Evaluation of transient visual pathway problems using a simulated reading task

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Abstract
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Evaluation of Transient Visual Pathway Problems Using A Simulated Reading Task

Presented by
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In partial fulfillment for the Masters of Education in Visual Function in Learning at Pacific University

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Introduction

Among educators, psychologists, and optometrists, the learning disability (LD) population has been a popular research group. Although a precise working definition of LD has eluded many researchers, a subset of LD has been identified. This population, known as Specific Reading Disability (SRD), has been defined by Williams et al. 1 as a learning disabled group, that does not possess usual factors associated with reading failure despite conventional instruction, adequate intelligence, and sociocultural opportunity.

In 1984, use of intelligence tests for assessing the needs of children with SRD became an issue in California, and a subsequent decision by an appellate court curtailed the use of such tests for assessing a child's need for special education. 2 In compliance with the judicial ruling, the California Department of Education prohibited the administration of intelligence tests to black children for any reason, including the identification of cases of SRD. Several school districts, including Los Angeles and San Francisco school districts, have discontinued the administration of intelligence tests not only to black children, but to all children.

In responding to these events, California school psychologists issued a report calling for alternative methods of assessment that are more curriculum based. 3 Using the Peabody Individual Achievement Test (PIAT), which was originally designed to assess reading ability from grades 1.9 to 12.8, Spring and French identified children with SRD. 4 Modifying the test to detect listening and reading comprehension scores, they identified a number of subgroups within the SRD population one of which is characterized by auditory-linguistic deficits. 5-8, 9-12 Recent evidence regarding transient and sustained visual pathway mechanisms indicate that the subjects in the SRD group process visual and auditory information at different rates, contributing to reading difficulties. 13-17

Verification for the dual channel visual processing model comes from anatomical, physical, and the psychophysical data, 18-22 which has had an influence on the optometric
management of SRD patients. Traditionally, the optometric role in managing reading
disabled patients has included the assessment of visual skills, refractive status, ocular
motility, accommodative and vergence function, and visual perceptual-motor development.
The literature regarding refractive status indicates that hyperopia 23-29 and anisometropia 28,
30,31 are associated with poor reading performance. There is also evidence supporting a
relationship between poor reading, reduced nearpoint visual acuity, and binocularly. 32,33
Taken as a whole, these correlational studies point to a relationship between LD and visual
anomalies.

New studies have implied a more direct etiological relationship between reading
performance, academic grades, and speed of word perception. 31,34,35 Current research
indicates that the dynamic visual process of reading is mediated by the transient and
sustained cell pathways, two distinct but interactive visual pathways. 36-41 The purpose of
this project was to evaluate the following hypothesis: The manifestation of the auditory-
visual and contrast sensitivity function (CSF) mismatch in the SRD group is caused by
deficient transient visual pathway.

**Transient and Sustained Visual Pathway
Differences at the Physical Level**

From physiological studies of ganglion cells in the retina, anatomical differences can be
used to separate the two pathways. The transient pathway cell comprise 10% of the retinal
ganglion cells in primates. It has an even distribution across the retina, and projects to the
magnocellular layers of the dorsal lateral geniculate nucleus (dLGN). The sustained
pathway cells comprise approximately 80% of the retinal ganglion cells in primates. The
sustained pathway cell has a relatively higher density in the fovea and projects to the
parvocellular layer of the dLGN. The lateral geniculate nucleus interacts with the remaining
10% of retinal ganglion cells for global body posture and balance functions.
The differential sensitivity of transient and sustained cells to different stimulus sizes is reflected in their spatial contrast sensitivity functions. Tootell et al. measured different spatial frequencies in the transient and sustained cortex streams. He found that transient system, also known as HTLS (high temporal, low spatial) or M (Magno-ganglion) system, is predominantly a flicker or motion detection system that is most sensitive to low spatial and high temporal frequencies. According to the dual channel theory, the transient system is a fast-operating, early warning system that transmits large amounts of visual information following a quick global analysis of a visual scene. In terms of specific contribution to perception, the transient system primarily carries motion, depth, and brightness information that is used in the control of eye movements and the localization of targets in space.

![Figure 1: Schematic diagram of the retina showing the following relationship between transient (M) and sustained (P) cells. A: Greater proportion of the sustained cells in the fovea. B: Uniform distribution of transient cells across the retina. C: Transient cells have larger receptive fields than sustained cells at any given retinal eccentricity, and D: transient and sustained cells receptive fields increase from fovea to periphery. The Figure is from an article by Bassi, C. and Lehmkuhle, S., Clinical implications of parallel visual pathways. JAOA, Vol 66, 1990, p98-110.](image)

The sustained system, also known as LTHS (low temporal, high spatial) or P (Parvo-ganglion) system, is predominantly a pattern detection system that is most sensitive to
stationary stimuli. The sustained system has high acuity (sensitivity to high spatial frequency stimuli) responds throughout the duration of a stimulus presentation, and continues to signal after removal of the stimulus. Thus, it is subject to a significant persistence effect. The sustained system seems to be designed for the identification of patterns, resolution of fine detail, and the perception of color.

Tootell's work, supported by others, states that there are three basic temporal differences of time, temporal resolution, and response duration between transient and sustained cells, aside from spatial differences.

**Conduction Time and Temporal Resolution:** The transient cell pathway, being more thickly myelinated, conducts more quickly than the sustained cell pathway, but much of the conduction speed difference may be lost in the temporal variability of transmission at the geniculocortical synapse. As discussed above, transient cells have a higher temporal resolution (i.e., respond better to fast moving stimuli) and critical flicker fusion (i.e., can resolve stimuli modulated at high temporal rates) than sustained cells.

**Visual Latency:** Visual latency, closely related to temporal resolving capacity, is a physiological response to a visual stimulus. The relationship between visual latency and the temporal resolving capacity is inversely proportional. Therefore, shorter visual latency means higher temporal resolving capacity. The latencies of transient cells were on the average about 15 msec shorter than sustained cells. This difference between the temporal resolution and visual latency of the transient and sustained cell pathways is influenced by the spatial parameters of the stimulus. At low spatial frequencies, the temporal resolution of the transient cell pathway is far superior to the sustained cell pathway. For higher spatial frequencies, the temporal difference diminishes.

**Response Duration:** Transient and sustained cells differ in their responses to stimuli. Response duration was initially measured in an attempt to classify different ganglion and
geniculate cell types. Some cells were classified as “sustained” because they continued to respond throughout the duration of the stimulus, whereas others were classified as “transient”, because they produced an initial burst of activity at stimulus onset that subsequently fell to baseline levels during the stimulus presentations.\textsuperscript{55}

Although these two systems operate in parallel, it is believed that the transient system has temporal precedence, operates preattentively, and functions as an early warning system. The transient system performs a global analysis of the incoming stimulus, parceling out the visual field into units and regions, and coding the position and movement of objects in space. This information serves to guide the sustained pathway processes and generates positional information essential for foveation, as well as producing a figure-to-ground framework so that the information about local detail can be associated and segmented. Thus, the functioning of the sustained system, depends to a degree on the prior output of the transient system.\textsuperscript{44, 45}

\textbf{Anatomical Evidence for Transient and Sustained Visual Pathway Differences}

Anatomical support for transient pathway malfunction has been provided Livingstone \textit{et al.}\textsuperscript{56} Autopsies of dyslexic specimens revealed that although there were no significant differences between controls and dyslexics in the cell sizes in the parvocellular layers, there was a difference in the magnocellular layers of the lateral geniculate nucleus. The decreased size of the magnocellular neurons might have functional consequences that are consistent with other physiological findings: smaller cell bodies, thinner axons, and slower conduction velocities. Resulting functional abnormalities might be magnified if there were also defects at earlier or later stages in the magnocellular pathway.

Earlier studies of these same autopsy subjects \textsuperscript{57, 58} reported anomalous cerebral asymmetry, characterized by the presence of large pyramidal cells and rich myelination, in a language area known as the planum temporal. These may form a part of the fast response
component of the auditory system, and contribute to developmental abnormalities of this and other language areas. Additionally, the pathologic factors that disturb the magnocellular subdivision of the visual pathway could also act directly on the development of the language areas. 59, 60

Livingstone et al. theorized that in dyslexics the rapid processing subdivisions (the magnocellular homologues) might be slower than normal. This theory was supported by Tallal et al. 61 In behavioral tests, they showed that 98% of language-impaired children who have trouble learning to speak as well as read could be differentiated from controls based solely on a battery of tests that required rapid speech production or rapid perceptual discriminations (both somatosensory and auditory).

**Transient and Sustained Visual Pathway Differences at the Psychophysical Level**

Along with physiological and anatomical data, human perceptual studies suggest that transient and sustained pathways differences at the psychophysical level are responsible for reading by providing spatial localization, depth perception, hyperacuity, figural grouping, illusory border perception, and figure/ground segregation. 62 During the interaction between two pathways, the sustained pathway is activated to separate the encoded visual information only after the transient pathway activity terminates following an eye fixation.

Breitmeyer et al. 63 theorized that SRD group may have different transient and sustained pathway interactions, leading to an inefficient termination of transient and sustained activities during an eye fixation. The result of such transient and sustained pathway interaction mismatch would cause overlap of words and letters, leading confusion by the reader during the period of recognition and interpretation. Clinical observations support Breitmeyer in that SRD patients often have poor stereoacuity, visual instability, and problems with visual localization, which are all related to the transient pathway function. 64
These observations are consistent with the hypothesis that these patients have transient pathway dysfunction rather than sustained pathway dysfunction. Lovegrove et al. reported that 70% of the SRD children tested displayed transient pathway dysfunction, and Williams et al. have demonstrated that the performance of SRD children on various perceptual tasks was predictable from Lovegrove's transient pathway dysfunction model. The perceptual consequence of this dysfunction seems to be an over-restriction of attention to global processing at the expense of local detail processing.

The perceptual consequences of a pathway problem could manifest themselves in a number of ways. If the SRD reader did not know which fixation the information derived from, he/she could experience difficulty sequencing the spatial arrangement of letters. This would lead to errors in word recognition while reading. This may partially explain the high prevalence of transient system deficits in the SRD group. Given what is known about perceptual functions and transient system function, it is reasonable to expect that children who have a reading disability resulting from transient pathway malfunction would show deficits in global operations particularly on tasks requiring fine temporal resolution.

Contrast Sensitivity Function Differences between Transient and Sustained Visual Pathway

Optimum contrast sensitivity for reading is in the midrange of human vision contrast sensitivity with lateral inhibition enhancing visibility by sharpening edges and contours. Contrast sensitivity is defined as the minimum amount of contrast needed to perceive a grating pattern with a particular spatial frequency. Contrast sensitivity functions can be plotted showing stimulus spatial frequency. For humans, sensitivity is greatest for spatial frequency of intermediate frequencies (6-10 cpd) and decreases for frequencies that are of lower or higher. With increasing luminance, there are typically three major consequences: the peak of the contrast sensitivity curve shifts to higher spatial frequencies, the function becomes less peaked, and sensitivity to higher spatial frequencies increases.
The contrast sensitivity at low spatial frequencies can be enhanced when gratings are moved or counterphased. One way to understand why movement enhances the detection of low spatial frequencies is to recall that the transient cell pathway has a higher sensitivity for low spatial frequency stimuli temporally modulated at 5-10 Hz. Low spatial frequencies elicit faster responses due to stimulation of the faster transient pathways. Intermediate and high spatial frequencies elicit smaller and slower responses from the transient cell pathway. As the spatial frequency increases, the response of the transient cell pathway diminishes and the response of the slower sustained cell pathway dominates. Reaction times are faster to lower than to higher spatial frequency stimuli.67

Kulikowski et al.67 found that for a 2 cpd grating, subjects with SRD were less sensitive than controls over a range of temporal frequencies, with the difference increasing as temporal frequency increased. Tolhurst68 supported Kulikowski et al. by noting that the transient system is maximally sensitive to high temporal frequencies. These results indicate a major difference between the two groups of subjects in the function of their transient systems or in the functioning of their flicker detecting mechanisms.69 The results of these experiments support the possibility of a transient pathway malfunction in the SRD group. This was further supported by Carmean and Regeth,70 who reported that reading comprehension scores were related to visual contrast sensitivity in a population of 155 elementary school children.

Reestablishment of Transient and Sustained Pathway Interaction with Image Blurring

Related with contrast sensitivity function of the SRD group, Meares71 observed that comprehension for her remedial students was significantly higher with low contrast copy, obtained with gray paper or with scratched and smudged overlays. Williams and Lecluyse72 produced the same effect by blurring the letters to lower their contrast. This was contrary to conventional observations because for normal readers high contrast is an
advantage. It seems counterintuitive to conclude that someone's reading may be handicapped by seeing too well.

Several studies have provided evidence for basic visual processing differences between normal and SRD readers involving the timing of saccades. In normal readers, transient and sustained systems can mutually inhibit each other. Therefore, the transient system response from eye movements could inhibit the continuing sustained system response, reducing the duration of the visual persistence. This termination of the sustained response allows the visual system to separate the information extracted from successive fixations. The resultant response is a stable distinct flow of visual input. This interaction between the two subsystems results in efficient and fluid reading.

For the SRD group, however, the foveal transient response seems to be sluggish, which may render the masking mechanism less effective in producing saccadic suppression. Increased fixation duration or intersaccade intervals would be required to compensate for a sluggish transient response in order to produce clear fixation intervals, an effect commonly observed in the reading behavior of SRD readers. Due to visual persistence, the SRD reader may still be "seeing" the information from the previous fixation when gaze is shifted to the next fixation. If this occurred, the two visual inputs may be seen but with no certainty of which came from the first or second fixation. The persistence of the visual input from the previous fixation would be manifestly confusing, making the text appear superimposed or overlapping.

Under blurred image conditions, performance of normal readers deteriorates and eye movement control becomes more difficult. However, SRD readers show improved reading performance demonstrating the beneficial effects of image blurring for this SRD subject group. Image blurring, which can function to diminish the persistence of high spatial frequency channels, may serve to cover the transient system defect, and thus render reading
more efficient. For this reason, the reading performance of SRD readers actually improves with blurred images. Therefore, image blurring suggests reestablishment of a more normal pattern of interaction between transient and sustained pathways with SRD individuals.

From the clinical and research data presented in this section, a relationship is present between transient pathway dysfunction, SRD group, reading, and contrast sensitivity function. To test our hypothesis that the manifestation of the auditory-visual and CSF mismatch in the SRD group is caused by deficient transient visual pathway, our subject group was be tested with modified PIAT for identification of SRD subjects. Rapid serial visual presentation (RSVP) attention shift paradigm developed by Sperling and Reeves was used to measure saccadic response time under clear and blur conditions. Contrast sensitivity function was measured according to the test protocol developed by Carmean and Regeth.
Methods

Subjects

Seventy subjects were involved in this study, 33 were females and 36 were males (sex of one subject was not recorded). The mean age for subjects was 10.0 years old with standard deviation of 1.55 years. The age of the subjects ranged from minimum of 8.0 years to 14.0 years of age.

All subjects, accompanied by either parent or guardian, were tested at the Pacific University College of Optometry in Forest Grove, Oregon. Prior to data collection, the nature of the study and the procedures involved were explained, and the parents/guardians signed informed consent forms. Parents/guardians also signed a letter allowing the experimenters access to the subject's academic records.

<table>
<thead>
<tr>
<th># of Subjects</th>
<th>Normal</th>
<th>General Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males/Females</td>
<td>11/13</td>
<td>7/8</td>
</tr>
<tr>
<td>Mean Grade</td>
<td>6.1 (1.7)</td>
<td>6.3 (1.3)</td>
</tr>
<tr>
<td>Mean Age</td>
<td>11.1 (1.6)</td>
<td>11.2 (1.2)</td>
</tr>
<tr>
<td>Mean Reading Percentage</td>
<td>76 (14)</td>
<td>34 (25)</td>
</tr>
<tr>
<td>Mean Language Percentage</td>
<td>76 (16)</td>
<td>29 (14)</td>
</tr>
<tr>
<td>Mean Math Percentage</td>
<td>72 (25)</td>
<td>45 (18)</td>
</tr>
<tr>
<td>Mean General Ability Percentage</td>
<td>78 (18)</td>
<td>40 (13)</td>
</tr>
</tbody>
</table>

During the data collection, the experimenter working with the subjects had no knowledge of the subject's academic classification. All subjects were visually corrected to 20/20 at both distance and near, and wore glasses or contact lenses as needed during data collection. A coupon for a free vision exam was provided to the subject upon completion of data collection.
PIAT-R

The Peabody Individual Achievement Test Reading Comprehension test (PIAT-R) is used to assess reading ability from Grade 1.9 to Grade 12.8. This comprehensive test consists of a series of unrelated but meaningful sentences. These sentences gradually lengthen, the grammatical structure becomes more complex, and the vocabulary demand increases from the beginning to the end of the test.

The original version of PIAT-R reading comprehension test includes 66 items, each consisting of a single sentence on one page of the test booklet. Each sentence is followed by a page illustrated with four pictures, only one of which corresponds exactly to the previous sentence. Each child is asked to read a sentence, then the examiner turns the page to reveal four pictures. The child is asked to point to the picture that best illustrates the event described in the sentence. In order to differentiate auditory and visual reading comprehension, Spring and French modified this procedure for half of the test. In the modified procedure subjects listened as the odd or even sentences were read aloud by an examiner rather than reading the sentences themselves. The division of PIAT-R subtest into two separate tests is possible due to high split-half reliability coefficients for the test.

Using the test, Spring and French found significant differences between SRD. They found that listening comprehension scores of SRD readers did not differ greatly from those of normal readers. For reading comprehension, however, it was found that the scores of SRD readers were significantly lower than those of average readers. The authors interpreted their results as evidence that SRD readers understood the test sentences as well as normal readers when they were presented aurally, but that SRD readers' visual performance was poorer on the repetition test due to inaccurate word decoding and to the additional demand on working memory imposed by slow word decoding.
For the present study, the Peabody Individual Achievement Test Reading Comprehension subtest was administered to the subjects via the modified experimental protocol of Spring and French in order to explore a possible link between the SRD group and transient pathway malfunction.

Procedure

Sentences for the PIAT-R test were divided into two equivalent groups. The two forms of the test were alternated among subjects. The items in each form were presented sequentially, starting with the two practice items, and the second form did not begin until the stopping criterion for the first form was reached. One form, consisting of even numbered items, was administered as the listening test. Subjects were allowed to see the sentences as they were played aloud by a tape recorder to reduce examiner bias. The examiner was allowed to replay the sentences if requested by the subject before the page was turned. The second part, consisting of odd-numbered items, was administered using the same protocol recommended in the original version of the test. The subjects were required to read sentences silently, and were allowed to reread them before the page was turned. The standard stopping criterion, five errors out of seven consecutive responses, was applied separately for each form. The score for each part was the total number of correct answers accrued before reaching the stopping criterion.

Instructional Set

Subjects were told: “This is a game to see how well you can read and understand.” If the subject was selected to listen to the tape first, she/he was told: “I want you to listen to the tape and follow instructions exactly.” If the subject was selected to read first, she/he was told: “I am going to show you a sentence, and I want you to read it silently to yourself. You can read it as often as you want, but you must not read out loud. When you are finished reading, you are to look at me and nod. I will turn the page, and show you four
pictures. Now, your job is to pick a picture that is most similar to the sentence that you just read. As we move along, you will find that sentences will get more difficult to read, and it will be harder to pick the correct picture. If you can’t finish the game, that’s OK. It’s designed to be that way. Remember, there is no right or wrong answer. I just want you to try your best.” Appropriate instruction modifications were made when the subjects listened to the sentences rather than reading them.

**RSVP**

The procedure used to measure the effects of masking was based on the rapid serial visual presentation (RSVP) attention shift paradigm of Sperling and Reeves. In the original RSVP procedure, a subject monitored a stream of alphabetic characters, flashed one after the other, for the presentation of a target letter. Following detection, the subject immediately shifted attention to a stream of numbers being presented one after another and attempted to remember the earliest occurring numeral. Typically, subjects remembered a numeral that occurred 300 to 400 msec after the target letter presentation. The onset time of the remembered numeral was defined as the saccadic response time (SRT).

**Procedure**

A modified RSVP attention shift paradigm was used in which the automaticity of reading and language ability was determined for each subject. Automaticity is a measure of visual-verbal response time and language fluency. The automaticity sheet (Appendix D), representing the computer generated letters, was read by each subject as fast as they were able. A total of four automaticity sheets were read by each subject, and the reading times were averaged and recorded on the data sheet.

The test was conducted under two conditions: clear and blur. The testing condition was selected by the subject, who randomly picked one of two piece of paper, marked either “CLEAR” or “BLUR” from inside a paper bag. In the clear condition, the subject was
tested wearing their habitual distance correction, and in the blur condition, the subject was
blurred until he/she could just read the 20/40 line on a Snellen card located 40 cm from the
subject. The blur was achieved with plus lenses ranging in power from +0.50 to +4.00
diopters sphere in +0.25 steps.

Figure 2: Illustration of RSVP procedure at position 1.

Once the testing conditions were selected, the subject was seated 40 cm from of the
computer screen set at eye level. At the center of the screen, a target letter was shown. The
subject was instructed to look for the target letter on the center of the screen as the letters
changed. Upon detecting the target letter, the subject was told to shift his/her attention to a
new location on the screen previously identified by the examiner, and remember the first
letter he/she saw. The subject was told that time between presentation of the target letter
and detection of the letter at the second location was being measured.

Training on this task started with letters changing once every 1.0 second. On each trial, a
set of 50 random characters was generated. The subject initiated the run by pressing a
button on the computer’s mouse. Under clear conditions, the presentation time was
decreased to 500 ms when the subject was able to identify one of first four letters at the
secondary location. Under blur conditions, the subject had to identify one of first seven letters at the secondary location before the presentation time was decreased to 500 ms.

The training was continued until the requisite response conditions were met. If the subject was able to meet the requirements at 500 ms, the presentation time would decrease to 250 ms, and then to 100 ms. When the subject satisfied the trial requirements at 100 ms, the subject was instructed that the second letter stream would be moved to one of four locations. Position 1 was located at 5.71" to the right. The position 2 was located at 11.31" to the right. Position 3 was 5.71" to the left of center at the screen, and position 4 was 11.31" to the left. With four secondary positions, there were 36 possible combinations for testing as listed on Table 2.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tr>
<td>1234</td>
<td>2134</td>
<td>3124</td>
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<td>1243</td>
<td>2143</td>
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<td>2341</td>
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<td>2413</td>
<td>3412</td>
<td>4312</td>
</tr>
<tr>
<td>1432</td>
<td>2431</td>
<td>3421</td>
<td>4321</td>
</tr>
</tbody>
</table>

Table 2: Listing of all 36 position combinations for RSVP test.

Each subject selected his/her testing combination by randomly picking a piece of paper, printed with the one of 36 of combinations from a paper bag. The random selection was conducted twice, one for the clear and another for the blurred condition. During the data collection, five demonstration trials were followed by three data collection trials. When the subject had correctly identified the letter 3 times per each of four locations at 100 ms presentation time, data collection was initiated. Head movements and mistrials during the run were noted on the data collection sheet.

**Instructional Set**

To evaluate automaticity, the subjects were told: "This is another eye test. I want see how fast you can see a letter. I want you to read this column of letters as fast as you can."
examiner recorded the time and turned the page, "Let's try again." The examiner recorded the time again, and repeated until all four pages of columns were read and timed. "Now, I want you to sit in front of the computer screen. Can you see the letter at the center of the screen? That's called the key letter. Your task is to look for that letter at the center of the screen as the letters flash by. The target letter can come anytime during the sequence. It can be at the start, middle, or at the end."

"Once, you see the key letter, I want you to look (examiner pointed to an area on the screen) here. This is called a secondary location. I want you to tell me the first letter that you see when you first change gaze from the center. Let me show you what I mean." With a stimulus presentation rate of 1 per sec, the examiner guides the subject through the process. The second trial is initiated by the subject by pressing on the mouse button.

"Now, I want you to try it on your own. When you are ready, you can press this button on the mouse to start the flashing." If the subject is able to recall one of the first four letters at the secondary location, then the time was reduced to 500 ms under clear conditions. The run time was reduced to 500 ms if the subject was able to identify one of first seven letters at the secondary location under blur conditions.

" Lets speed the flashing up a bit." Following the criterion described, the examiner then decreased the presentation time to 100 ms. "Now, we are ready for data collection. There will be five demonstration runs followed by three data collection runs. During the trial, I will be noting not only your speed, but also your head movement as well as your mistrials. It may seem like the letters are going by too fast for you to identify them. I just want you to try your best, and tell me the first letter you remember at the secondary position, even if you have to guess. Remember, there is no right or wrong answers in this test, just try your best."
Using the test protocol developed by Carmean and Regeth, Contrast Sensitivity Function (CSF) testing was used to investigate a potential mismatch between SRD and normal readers. The CSF test used was from Vistech Consultants, Inc., model VCTS 6000, serial number 6002977 (1372 North Fairfield Road, Dayton, Ohio 45432). This test is marketed as a professional diagnostic device for optometrists and ophthalmologists.

Table 3: Contrast sensitivity value key

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Up</td>
<td>Right</td>
<td>Right</td>
<td>Up</td>
<td>Left</td>
<td>Up</td>
<td>Right</td>
<td>Left</td>
<td>Blank</td>
</tr>
<tr>
<td>(1.5)</td>
<td>11</td>
<td>22</td>
<td>30</td>
<td>40</td>
<td>53</td>
<td>71</td>
<td>95</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Up</td>
<td>Right</td>
<td>Left</td>
<td>Left</td>
<td>Up</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
<td>Blank</td>
</tr>
<tr>
<td>(3)</td>
<td>17</td>
<td>31</td>
<td>41</td>
<td>55</td>
<td>73</td>
<td>98</td>
<td>130</td>
<td>174</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Up</td>
<td>Left</td>
<td>Up</td>
<td>Up</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
<td>Up</td>
<td>Blank</td>
</tr>
<tr>
<td>(6)</td>
<td>20</td>
<td>41</td>
<td>54</td>
<td>72</td>
<td>96</td>
<td>128</td>
<td>171</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Up</td>
<td>Left</td>
<td>Left</td>
<td>Right</td>
<td>Up</td>
<td>Up</td>
<td>Left</td>
<td>Up</td>
<td>Blank</td>
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<td>(12)</td>
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</table>

Table 3 represents contrast sensitivity value for Vistech, model VCTS6000. For example, fourth circle on row B has a contrast sensitivity value of 55.

The test consists of five rows and nine columns of circles. Each circle (except for those in the last column) contains alternating light and dark bars oriented vertically or tilted 15° to left or right. The subject's task is to detect the orientation of the bars. The bar pattern is sinusoidal so the transitions are without sharp edges. Each pair of light and dark bars comprise a cycle of a sine wave; the number of cycles per degree increases from 1.5 to 18 per circle from the top to the bottom row. As the subject looks across a row, the contrast between the peak of the sine wave (light area) to the trough (dark area) progressively decreases, and the task becomes more difficult.

Data from the test can be compared to norms provided by Vistech. For row A (1.5 cycles per degree) the mean for the last correct circle identified by normal subjects was 6.2 with a standard deviation of 0.9. For row B (3 cycles per degree) the mean was 6.9 with a
standard deviation of 0.8. For row C (12 cycles per degree) the mean was 6.8 with a standard deviation of 1.1. For row D (15 cycles per degree) the mean was 6.7 with a standard deviation of 1.3. For row E (18 cycles per degree) the mean was 5.9 with a standard deviation of 1.3.

Grating orientations shown on Table 3 were used to evaluate the observer's response for each stimulus. The letters in each block correspond to the orientation of each bars within a circle on the chart. R is for right, L is for left, U is for up and down, and B is for blank. The numbers correspond to the contrast value for each bar. The highest numbered bars within a circle that could be correctly seen in each row of the chart determined the observer's contrast sensitivity for that spatial frequency.

Although three equivalent cards were supplied with the test, all subjects were tested with Card B. The test card was mounted in a simple handheld plastic frame supplied with the test. This standardized the presentation distance at 45.5 cm so that the visual angle of each circle was 1'. The narrow end of the holder was placed against the cheek of the subject during the examination.

Illumination was standardized at the level recommended by the manufacture: 65 ft-c was measured with a light meter in the incidental mode with the photocell at the recommended location parallel to the floor. Using the reflected mode, 7.5 ft-c was measured with the cell 2 cm from the face of the test card along the viewer's line of sight.

Procedure

Each subject was tested individually. First, the test was explained and examples were provided. The subject considered the gratings binocularly, starting with the top row and continuing across each row as far as possible. The subject responded by pointing his/her hand in the direction of the pattern orientation. Subject responses were recorded during testing, however, scoring was completed without the subject present. As suggested in the
test manual, the score for each level was the last stimulus circle in the row correctly identified. If the subject made an error early in a row but followed it with two or more correct responses, the error was ignored in the calculation of the score.

**Instructional Set**

The examiner explained: “This is a new type of eye test. I want to know how well you see fuzzy bars of different sizes. It is important that you do not squint or lean forward during the game. Each of the circles of this chart contains bars of different sizes. Each row contains a smaller pattern of bars. The four circles on the this page are examples of the four ways in which the bars may be pointed. The bars can be straight up and down, slanted slightly up to the right, slanted slightly up to the left, or blank. Your job is to read across each row, starting with top left circle, and tell me whether the bars are left, right, up and down, or blank. Some of the bars in the circles will be very light and smaller, so it will be hard to see which way the bars are pointed, but I still want you to tell me which way the bars are pointing, even if you have to guess. Remember, this test has no right or wrong answers. I just want to know how well you can see.”
Results

Figure 3: PIAT-R age equivalency vs. actual ages.

PIAT: Visual Testing

The results of the PIAT-R visual testing can be seen on Figure 3. It shows that the average reading performance of the SRD group was 1.74 years below the average of the normal group. The standard deviation was 3.95 for the normal group and 2.85 years for the SRD group. The means were significantly different (t-test, P<0.05). The largest age equivalency difference (4.99) between normal and SRD groups was seen in the 13 year old group. Smallest age equivalency difference between normal and SRD groups was seen in the 8 year old group at 0.29 years. For grade equivalency, the means for the two groups were also significantly different (t-test, P<0.05). The average grade equivalency for the normal group was 8.44, while the SRD group mean was 5.77. In agreement with age equivalency, the SRD group tested 2.67 grade levels below the normal group.

21
**PIAT: Auditory Testing**

The results from the PIAT-R auditory testing can be seen on Figure 4. Unlike the visual data, there is no difference between normal and SRD groups (t-test, P>0.05). For the normal group, the average age equivalency is 13.71 years old, while for the SRD group it is 13.61 years old.

![Figure 4: PIAT-R auditory testing with age equivalency.](image)

Grade equivalency testing revealed that the normal group had a mean grade level of 9.12 with a 3.31 standard deviation. The SRD groups had a 8.54 grade level with a 3.65 standard deviation. This difference was not significant (t-test, P>0.05).

**Automaticity**

Automaticity was measured just prior to RSVP testing. Automaticity is a measure of visual-verbal response time and language fluency. For this study, automaticity was assessed by measuring how quickly subjects were able to call out a series of printed letters. Automaticity gives an indication of the visual and verbal processing speed of the subject.
This measure was relevant because three tests (RSVP, CSF, and PIAT) required the subject to make a verbal response to visual representations of letters (see Appendix A). The visual and verbal automaticity measure was useful in understanding the subject's performance on these three tests.

Figure 5: Average automaticity time of normal and abnormal group.

It can be seen from Figure 5, the SRD group exhibited slower automaticity responses than the normal group, and the means were significantly different (t-test, P<0.05). The trend shows that the gap grows wider as the chronological age increases. The average at age 8 was 6.74 seconds for normal group and 6.30 seconds for the SRDs. By the time the subjects were 13 years-old, the difference was 2.47 seconds when normal group's time was at 4.14 seconds, while the SRD group's time was at 6.61 seconds. It shows that normal subjects were able to increase their automaticity time by 2.6 seconds while SRD's automaticity time did not change as much.
**RSVP Testing**

Figure 6 shows results of RSVP testing for two groups conducted under clear conditions. It can be seen that the SRD group lags the normal group in all four positions, especially in Position 1. For the normal group, the average RSVP time was 522 ms, while it was 623 ms for the SRD group. The mean SRD versus Normal RSVP times were statistically different for position 1 (ANOVA, P<0.05), but they were not different for other positions (ANOVA, P>0.05).

*Figure 6: Average RSVP time under clear conditions.*

In Figure 7, the average RSVP times obtained under blur conditions are shown. The subjects were blurred to near Snellen 20/40 letters, and the RSVP times were recorded from all four positions. Statistical analysis showed that the mean times for values for Positions 1 and 2 were significantly different (ANOVA, P<0.05), but the times for position 3 and 4 were not (ANOVA, P>0.05). Figure 8 shows the performance of the normal group under clear and blur conditions. It can be seen that under blur conditions for the average RSVP time the normal groups decreased at Positions 1 and 3.
Figure 7: Average RSVP time under blur conditions.

![Graph showing average RSVP time under blur conditions.]

Figure 8: Average RSVP time for the normal group.

![Graph showing average RSVP time for the normal group.]

However, blur condition performance at Position 2 was better than under clear condition.
performance. It can be seen that the two conditions did not affect the performance at the Position 4. At Position 2, the normal group was timed at 574 ms under clear conditions, while the same group was timed at 553 ms under blur conditions. Also at Position 4, the same group performed at 601 ms under clear conditions and at 599 ms under blur conditions.

Figure 9: Average RSVP time for the SRD group

![Figure 9: Average RSVP time for the SRD group](image)

Figure 9 shows performance differences by the SRD group under clear and blur conditions. At Position 1, the SRD group performed better with blur conditions than with the clear condition. In the clear condition, the SRD group performed at 623 ms while under blur conditions the SRD group was timed at 574 ms. The performance difference between two conditions was 49 ms.

It can also be seen in Figure 9 that at Position 4 the SRD group's performance was similar under both conditions. In the clear condition, the group was timed at 623 ms, and in the blur condition, the same group was timed at 616.67 ms. The difference in performance
was only about 6.25 ms between two conditions, and taking standard deviations into account, the difference is not significant.

Performance differences between the two conditions were seen at two positions. At Position 2, the SRD group was timed at 579 ms under the clear condition and 611 ms under the blur condition with a difference of 32 ms. The greatest time difference between two conditions was seen at Position 3. The SRD group performed at 547 ms under clear conditions, and 603 ms under blur conditions. The performance difference under the two conditions was 56 ms.

**Figure 10:** Average CSF function for all age groups

Contrast sensitivity testing with the VisTech 6000 resulted in different mean CSF functions for the SRD and normal groups as shown Figure 10. The SRD group's contrast sensitivity is lower than the normal's at lower spatial frequencies. Using a t-test, the difference between the two groups was significant (P<0.05). The greatest difference was seen at
Row C, with a spatial frequency of 6 cycles per degree. The normal group's CSF value was at 115.87 with a value of 102.13 for the SRD group. However, in Row E, with spatial frequency of 18 cycles per degree, the contrast sensitivity of two groups is similar with values of 31.32 for normals and 29.63 for SRDs.
Discussion

The SRD subjects who participated this study were classified by their school district as learning disabled through standardized testing. However, the traditional standardized tests used in school districts, are conducted under visual conditions only, without allowing the auditory feedback (i.e. reading out loud) that the SRD group needs to perform at a "normal" level. Typically, a child is not identified as learning disabled until third grade. In school, third grade is a critical transitional year in which a child must read to learn rather than learn to read as in K through second grade. If the child has transient pathway dysfunction, he/she may have learned to compensate with auditory feedback, via reading out loud, or by relying on verbal instructions. Early reliance on auditory skills would explain the higher level of auditory comprehension that was found in the "normal" children. However, traditional education emphasizes visual rather than auditory processing of information, so that early gains made in auditory processing are often reduced for the sake of more efficient visual information processing in ensuing years.

If this is correct, it would be expected that the SRD reader would respond better on reading tasks that require minimal eye movement. Transient pathway dysfunction in mild forms may not even be evident under everyday circumstances when the child can use his/her coping strategies. However, with a more severe form of transient pathway dysfunction, it may interfere with reading ability or show up as below average performance under standardized testing, despite the fact that the child possesses normal intelligence. This may partially explain the high prevalence rate of transient pathway dysfunction in the SRD group. Given what is known of the perceptual functions and how the transient system performs, it is reasonable to expect children with a reading disability caused by transient pathway dysfunction to show deficits in global, preattentive processing operations and on tasks requiring fine temporal resolution.

Spring and French found that auditory comprehension scores of SRD readers did not differ greatly from those of normal readers. However, it was found that the scores of SRD
readers were significantly lower than those of average readers for visual reading comprehension. This suggests that SRD readers auditory comprehended auditory test sentences as well as normal readers, but that SRD group's performance was reduced with visual reading due to inaccurate word decoding because of transient pathway dysfunction.

Figure 11: Modified PIAT testing performance under dual conditions for two groups.

In accord with results reported by Spring and French, 4 the modified PIAT testing showed that there was a significant difference between the SRD and the normal group when sentences were presented visually, but there was no performance difference with auditory presentations. Figure 11 represents the performance difference under visual and auditory conditions in grade equivalency. Under auditory testing conditions, the performance of both groups improved. The normal group performed at 1.16 years or 0.7 grade level above visual testing conditions. The SRD group improved remarkably 2.8 years or 2.77 grade levels above the visual testing conditions. For the SRD group, auditory processing compensates for the transient pathway dysfunction under some testing conditions. In
Figure 4, it can be seen that the 8 year-old SRD group possesses a higher level of auditory age and grade equivalency when compared with the normal group.

Figure 12: RSVP reaction time difference between clear and blur testing conditions at Position 1.

The modified PIAT testing result supported several studies, which found visual processing differences between normal and SRD readers in the timing of saccades. 74-79 For SRD readers, the duration of visible persistence is longer, 81 and the SRD readers may be seeing the information from the previous fixation when gaze is shifted to the next fixation point due to its persistence. When this occurs, the two visual inputs may be seen, but the reader has no certainty of whether the information came from the first or second fixation. Thus, persistence of the visual input from the previous fixation would be confusing to the reader by making the text appear superimposed or overlapping. Therefore, increased fixation duration, required to compensate for a sluggish metaccontrast mechanism, is commonly observed in the reading behavior of disabled subjects. 1
In direct measurement studies using the RSVP attention shift paradigm, it was discovered that the rate of foveal visual processing was slowest in SRD children. These findings are consistent with previous reports of increased temporal resolution with age, and with reports of sluggish temporal processing in SRD readers. It can be seen in Figure 6 that under clear testing conditions, there was a lag in the time required to shift gaze and attention for the SRD group. The difference was greatest at Position 1 where the SRD group lagged the normal group by 101 ms. The RSVP result is supported by fixation-saccade sequence model related to transient pathway dysfunction as proposed by Breitmeyer and Ganz and Breitmeyer.

Under blur conditions, the SRD subjects' performance improved, which supports data reported by Williams et al. Image blurring, however, decreases the performance of normal readers by disrupting the normal pattern of transient-sustained interactions. Although the transient pathway dysfunction affects eye movements in all positions, performance at Position 1 was affected most. Examination of the performance curves on Figures 4, 5, 6, 7, and 12 shows that image blurring re-established the normal pattern of interaction between transient and sustained pathways for the SRD group. The SRD group's overall performance did not change significantly in Figure 7, but it can be seen in Figure 12 that there was a significant change of performance under blur conditions. The difference between SRD and normal group decreases at Position 1 to 26 ms. The SRD group still lagged the normal group, but it is clear from Figure 4, that the SRD performance curve under blur conditions resembles the normal group's performance curve under clear conditions.

Another clinical manifestation of transient pathway dysfunction involves a decrease in contrast sensitivity for low and middle spatial frequencies. This data was supported by Carmean and Regeth, who reported that reading comprehension scores were directly related to a visual contrast sensitivity measure in a population of 155 elementary school
The data from our experiment shows high correlation with these results. As shown in Figure 10, the CSF for the SRD group was lower in the area of low and middle spatial frequencies than that of the normal group.

Williams et al.\textsuperscript{1} stated that the performance of SRD children on various perceptual tasks was predictable from a transient pathway dysfunction model, and data from our experiment supports their claim. A relationship was present between the manifestation of the auditory-visual and CSF mismatch in the SRD group that could be caused by a deficient transient visual pathway. Modified PIAT testing showed that the SRD group was slower than the normal group in processing visual information but their auditory informational processing was comparable with the normal group. RSVP testing revealed that under clear conditions, SRD group's performance was inferior to that of the normal group. However, under blur conditions, SRD group's performance improved while the performance of the normal group decreased. The relationship was also present with the SRD group and the CSF testing. It revealed that the SRD group's CSF decrease was present for low and middle spatial frequencies.

For a child with transient pathway dysfunction, reliance on the auditory feedback system becomes paramount as he/she progresses through the academic system. Because early academic learning requires learning to read rather than reading to learn, there is a large amount of auditory feedback present in the classroom. This works to the SRD child's advantage, because unlike other children, the transient pathway dysfunction child has very well developed auditory language processing ability to augment the defective visual system. This effect can be seen in the graph in Figure 4 showing that the SRD children in the 8 year-old age group possess a higher auditory language processing level than the normal group.

Due to this early auditory maturation, children with transient pathway dysfunction may not be identified as learning disabled within the first one or two academic years. Rather, just
the opposite may happen. Because the first two or three years in school emphasize both auditory and visual ability, children with transient pathway dysfunction may even excel at academic work. The problem appears in third grade where the emphasis on education changes to reading to learn rather than learning to read. It is a subtle change and being handicapped by transient pathway dysfunction, these children's academic performance and self-esteem suffers. After being labeled as SRD via standardized testing, the pattern of failure has been established, and is very difficult for the child to break the cycle and overcome the expectations of teachers and peers. To avoid mislabeling of children via inappropriate academic testing, further investigation into transient pathway dysfunction is essential as well as development of proper screening methods to detect children with this problem.
Appendix A: Data Collection Sheet

Peabody Data

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Automaticity Data

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Rolodex Data

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## Appendix B: Answers to Data Collection Sheet

### Peabody Data Key

Once the subject misses five questions consecutively, the scoring can be concluded, and the grade level can be ascertained from the Peabody instruction book.

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### Automaticity Data

The average time from four trials can be calculated and placed on the spread sheet.

### Rolodex Data

The average time from eight trials can be calculated and placed on the spread sheet. List number of mistralls and amount of head movement for each testing condition (clear/blur). **Note: first few patients were tested under different speed.**

### Contrast Sensitivity Value Key

Row A equals 1.5 cycles per degree. Row B equals 3 cycles per degree. Row C equals 12 cycles per degree. Row D equals 15 cycles per degree. This key is used to evaluate the observer’s visual contrast sensitivity on each test chart. The letters in each block correspond to the orientation of each bars within a circle on the chart. R is for right. L is for left. U is for up and down, and B is for blank. The numbers correspond to the contrast sensitivity value for each bars. The highest numbered bars within a circle that can be correctly seen in each row of the chart is the observer’s contrast sensitivity for that spatial frequency.

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Appendix C: Peabody Questions Tape Counter Values

All tapes start at # 008

### Aural Even Questions

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### Visual Questions

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Appendix D: Automaticity Sheets

Automacticity Sheet #1

V
J
C
H
I
R
O
P
W
G
S
Appendix E: RSVP Instructions

Figure 15: Key letter shown on the computer screen.

"On the computer screen is a key letter that you will be looking for. The key letter will be shown only once during a flash sequence or trial run. When you are ready, I want you to push the button on the mouse. The letter will disappear and then it will start to flash. I want you to tell me when you see the key letter again."
"During the last trial, as the key letter disappeared and the letters started to flash, you noticed a second column of letters to your right. So this time, When you see the key letter, I want you to look over to the new column of letters, and tell me the first letter you see."
"I want you to look at the second column of letters without moving your head, just move your eyes. Now, the key letter will be changed during each trial run, so you need to concentrate."

The concept may need to be presented more than once before the subject understands it.

If the subject meets the criteria, go on to use the lens flippers.
Figure 18: Presentation of lens flippers.

“Now, I am going to make things little different. This time, I want you to hold this lent flipper over your eyes, like this. Examiner shows the subject how to hold on to the lens flippers. I want you to remember the first letter that you see in the new column after you see the key letter at the first column through the lens flipper.

The first run through will be done with the +0.12 diopter lens in place. It may be necessary to repeat the trial several times until the subject understands the task. If the subject is able to meet the criteria, go on to blur the subject to near Snellen 20.40 line.
"Now, I want you to look at the screen. You will see the row of letters on the card. 20/30 and 20/40 lines will be isolated on the near Snellen card. As I change lens in the flipper, I want you to tell me when you cannot see the lower row of letters any more." With the subject blurred to 20/30 and barely able to make out the 20/40 line, run the trial again.

"Now, we are going to do the same thing as before. Things will be little different now, but let see how well you can detect the letter on the second column." If the subject meets the criteria, go on to the demo and data collection phase.
"Now, there will be four positions on the screen where the second column of letters can show up. You can see where the four positions will be on the diagram on this page. Although the positions are numbered from one to four, they will not show up in that order. I will tell you which position to look at before starting at each new position."
Appendix F: Academic Records Release Form

PACIFIC UNIVERSITY
College of Optometry
Family Vision Centers

Date: __________________________

Name of School: _________________________________________________
Address of School: _______________________________________________

Re: ____________________________________________'s Test Records
Dear ____________________________________________ Staff:

We are conducting research involving the relationship between the visual system and reading. We would very much appreciate receiving the results from ____________________________________________'s most recent reading assessment(s). The results of any perceptual/intellectual/behavioral assessments would be very helpful also.

This information will be held in confidence. Potential future publications of this research will not identify individual subjects or specific test scores.

A parental signature authorizing release of this information to use is included on the bottom of this page.

Thank you very much for your assistance. Please forward the information to: Hannu Laukkanen, Pacific University College of Optometry, 2043 College Way, Forest Grove OR 97116.

Hannu Laukkanen, O. D.

I consent to your sharing educationally-related about my child, including consulting my child's teacher, for up to six months from this date. I understand that this information cannot be released without my consent and that I have the right to revoke my consent at any time.

Parent/Legal Guardian ___________________________ Date ________________

Pacific Avenue at Birch
Forest Grove, OR 97116
(503) 357-5800

Portland Medical Center
511 S.W. 10th Avenue
Portland, OR 97205
(503) 224-2323

Portland Community College
Cascade Campus
600 N. Killingsworth Street
Portland, OR 97217
Appendix G: Parent Information Sheet

PACIFIC UNIVERSITY

College of Optometry
Family Vision Centers

April 17, 1991

TO: Interested Parents

FROM: Dr. Hannu Laukkanen, Asst. Clinical Professor of Optometry
       Bonnie Gauer, Research Coordinator

Pacific University College of Optometry is offering an opportunity for grade school students to participate in a project involving the visual system and reading. Participants will be given several evaluations including computerized analyses of reading and visual skills. The project will require four hours and is limited to children in the third through eighth grades.

Benefits of the program include a parent briefing on their child's reading abilities and learning performance. In addition, children participating in the project will receive vouchers redeemable for two complete visual examinations in the College of Optometry Clinic. One voucher is to be used by the participant, and the other may be used by any family member.

For more information on this project, please contact Dr. Hannu Laukkanen, Pacific University College of Optometry, 2043 College Way, Forest Grove, OR 97116. Please respond as soon as possible, because not all children will be able to participate in this project.

If you have a child who is interested in participating in the project, please complete this form as soon as possible and send it to: Dr. Hannu Laukkanen, Pacific University College of Optometry, 2043 College Way, Forest Grove, OR 97116.

Parent Name (Print)

Student's Name

School
Grade
Age
Sex

Address

Phone

Pacific Avenue at Birch
Forest Grove, OR 97116
(503) 357-5800

Portland Medical Center
511 S.W. 10th Avenue
Portland, OR 97205
(503) 224-2323

Portland Community College
Cascade Campus
600 N. Killingsworth Street
Portland, OR 97217
Appendix H: Subject Informed Consent Form

Informed Consent Form

Institution

A. Title of Project: Electroencephalographic Characteristics of Children with Reading Difficulties

B. Principal Investigator: Hannu Laukkanen, O. D. - 357-5984/357-6151

C. Advisor: Robert Yolton, O. D., Ph. D. - 357-6151, ext 2272

D. Location: Pacific University College of Optometry, Forest Grove, OR Room 309

E. Date: March 15, 1991

1. Description of Project: This project is designed to look at brain signals generated by good readers and by those who have trouble reading. Brain signals will be recorded by placing small metal disks on the scalp overlying particular areas of the brain which the researchers wish to monitor. While brain signals are being recorded, subjects will be asked to look at checkerboards, words or symbols on video display screen, and will be asked to listen to tones. Subjects will also be asked to do arithmetic in their heads, to imagine scenes such as their house, or to simply relax. The experimenters will explain what is required for each of these tasks to the subjects in detail at an appropriate time.

2. Description of Risks: Placement of EEG electrodes requires cleaning the scalp area with alcohol and rubbing material called Omni-prep on the skin. (Omni-prep is a commercially available product made for this purpose.)
Small silver disk electrodes are then held in place by using sticky electrode paste. Up to 12 electrodes may be placed on the scalp, and an electrode will be placed on the skin above and below the right eye to monitor eye movements. The electrode placement procedures are standard ones utilized in hospitals and research clinics for monitoring brain signals. There have been infrequent reports of mild skin irritation from the application of the electrodes and subjects/parents are asked to notify the experimenters should such irritation be detected. It is especially important that the areas where the electrodes were placed be well cleaned with shampoo and/or soap when the subject returns home.

3. **Description of Benefits:** This study is designed to help the researcher understand how to detect the problems associated with reading difficulties. As a result of our work on this project, we want to be able to diagnose children who have reading difficulties associated with brain problems as opposed to problems in focusing on the reading material or moving their eyes from word to word.

4. **Alternatives Advantageous to Subjects:** Not applicable

5. **Records:** Records from this project including any information on reading ability will be maintained in a confidential manner and no name identifiable information will be published.

6. **Compensation and Medical Care:** If you are injured in this experiment it is possible that you will not receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the experiment. All reasonable care will be used to prevent injury however.
7. **Offer to Answer Any Inquiries:** The experimenters will be happy to answer any questions that you may have at any time during the course of the study. If you are not satisfied with the answers you receive, please call Dr. James Peterson at 357-0442. During your participation in this project, you are not a Pacific University clinic patient or client for purposes of the research, and all questions should be directed to the researchers and/or the faculty advisor who will be solely responsible for any treatment (except for an emergency). You will not be receiving complete eye, vision, or health care as a result of your participation in this project. Therefore, you will need to maintain your regular program of eye, vision, and health care.

8. **Freedom to Withdraw:** You are free to withdraw your consent and to discontinue participation in this project or activity at any time without prejudice to you.

I have read and understand the above. I am 18 years of age or over, or this form is signed for me by my parent or guardian.

Printed Name

Signed Date

Address

City State Zip

Phone

Name and address of a person not living with you who will always know your address:
References


2 Larry P. vs. Riles, 793 F.2nd 969 (9th Cir. 1984).


42 The work was based on previous investigations on differential measurements of 2-DG (2-deoxyglucose), a labelled glucose analog, activity. If 2-DG is administered to an animal, it will be taken up into metabolically active cells and cannot be enzymatically altered. Thus, it can be used to measure which cells are most active during a task.


70 Carmean & Regeth, Optimum level of visual contrast sensitivity for reading comprehension. Perceptual and Motor Skills, 1990, 71, 755-762

71 Meares, O. (1980) Figure/ground, Brightness contrast and reading disabilities. Visible Language, 14, 13-49.


81 Lower spatial frequency stimuli produced shorter visible persistence durations. Visible persistence increased monotonically with increasing spatial frequency. Visible persistence was approximately 150 msec with a 2 cpd stimulus and greater than 300 msec for 12 cpd stimulus.


84 T-test was used to analyses the significance of the data obtained. It was performed using Microsoft Excel version 4.0 with one tail and type sitting at independent or 1. If the resultant value, "P", is less than 0.05, the data analyzed was considered significant. If the "P" value was greater than 0.05, the data was considered to be non-significant.