researchers to expand their perspectives to include literal, interpretive, and evaluative aspects of progress in reading research and practice from neuropsychological perspectives.

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