DYSLEXIA:
ONE APPROACH TO OPTOMETRIC DIAGNOSIS

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INTRODUCTION

In 1968, the World Federation of Neurology published the following definition of dyslexia:

> "a disorder manifeseted by difficulty in learning to read despite conventional instruction, adequate intelligence, and socio-cultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin"

Public Law 94-142 of 1975 includes dyslexia in its definition of children with specific learning disabilities. Excluded, are children who have a reading difficulty resulting from visual, hearing or motor handicaps, mental retardation, emotional disturbance, environmental, cultural or economic disadvantage.

Taken together, it is clear that dyslexia is an inability to learn to read and a recognized learning disability. It is not clear as to what dyslexia is - only what it is not. Consequently, dyslexia has been defined in terms of exclusionary criteria. A child who has difficulty learning to read but is of normal intelligence, is dyslexic as long as there is no overt neurological deficit and the child is not culturally, psychologically, or environmentally disadvantaged.

Optometry, through developmental vision and visual training, has had an interest in dyslexia for quite some time. The specific role of optometry in terms of remediation remains controversial. Without regard to remediation, however, optometry has a unique opportunity to identify those children who may be dyslexic. That is the thrust of this study.

Optometry is often consulted early when a child has difficulty with reading. Children are referred by school systems or parents to identify or rule out possible contributory visual problems. When refractive , oculomotor and related causes are eliminated, optometry can use the opportunity provided by the visual referral to diagnose a learning disability, such a dyslexia, provided the proper tools are available. John R. Griffin O.D. and Howard Walton O.D. have developed the DYSLEXIA DETERMINATION TEST [DDT] as just such a resource available to optometry. The DDT, according to its authors, is designed to identify and differentiate a child who demonstrates dyslexia as opposed to a child who is behind in reading due to other causes.

The objective of this study is to determine if the Dyslexia Determination Test can reliably identify persons who in fact demonstrate dyslexia as opposed to normal readers. The null hypothesis is that no difference will be shown at the comparable reading levels. To test this hypothesis, the DDT was administered to a group of subjects who were deficient in reading but normal in all other respects. The results were compared to a matched group of normal readers.

In the material which follows, a selected review of the literature pertaining to dyslexia is presented. This is followed by the DDT study design and methodology as well as the findings and conclusions. The final section includes a discussion of the significance of the findings.

LITERATURE REVIEW

The literature relating to dyslexia is very extensive and crosses the lines of optometry, medicine, psychology and education. A comprehensive review is clearly beyond the scope of this paper. This section simply attempts to review some of the salient literature from each of dyslexias many directions. Included is literature pertaining to prevalence, laterality, perception, dyslexia sub-typing, possible causes and findings of special interest to optometry. The objective is to show some of the transition of thought relative to dyslexia. This is important as it relates to the Dyslexia Determination Test and any face validity which might be inferred from prior research. The reader interested in a more in depth review is referred to Vellutino (1979), Hynd and Cohen (1983), Duffy and Geschwind (1985) and Pavlides and Fisher (1986).

Prevalence and Characteristics

Without definite criteria, it is difficult to determine the magnitude of dyslexia. There are undoubtedly a number of variables ranging from age, sex, and location to nutrition and prenatal care which may impact the actual number. Yule (1973) examined 3300 children aged 9-11 to attempt to put the problem in perspective. The author and associates were interested in the epidemiology of backward readers. The findings of this study, which became known as the Isle of Wight Studies, showed a higher percentage of barkward readers than would be expected in a normal population. Though not using the term dyslexia, Yule found 3.5 to 6 percent of the population were reading retarded while of normal intelligence, without neurological deficit and otherwise developmentally, socially and behaviorally normal. The varience in percentage was by age and location. For the U.S., Kirk and Chalfant note that 3.82 percent of the enrolled school age population were learning disabled in the school year 1982-83. Though an actual number does not exist for dyslexics, it is reasonable to assume that not all learning disabled are dyslexic. From the Isle of Wight, it is also shown that prevalence may vary by age and location.

If it is assumed that less than 4 percent of school age children are dylexic, how can they be identified? Though actual diagnosis is discussed later, the stereotyped dyslexic child is a left handed male with a family history of learning disability. The literature tends to support this stereotype. The just mentioned Isle of Wight Studies found that among the reading retardeds, males outnumbered females 3.3 to 1. Critchley and Critchley (1978) also cite evidence from 1945 that 1367 of 1633 dyslexic children (5.5 to 1) were male. Geshwind and Behan (1982 and

1984) in examining left handednes, dyslexia and immune disorders found a markedly higher frequency of immune disease and learning disability among left handers as compared to a control group of right-handers. The authors have postulated that the link between left-handers and immune disorders may be explained by high testosterone levels or an elevated sensitivity to testosterone during fetal life. Related to this hypothesis, Smith [1983], has linked dyslexia to the 15th chromosome. This chromosome contains the genes involved in the formation of testes and the immune responses. This link to the 15th chromosome evolved from a study of several families in which dyslexia was prevalent.

The stereotype of left-handed males seems to fit. Accordingly, it is reasonable to question why. If testosterone is involved it is also reasonable to question dyslexia from the standpoint of laterality.

Laterality / Cerebral Dominance

Historically, deficient hand preferences were associated with problems in oral language and reading. That is, a student must be right-handed to be a proficient reader. Orton [1925, 1928], as one of the early researchers in dyslexia, was familiar with the current beliefs related to reading. However, Orton beleived that reversals in reading letters or words was due to defective cerebral dominance. Specifically, a stimuli presented to both hemispheres of the brain would be correctly presented to the left hemisphere, but as a mirror image to the right hemisphere. Due to delayed cerebral dominance, the mirror image would be read on occassion. This he called "Strephosymbolia" or twisted symbols. The delayed cerebral dominance theory, though not valid as pointed out by Hynd and Cohen [1983], did open a number of remedial approaches which hinged upon stimulating developmental maturity.

It has long been known that the left planum temporale is roughly equivalent to Wernicke's speech area and is larger and presumed dominant in the left hemisphere. Heir [1978] hypothesized that some forms of dyslexia may be related to reversals in this normal left hemisphere development. To test his hypothesis, the author obtained CT scans of 24 dyslexics. These CT scans ruled out neurological lesions. They also showed that of the 24, 10 had right parieto-occipital regions larger than the left, 6 were equal and 8 were larger on the left. Of those with a larger right parieto-occipital region, 40 percent had delayed speech acquisition as opposed to 7 percent in the typical asymmetry. In this same group, 12 subjects were normal in overall performance, but at least 2 grade levels behind in reading. Of these 12, only 4 were among the group with a larger right parieto-occipital lobe. From this study, it is noted that cerebral asymmetry and left hemisphere dominance does seem to be associated with language acquisition. It is not clear that such a relationship exists for reading levels associated with dyslexia.

In the above study, lateralization did not seem to be a predictor of dyslexia. In fact, a more typical asymmetry was shown for the majority of dyslexics. This might then be suggestive of more than one type of dyslexia relating to cerebral lateral dominance. Bakker and Vinke [1985], demonstrated a mixed dominance among 136 dyslexics in Amsterdam. The purpose of their study was to assess the effect of hemisphere specific visual stimulation on scholastic achievment. Their findings showed that scholastic achievement could be improved if the dominant hemisphere was stimulated. The authors findings are perhaps not as interesting as their use of listening preference to classify dyslexics. Earlier research by Kimura (1961) showed that the majority of normal subjects responded to verbal stimuli via the right ear/ left hemisphere and non-verbal to the left ear/right hemisphere. In classifying their 136 dyslexic subjects, Bakker and Vinke used dichotic listening to form three groups: 53 with right ear (left hemisphere) preference, 45 with left ear preference and 3 without a right left preferance (apparently the pool of subjects was reduced from 136 to 101).

The literature pertaining to laterality is vast, only a small fraction is presented here. What is interesting to note is that a clear laterality answer to dyslexia is not apparent. Dyslexics were found with left cerebral dominance as expected in normals. However, dyslexics were also found with the earlier hypothesized mixed dominance (no ear preference/equal sized hemispheres) and right hemisphere dominance. This does not necessarily dismiss the issue of hemispheric dominance. It does bring into question the idea that dyslexia is a single entity. The atypical dominance of one hemisphere may in fact be the adaptation to a deficit in the typically dominant hemisphere. Dyslexia may also be three or more separate entities which correspond to right, left or mixed dominance.

Perceptual Deficit

Laterality, via Orton, stimulated a great deal of dyslexia research. The research took several directions, one of which is the perceptual deficit approach. That is, dyslexia is represented by a single perceptual deficit in vision, hearing or memory.

In a study by Ormrod and Lewis (1985), 56 high school students were examined to determine if visual or auditory perceptual difficulties were involved in poor reading achievement. Ten of the 56 were learning disabled, 15 were classified as low readers and 31 were non-disabled controls. The learning disabled showed a deficit in achievement despite normal intelligence and showed some perceptual difficulty. The low reading group was 4 years behind in reading achievement. A number of tests were administered to each group including auditory Digit Span, Visual Memory for Words, Auditory Memory for Sentences, Auditory Memory for Directions, Auditory Memory for Unrelated Words and Visual Memory for Pictures and Sentences. The authors found a significant difference between the learning disabled group and normals on visual memory tasks and not auditory tasks suggesting a visual memory deficit. Though not emphasized by the authors, the test performance data showed that the low reading group also differed from the normals on nearly all auditory tasks and some visual tasks. Since the low reading group was not clearly defined, it is difficult to determine if this group should be considered as a separate group or a sub-group of learning disableds.

Vellutino (1978,1987) performed several studies in which he dismissed any visual perceptual deficit in favor of a single auditory perceptual deficit. The earlier study (1978) used visual half-field presentation of chinese characters paired with English referents to normal and poor readers. The findings showed normals to be greater than poor readers in all hemispheres and thus nonconclusive. The later studies (1987) challenged the visual-spatial deficit concept believed to be involved in letter reversals and mirror writing. Vellutino identified dyslexia as a subtle language deficiency rooted in phonological-coding deficits (inability to represent and access a word), deficient phonemic segmentation (inability to break words into component sounds) and poor vocabulary development. The author sustained his hypothesis via two studies. The first study involved poor readers in second through sixth grades who frequently made reversal errors. The subjects were asked to copy designs, words, scrambled letters and numbers after a brief visual presentation. Subsequently, they were asked to name the stimuli that were actual words. Vellutino found that poor readers could reproduce the letters in a stimulus word correctly even when they could not name the word (e.g. they copied WAS correctly, but called it SAW). They could also name the letters of most words in the correct order even when they named the word incorrectly. The author concluded that the deficit involved was one of storing and retrieving the names of printed words rather than a dysfunction in visual spatial processing. In a second study, groups of dyslexics and normals were asked to print Hebrew words and letters in the proper sequence after brief visual exposure. The findings showed that the visual recall was no more difficult for the dyslexics than it was for the normal readers. In each case, the words and letters were foreign and lacked any linguistic significance. It was also concluded that dyslexics could hold a memory trace as along as a normal reader.

In a somewhat related study Hatchette and Evans (1983) considered both visual and auditory processing deficits. In this study three groups of 18 subjects were formed: one group consisted of normal readers, one group of learnig disabled with visual processing dysfunction, and one group of learning disabled with auditory processing dysfunction. Each group was compared on six pattern matching tasks to include: auditory-temporal to visual-spatial , auditory-temporal to visual temporal, visual-temporal to visual-spatial, auditory-temporal to auditory-temporal, visual-temporal to visual temporal, and visual-spatial to visual spatial. The authors found a significant difference between normal readers and learning disableds on all tasks except visual-temporal to visual-spatial. Interestingly, no significant difference was found between the learning disabled groups on any of the matching tasks. From this, the authors conclude that the learning disableds are deficient in auditory-visual integration.

The literature on perceptual deficit, like laterality, is not clear in terms of a single deficit. There is some evidence for a visual deficit, evidence for an auditory deficit and evidence for an auditory-visual integration deficit. This seems to reasonably suggest that dyslexia is not a homogeneous entity, but rather an umbrella term encompassing several sub-types.

Dyslexia Sub-Types

One of the earlier studies of the heterogenity of dyslexia was done by Elena Boder (1973). This study was undertaken to facilitate the early identification of dyslexia and classification of clinical sub-types. The work of Boder is very important to the Dyslexia Determination Test as the DDT is essentially an update of Border's original work. Borders original study involved 107 children identified as dyslexic by traditional criteria. These children were in grades 3 through 10 and ranged in age from 6 to 16. Three tests were utilized to establish sub-types: a reading test, a spelling test and a supplementary test. The reading test used 8 lists of 20 words forming a Word Recognition Inventory. A flash presentation was made to determine sight vocabulary (whole word gestalt) and an unlimited presentation was made to determine the ability to analyze words phonetically. The spelling test complemented the reading test. In the first portion, the subjects were asked to write 10 of the know words from the flash presentaation spelling test to determine the ability to revisualize. In the second part, the subjects were asked to spell unknown words to determine the use of phonetics. Supplementary tests included reciting and writing the alphabet to test auditory and visual sequential memory and reading a paragraph to see if the ability to read improves if words are in context. As a result of this test, 100 of the 107 subjects fell in three distinct categories:

1. Disphonetic- a deficit in symbol-sound integration. That is, an inability to phonetically analyze words.
2. Dyeidetic- a deficit in the ability to perceive letters and whole words as configurations (visual gestalts).

3. Mixed Dysphonetic- Dyseidetic (Alexia)- a deficit in both the ability to develop phonetic word analysis and to perceive letters as whole words.

The dysphonetic group represented 67 percent, the dyseidetic group 10% and the mixed group 23%. Very typical reading patterns were identified for each of the groups. The somewhat classic reversal of words and letters was noted in all three groups and found to be a function of age as opposed to dyslexic sub-type.

The initial classification proposed by Border has been utilized by others to assess laterality, imbalance in cerebral information processing and rapid alternating stimulus naming. In each case, differences were noted by dyslexic sub-type.

Obrzut (1979) administered dichotic listening tasks to 144 male second and fourth grade readers who had been classified according to the Border system. The dysphonetic group showed a right ear/left hemisphere preferencee, but scored well below normals. The dyseidetic group showed a mixed laterality with scores approaching normal. The alexic or mixed dysphonetic-dyseidetic group showed a right ear dominance but performed well below all other groups.

Dalby and Gibson (1981) also showed atypical lateralization on 112 males in the second through ninth grades. The subjects were tested on hemispheric time sharing and tactile directional perception. The authors found the following:

1. Controls showed left laterization (hemisphere) of language and right lateralization of spatial functions.
2. Dysphonetic group showed bilateral representation of both verbal and spatial functions.
3. Dyseidetic group showed bilateral verbal representation and right lateralization of spatial functions.

These findings agree with Obrzut's earlier study for dyseidetics, but expand these earlier findings with a more comprehensive testing approach.

Aaron (1978) administered four tests to 46 subjects who had been classified as dysphonetic or dyseidetic according to the Border system. These tests included:

1. Memory for Faces: non-verbal information
2. WISC Digit Span: memory for auditory sequential memory
3. Reproduction of Paired Letter Stimuli: information processing
4. Reproduction of Individual Letters and Shapes: tendency for reversals under immediate and delayed recall.

Four significant findings resulted:

1. Dysphonetics identified more faces than dyseidetics and were similar to controls
2. Dysphonetics produced more paired letters than dyseidetics or controls
3. Dysphonetics reversed more letters and shapes than dyseidetics or controls under delayed recall

4. Dyseidetics recalled more sequences of digits than dysphonetics, but fewer than controls.

The authors conclude that dyslexics deficient in one information strategy are normal in other processes and confirms that dyslexia is due to either: 1) a deficiency in analytical-sequential processing (Dysphonetic) or, 2) a deficiency in holistic-simultaneous processing (Dyseidetic). These are believed to be mediated by the left and right cerebral hemispheres respectively.

Wolf (1986) utilized rapid alternating stimulus naming in a 3 year longitudinal study to again identify dyslexic sub-types. This study included 98 children, of which 14 were identified as dyslexia via standard criteria. The children were tested at the end of kindergarten, first and second grade with naming tasks of 5 letters and five numbers. In addition to other analyses, a binary profile was established for each impaired reader. This profile showed three distinct groups: dissociated comprehension deficits, dissociated decoding deficits and global reading deficits. These categories, as descsribed by the authors, correspond to the dysphonetic, dyseidetic and mixed dysphonetic-dyseidetic grouping, determined by Boder.

There is additional literature which sustains the heterogenous nature of dyslexia and supports the sub-types identified by Border. It is worth noting that no literature could be found which contradicted the Boder sub-types. It is reasonable to assume that dyslexia is not a single entity. From the standpoint of remediation, sub-type identification seems to offer possible directions.

Possible Causes of Dyslexia

It seems apparent from the literature that dyslexia involves deficits in holistic or analytical processing or both. It also would appear that somewhat atypical cerebral dominance may be involved. It seems possible that some neuropathology may be involved.

Hynd and Cohen (1983), in comparing dyslexia secondary to cerebral trauma, have concluded that developmental dyslexia most likely involves the left angular gyrus which is vital in cross-modal integration. These authors suggest that neuropathology or neurodevelopmental anomalies are implicated with intrahemispheric adjustments accounting for regained yet deficient function.

In support of this contention, Galaburda (1982) performed autopsy studies on 4 brains of dyslexics. These were males with a family history of left-handedness, allergies and/or immune disorders, and familial dyslexia. All subjects met the standard definition of dyslexia. Galaburda found that these dyslexic brains differed from normals in the following respects:

1. All four brains showed symmetry in the left temporal language region. This is opposed to a typical larger left planum temporal.
2. Subcortical alterations were found to include dysplasias (disordered cellular architecture) and ectopias (neural elements where they are normally absent).

The subcortical alterations varied in severity, but showed a predilection for the inferior frontal gyrus (anterior speech zone) and the posterior temporparietal region (posterior language zone). Galaburda concludes from the anomalies that they originated in fetal life and could not be the result of damage at birth or postnatally.

Taking a different approach, Duffy (1985) utilized a 20 electrode EEG and Evoked Potential (EP) to develop a method of topographic mapping known as Brain Electrical Activity Mapping or BEAM. Brain electrical activity was amplified, tape recorded and assigned colors to produce an animation effect that highlights the spread of EP over the brain. EPs were formed from 250 to 500 stimuli designed to activate the left hemisphere, right hemisphere and both hemispheres. The Beam analysis was applied to a group of dyslexic boys and normal controls. Duffy found right posterior quadrant anomalies common among the dyslexics. Additionally, he found that abnormality in the left central-parietal-postereior temporal region was also characteristic of dyslexia. Interestingly, Duffy was also able to categorize his subjects into sub-type. His categories semantically differed from Boders and were identified as:

1. Anomic- paraphasic errors and use of circumlocation on confrontation naming
2. Dysphomemic- loss of sequential order of material in repetition tasks.
3. Global or Mixed Disorder- below average on most or all language measures.

These sub-types correspond to the Boder classification of Dyseidetic, Dysphonetic and Alexic respectively. In applying his BEAM analysis, Duffy found differences by sub-type. These were:

1. Bilateral medial frontal and occipital involvement predominated for the anomic group
2. Bilateral central parietal and left temporal involvement were demonstrated for the dysphonemic group with minimal occipital and no frontal involvement.
3. Globals showed extensive bihemispheric regional differences with the left hemisphere more involved.

The work by Duffy is innovative in that it appears to show actual processing differences. In line with the findings of Galaburda, dysplastic and ectopic cerebral development would tend to support different neural pathways with possibly different integration and processing patterns. Also of interest was the frontal involvement of the anomic group. In that the frontal region controls saccades, it is possible that it is this anomic group which may show atypical eye movement patterns.

Of Special Interest To Optometry

In addition to the Dyslexia Determination Test, some of the more recent literature has noted certain eye movement and fixation patterns which may be related to Dyslexia. These latter concepts, if valid, may reasonably be considered within the scope of optometry.

Pavlides (1981, 1986) believes that eye movement analysis may be a key to diagnosing dyslexia. It is his contention that the in utero over production of testosterone is related to erratic eye movements to include unsteady fixation and an abnormal number of regressions. In one 1981 study, Pavlides tested nine dyslexic children and nine matched control normal readers. He found an overall erratic pattern for the dyslexics with more saccades and regressions that were greater in frequency, larger in size and often clustered together. For this study, however, written material was utilized. To separate backward reading from a central processing dysfunction, a second study was conducted which utilized sequential LEDS of varying duration (90 cm test distance with 2 of arc). Fourteen dyslexics aged 8 to 13 were compared to 16 normal reading controls aged 7 to 10 and 17 backward readers aged 8 to 12. Again, Pavlides found significantly more regressions among the dyslexic group. No significant difference was found between the backward and normal readers. From this, the author concludes that testing with LEDS in a sequential task can be diagnostic of dyslexia.

The conclusion reached by Pavlides, if valid, would have a significant impact on the early diagnosis of dyslexia. Unfortunately, other studies have not sustained the findings of Pavlides. Stanley (1983) replicated the work of Pavlides with LEDS on 15 dyslexic children and 15 controls. Stanley found no significant difference in eye movements between the groups. Brown (1983) also replicated the Pavlides study with 34 dyslexics and 33 controls. Again no significant difference was found except that the control group made more saccades than the dyslexics. Black (1984) compared 35 dyslexics to 35 normal controls. Again LED sequential tracking was used with a somewhat more varied sequence than Pavlides. Black, like Stanley and Brown, found no difference in regressions between dyslexics and controls. Unlike Brown, Black's finding showed no difference in saccades.

In terms of other eye movements, Lahey (1982) did find some differences between dyslexics and controls. Twelve learning disableds were compared to 12 grade equivalent and 12 reading level equivalent controls. The learning disableds (meeting exclusionary criteria for dyslexia) showed a slower eye movement pattern that was less smooth, showed a more variable fixation pattern, and the males showed more regressions than females. Black (1984)considered smooth pursuits in dyslexics. In this study, the author compared 26 dyslexics to 34 controls on horizontal eye movement using an E.O.G. approach. Black found that 7 of the 26 dyslexics showed a raised saccadic component superimposed on smooth pursuits.

The finding of Black involving 27 percent of the Dyslexics again is somewhat suggestive of sub-types. Stein (1985), in testing monocular occlusion on dyslexics, found that 68% of 101 subjects had unstable vergence eye movement with the remainder being normal. Duffy's BEAM analysis also showed bilateral medial frontal and occipital processing differences in his anomic group. It might be possible that the frontal involvement could impact voluntary eye movements. It would be interesting to see the work of Pavlides replicated utilizing the sub-types as determined by Boder. All of the eye movement studies were well constructed and controlled. The large difference in findings may be suggestive of eye movements being effected in only a single sub-type (ie Dyseidetic/ Anomic).

There is one other recent study which may be of special interest to Optometry. This involves the relationship between foveal and peripheral vision. Geiger (1987) tested 5 dyslexic and 5 normal readers to determine how well they identified short strings of letters briefly presented in the peripheral field at the same time a single letter was presented foveally. Two basic physiological optics concepts were involved: The Aubert-Foerster law which explains the decrease in recognition of a letter as eccentricity increases, and lateral masking. In this case it was primarily the masking of the central letter in a group of 3 letters presented in the periphery. Geiger found three interesting differences between dyslexics and normals:

1. Though correct identification fell off for both groups with eccentricity, the dyslexics ability to correctly identify letters was much higher than normals at 7.5 10 and 12.5 eccentricity.
2. At eccentricities near the fovea, normals were far more accurate than dyslexics. (Both groups were equal at 2.5 eccentricity.
3. In terms of lateral masking, dyslexics improved in accuracy for the middle letter at 10 eccentricity. Normals dropped linearly.

Geiger concluded that dyslexics learn to read outside the foveal field. He tested this conclusion on one severe dyslexic who at age 25 was reading at a third grade level. A mask was provided with a fixation point and a window 8 or 9 letters wide at 7.5 eccentricity. The subject covered his reading material with the mask and read with eccentric viewing. The subject improved in reading and claimed to finally see things clearly.

In seletcing his subjects, Geiger stated that he used subjects who had only a diagnosis of dyslexia with no other anomalies. He does not comment on the acuities of the patients, their binocular status, eccentric fixation, anomalous correspondence or if the test was done monocularly or binocularly. Consequently, it is difficult to determine if other variables may have entered into his findings.

In looking at the literature as a whole, it seems reasonable to conclude that dyslexia is not one simple entity except as it impacts a persons ability to read. Conversely, dyslexia seems to be a developmental neurological deficit with variable expression and possible x-linked characteristics. Regardless of the underlying anomaly, three basic expressions or sub-types seem to emerge with each sub-type effecting the reading process somewhat differently both functionally and neurologically.

METHODOLOGY

The purpose of this study is to determine if the Dyslexia Determine Test [DDT] can differentiate normal readers from those demonstrating dyslexic tendencies. The null hypothesis is that no difference will be found in performance at equivalent reading levels. This hypothesis was tested by administering the DDT to a group of deficient readers who met the exclusionary criteria of dyslexia and a group of normal readers.

Subjects

The subjects for the study included 2 groups of deficient readers and a single group of normal readers. Five deficient readers were obtained through the Big Rapids Michigan School System. An additional 7 subjects were obtained through the Macomb County Michigan School System and were all attending the Ojibwa Elementary School. All subjects were receiving remedial reading assistance. The Ojibwa School subjects were all in Chapter I remediation. By history, it was determined that the deficient reading group was of normal intelligence, had no visual or auditory deficits, no overt neurological deficits and had at least a normal opportunity to learn to read. This group was, at least 1.5 years behind grade level in reading performance. The control group of 7 normal readers was obtained from the Ojibwa Elementary School and the Ferris College of Optometry. The controls originally were to be matched on reading level. However, it was found during testing that a reading level comparison would not show a difference between groups even though significant differences existed in reading levels. Consequently, the experimental and control groups were matched on grade placement level. In addition, the controls from the Ojibwa School, though normal in terms of reading level, were by teacher evaluation having some difficulty with reading. This selection of controls was done deliberately to see if the DDT could differentiate between readers who were below grade level from those who may have difficulty due to some other cause.

Dyslexia Determination Test (DDT)

The DDT (copyright 1981 by John Griffin and Howard Waton) utilizes essentially the same methodology as developed by Elena Boder in determining dyslexia sub-types. In many respects the Boder and Griffin tests are very similar. The DDT differs from Boder's work in 3 important areas:

1. Boder's original work included 8 word lists of 20 words each from pre-primer to 6th grade. The DDT includes 22 word lists of 10 words each up to the college level.
2. Boder's original word lists were based upon common vocabulary. The DDT has organized words such that 5 words in each

list are phonetic (eg devoted) and 5 are non-phonetic (eg trudge). Though Boder's lists included both phonetic and non-phonetic words, the DDT arrangement is much easier to administer and evaluate.

3. Boder's original test identified 3 categories of dyslexics: Dysphonetics, Dyseidetics and Alexics/Mixed. The DDT utilizes 7 categories. Three are the same as Boder's. However, the DDT includes a Dysnemkinesia category for analysis of reversal problems. This new category, in combination with the others, results in 7 possible findings.

The DDT scoring criteria is the same as that utilized by Boder for the determination of reading level, dysphonesia and dyseidesia. A separate scoring criteria is provided for the number of reversals necessary for the determination of dysnemkinesia. This is maturation related and counts as normal up to 9 reversals for 1st grade but only an occasional reversal for 5th grade.

Testing Procedure
As mentioned, the DDT was administered on an individual basis to each subject. A quiet uninterrupted setting was chosen. The specific testing procedure used is spelled out in the DDT instructions. A summary of this procedure is as follows. The appropriate scoring sheets are included as an appendix to this paper.

1. Dysnemkinesia Testing
   - Subjects writes numbers from 1 to 10 on the scoring sheet
   - Subject prints the alphabet from A to Z in upper and lower case letters
   - Reversals are counted from the numbers and either the upper or lower case alphabet.

2. Decoding Testing
   - The subject is given 2 seconds per word to read each of the words in the word lists up to the highest grade level possible. Every word read correctly in 2 seconds is checked as eidetic (flash Known)
   - A reading level is determined by the word list in which 50% of the words are read within 2 seconds.
   - The subject is again shown the word originally missed on all lists up to grade level. An untimed opportunity is provided phonetically to read each word. Words read analytically are checked as phonetic, the others are checked as unknown.

At the completion of this step, an early impression is possible relative to the reading technique i.e. eidetic or phonetic.

3. Dysphonetic Testing
   - The subject is dictated 10 flash known words up to grade level. Only non-phonetic words are used. The subject must revisualize and write each word as it is dictated.

-Scoring is based upon the percentage of words correctly reproduced.

4. Dyseidesia Testing
   - The subject is dictated another 10 words which are either phonetic or non-phonetic. These are chosen from unknown words. After each word is dictated, the subject is asked to write the word as it sounds.
   - Scoring is based upon the number of correct phonetic equivalents.

The specific scoring criteria is as follows for each category:

1. Dysnemkinesia
   - One grade level below placement is mild
   - Two grade levels below placement is moderate
   - Three grade levels below placement is marked

   The grade levels are:

Grade	Allowable Reversals
First	9
Second	7
Third	5
Fourth	3
Fifth	1

2. Dysphonesia and Dyseidesia

100%	correct	above normal
80%	correct	normal
60%	correct	boderline normal
40%	correct	mild
20%	correct	moderate
0%	correct	marked

The below normal categories apply to dysphonesia testing and dyseidesia testing. For example, a score of 80% on dysphonesia testing and 20% on dyseidesia would indicate dyseidesia. A low score in both would indicate dysphoneidesia (Boder's classification of alexia).

FINDINGS AND DISCUSSION

The findings of the DDT testing are listed below. As mentioned in the methodology section, it became necessary during the testing process to adjust the criteria from a reading level comparison. The reason for this change was that normal subjects who read at or above grade level may show a deficiency in either eidetics or phonetics. They are not, however, considered dyslexic by the DDT because they can achieve according to grade level criteria. A comparison on reading level would therefore be erroneous in that it would show non-dyslexic readers as having dyslexic tendencies. In other words, a third grader who reads at a seventh grade level may have a poor whole word memory for seventh grade [or even third grade] words, but can very effectively use phonetics to read at greater than expected levels. This indicates an effective reading methodology and not a dyslexic tendency. In the results which follow, Dyslexic Type is shown for the experimental group to show the actual DDT dyslexic tendency found as well as for the control group to show the reading strategy used.

DDT Findings

Experimental Group

Grade Level	Subject	Reading Level	Dyslexic Type
2	JB	Primer	Dyseidetic
2	MS	Pre-Primer	Dysphonetic
2	JM	First	None
3	TS	Second	Dysphonetic
4	AVA	Second	Dysphonetic
4	CL	Third	Dysphoneidetic
4	JG	Third	Dysphonetic
4	KK	Third	Dyseidetic
4	BB	Third	Dysphonetic
4	SP	Third	Dyseidetic
College	MB	9-12	None
Graduate	AR	7-8	Dyseidetic

Control Group

2	EE	Second	Normal
2	KB	7-8	Dyseidetic
3	BM	Sixth	Dysiedetic
4	WW	Sixth	Dyseidetic
4	OG	Fourth	Dysphonetic
College	TH	College	Normal
Graduate	RM	College+	Normal

To summerize these findings for the experimental group:
- 17% Showed no dyslexia, but read below grade level
- 33% Showed dyseidesia
- 33% Showed dyseidesia and dysphonesia and were classified as dysphoneidesia
- 17% Showed dysphonesia

For the control group, all subjects read at or above grade level. In terms of reading methodology:
- 43% Were normal in both eidetics and phonetics
- 43% Primarily used phonetics at their reading level and showed as dyseidetic on the DDT
- 14% Primarily used eidetics and showed as dysphonetic on the DDT

It is important to note that for the controls, no dyslexia was found in that reading was at or above grade level. The DDT finding of dyseidesia or dysphonesia simply seems to reflect the reading strategy used at the level achieved.

It is also worth noting that among the experimental group, the degree of dyslexia varied by the severity of the reading deficit. That is, the learning disabled subjects from the Big Rapids School District showed a deficiency of 2 or more grade levels and dyslexic tendencies which ranged from moderate to marked. Those from the Ojibwa School showed only a single grade level deficiency and dyslexic tendencies which ranged fronm mild to borderline normal. There were 2 exceptions in that one subject who was only 1 grade behind in reading showed moderate dyseidesia and another who was at least 2 grade levels behind showed only mild dyseidesia.

None of the experimental subjects showed a tendency toward dysnemkinesia. Of the reversals made, all were well within grade placement expections. Once again, the learning disabled subjects tended to make more reversals than those who were less severly reading disabled.

Discussion

In examining the results, the null hypothesis is sustained. That is, when comparing on reading level, the Dyslexia Determination Test does not show a difference between dyslexics and non-dyslexics. The test does identify a deficiency in reaing level and does illustrate the reading strategy utilized. It also shows the weaker area or areas of reading technique. When comparing on grade level, the DDT does show a difference between dyslexics and normals. The difference which is shown, however, appears to be reading level.

As shown in the literature, Boder and subsequent authors have shown differences between sub-types. The DDT is essentially a refinement of the original Boder test and thus is expected to have reasonable face validity. The findings here are not as clear as those reported by Boder. This difference may be attribured to 2 factors:

1. This study included only 12 experimental subjects. The Boder study had 107 subjects.
2. The control group for this study was comprised of truely normal readers as well as readers who were at or above grade level, but by teacher evaluation showed some difficulty in reading.

The first factor, sample size, may account for a large percentage of the variation from the Boder study. For example, Boder found 67% dysphonetics whereas only 17% were found here. There is a similar lack of correlation among the other categories. Were the sample size larger, it is possible that the findings may have been more representative of Boder's earlier work.

The second factor, control group selection, may also account for some of the variation in findings. The use of normal grade level readers who were having difficulty with reading was done to determine if the DDT could in fact differentiate between dyslexics and those having reading difficulty due to other causes. The controls who were normal in reading did show as normal on the DDT. Of those who were having some difficulty with reading, one tested as normal while the others tested as positive for one of the dyslexia sub-types. To reemphasize, the DDT does not classify these as dyslexic because they can read at or above grade level.

The DDT did show some variation in its sensitivity. The test seemed to ge very sensitive as to the severity of reading disability. As mentioned, the degree of dyslexia and number of reversals was shown to be amplified for the learning disabled versus those with less severe reading difficulty. However, the DDT became less sensitive and more difficult to administer at its two extremes. At the low end, there seemed to be a great deal of variation among subjects who read at a primer [kindergarten] or pre-primer level. Consequently, it was difficult to identify a sufficient number of known words to adequately test for dyseidesia. A somewhat similar problem existed at the other extreme. It was difficult to find a sufficient number of unknown words at the high school and college level to test for dysphonesia. Additionally, there seemed to be a sometimes significant differences between equivalent level words on the A and B lists. Some subjects who could read at a specific level on one list showed a much lower performance on the equivalent list. In one instance, there was a difference of an entire grade level. Finally, the use of 10 words for dyseidesia and dysphonesia testing seemed to increase the possibility of erroneously classifying subjects. The 10 word list, as opposed to Boder's 20 word list, decreases the threshold between categories making misclassification more likely.

In looking at the DDT within the total perspective of dyslexia, it is difficult to reach a definitive conclusion. It is tempting to argue from two extremes. The first being that the DDT is sufficiently viable such that dyslexic tendencies can be identified regardless of reading level. This argument would imply that the definition of dyslexia does not include a reduction in reading level, but rather soley a deficiency in the ability to process information using one or more methodologies during the reading process. The other extreme is that the DDT can only identify a deficiency in grade expectation reading level. This might imply that reading methodology[s] are independent of dyslexic tendencies. That is, the same methodologies are utilized regardless of reading achievment and that dyslexia has nothing to do with dysphonesia, dyseidesia or dysnemkinesia.

There is not sufficient evidence here to sustain either conclusion. The DDT does seem reasonably effective at identifying reading level and the methodology or methodologies used to read. It is not clear that a deficiency in reading is tied to a deficiency in a methodolgy or that a deficiency in a methodology necessarily leads to a deficiency in reading.

Clearly, a opportunity exists for much more research in dyslexia. Dyslexia sub-type identification, BEAM analysis, Masking and eye movement analysis all seem to have merit. Individually, each also seems to be inadequate. The question of dyslexia remains open. Perhaps research involving combinations of testing may provide more definitive evidence.

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APPENDIX

Dyslexia Determination Test Scoring Sheets

INTERPRETATION RECORDING FORM

Dyslexia Determination Test (DDT)

aminee's Name ______________________ AGE: Yrs. ______ Mos. ______ Birth Date ______ Grade Placement ___

History Summary: ______________________

____

I. **Grapheme-Nemkinesis Testing** (Comments:) ______________________

____

II. **Results of Decoding:** Form A ☐ Form B ☐

Highest grade level of sight-word recognition (50%) ______________________

Number of Flash-Known words (at DDT grade level) ______________________

Decoding Mode: Relatively more phonetic ☐ Relatively equal ☐

Relatively more eidetic ☐ Comments: ______________________

III. **Results of Encoding**

Spelling of FLASH-KNOWN words for evaluation of DYSEIDESIA (using words that are DDT grade level and below for testing of ability of "re-visualization" of words). *Comments and results:* ______________________

____

Spelling of UNKNOWN words (for phonetic equivalents) for evaluation of DYSPHONESIA (using words that are DDT grade level and above for testing of "phonetic word analysis," ability. *Comments and results:* ______________________

____

DYSPHONEIDESIA (Dysphonesia and Dyseidesia). *Comments:* ______________________

____

Observation of behavior during writing (e.g., reversals, poor posture, poor pencil grip, slow speed of writing, poor eye-hand coordination, lack of fine motor control):

Interpretation (Synthesis of the results of the above testing)

0. ☐ No dyslexia (No dyslexic pattern found)
1. ☐ Dysnemkinesia
2. ☐ Dysphonesia
3. ☐ Dyseidesia
4. ☐ Dysphoneidesia
5. ☐ Dysnemkinphonesia
6. ☐ Dysnemkineidesia
7. ☐ Dysnemkinphoneidesia

Comments: ______________________

____

____

Signature of examiner: ______________________ Date ______________________

Grapheme – Nemkinesia Testing

(Writing Numbers and Letters by Examinee)

Encoding (Spelling by Examinee)

Flash-Known Words – Non-phonetic (odd numbered) words only.

Unknown Words – Either phonetic (even-numbered) or non-phonetic (odd numbered) words.

Checklist Sheet

Date ____________

DDT Decoding Patterns for FORM A
RECORDING PAGE

Examinee's Name ______________________ Birth Date __________ AGE Yrs. ______ Mos. ______ Grade Placement ________

Odd Numbered Words — Non Phonetic
Even Numbered Words — Phonetic

	p-primer	E	P	U
1	green			
2	an			
3	look			
4	go			
5	mother			
6	no			
7	said			
8	stop			
9	ball			
10	in			
	Totals			

	primer	E	P	U
1	are			
2	yes			
3	ready			
4	did			
5	lock			
6	up			
7	black			
8	on			
9	came			
10	it			
	Totals			

	1st	E	P	U
1	money			
2	him			
3	call			
4	if			
5	guess			
6	fast			
7	funny			
8	we			
9	here			
10	with			
	Totals			

	2nd	E	P	U
1	does			
2	ask			
3	listen			
4	just			
5	uncle			
6	sled			
7	city			
8	step			
9	rolled			
10	wet			
	Totals			

	3rd	E	P	U
1	business			
2	lamp			
3	believe			
4	jump			
5	heavy			
6	path			
	laugh			
8	drink			
9	should			
10	dish			
	Totals			

	4th	E	P	U
1	delight			
2	human			
3	familiar			
4	pupils			
5	soared			
6	trunk			
7	rough			
8	whisk			
9	glisten			
10	prison			
	Totals			

	5th	E	P	U
1	height			
2	invent			
3	doubt			
4	planted			
5	position			
6	grand			
7	contagious			
8	handed			
9	vowed			
10	ambush			
	Totals			

	6th	E	P	U
1	badge			
2	abandon			
3	conceited			
4	melting			
5	foreign			
6	album			
7	knapsack			
8	varnish			
9	decisions			
10	shifted			
	Totals			

	7—8	E	P	U
1	coolie			
2	edit			
3	graciously			
4	blunt			
5	tomorrow			
6	abhor			
7	trudge			
8	devoted			
9	aeronautic			
10	abolish			
	Totals			

	9—12	E	P	U
1	heinous			
2	minus			
3	graduation			
4	detested			
5	pollute			
6	digit			
7	snuggle			
8	prevalent			
9	exonerate			
10	bonus			
	Totals			

	College	E	P	U
1	homologous			
2	emigrant			
3	homeopathy			
4	subabdominal			
5	rheostat			
6	admonish			
7	demagogue			
8	demented			
9	euphony			
10	minuet			
	Totals			

Column Designations

"E" — Flash Known (Eidetic)
"P" — Untimed Known (Phonetic)
"U" — Unknown Words

Results of Decoding — FORM A

Highest grade level of sight word recognition (50% Flash Known) ____________
Number of Flash-Known words at DDT Grade Level ____________

Decoding Mode:

Relatively more phonetic ☐ Relatively more eidetic ☐ Relatively equal ☐

Comments: ____

____

____

____

Examiner: ______________________ Date: ______________________

Checklist Sheet Date ____________

DDT Decoding Patterns for FORM B
RECORDING PAGE

Examinee's Name ______________________ Birth Date ________ AGE Yrs. ____ Mos. ____ Grade Placement ________

Odd Numbered Words — Non Phonetic
Even Numbered Words — Phonetic

	p-primer	E	P	U
1	see			
2	me			
3	little			
4	at			
5	house			
6	and			
7	ride			
8	red			
9	to			
10	run			
	Totals			

	primer	E	P	U
1	come			
2	be			
3	you			
4	pet			
5	work			
6	is			
7	store			
8	this			
9	like			
10	so			
	Totals			

	1st	E	P	U
1	father			
2	robin			
3	could			
4	nest			
5	know			
6	ring			
7	snow			
8	must			
9	there			
10	them			
	Totals			

	2nd	E	P	U
1	animal			
2	best			
3	light			
4	milk			
5	grow			
6	himself			
7	would			
8	thank			
9	buy			
10	string			
	Totals			

	3rd	E	P	U
1	calf			
2	stop			
3	enough			
4	fish			
5	pigeon			
	seven			
	meadow			
8	going			
9	coat			
10	thing			
	Totals			

	4th	E	P	U
1	decorate			
2	absent			
3	goggles			
4	magnet			
5	spectacles			
6	admit			
7	league			
8	invest			
9	pain			
10	grind			
	Totals			

	5th	E	P	U
1	boulder			
2	trap			
3	cautious			
4	hotel			
5	ancient			
6	flesh			
7	toughen			
8	apt			
9	opposite			
10	plan			
	Totals			

	6th	E	P	U
1	allegiance			
2	branded			
3	deceive			
4	adrift			
5	leisure			
6	wiping			
7	elementary			
8	thinking			
9	deny			
10	wisdom			
	Totals			

	7—8	E	P	U
1	intrigue			
2	abated			
3	dominion			
4	alkali			
5	bridge			
6	sprang			
7	wrest			
8	adept			
9	poorly			
10	embankment			
	Totals			

	9—12	E	P	U
1	risible			
2	apnea			
3	ritual			
4	albino			
5	regime			
6	adobe			
7	islet			
8	aroma			
9	endeavor			
10	inept			
	Totals			

	College	E	P	U
1	misogynist			
2	emolument			
3	prognosticate			
4	emeritus			
5	oligarchy			
6	opulent			
7	gynarchy			
8	atavism			
9	heterogeneous			
10	stipend			
	Totals			

Column Designations

"E" — Flash Known (Eidetic)
"P" — Untimed Known (Phonetic)
"U" — Unknown Words

Results of Decoding — FORM B

Highest grade level of sight word recognition (50% Flash Known) ____________
Number of Flash-Known words at DDT Grade Level ____________

Decoding Mode:

Relatively more phonetic ☐ Relatively more eidetic ☐ Relatively equal ☐

Comments: ____

Examiner: ______________________ Date: ______________________