Testing of remapping for reading enhancement for patients with central visual field losses

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ABSTRACT

Retinal pathology often results in visual field loss. Age Related Macular Degeneration (ARMD) and Stargardt's disease (a congenital disease) typically affects the central macular region of the retina, resulting in visual field loss to the region of the retina with the highest resolution. Due to the central visual field losses, patients with ARMD and Stargardt's disease often experience difficulty in visual tasks, such as reading and facial recognition. NASA Johnson Space Center has developed an electronic remapper that can warp an image from one coordinate system to another on a television screen. The remapper can be used with patients with central visual field loss to redistribute information projecting off of the macular lesion (corresponding to the central scotoma) and onto the still functioning peripheral retina. The purpose of this research project was to investigate whether remapping of text around the central scotoma improved reading performance (increased reading rate) for patients with ARMD or Stargardt's disease. The subjects moved the text on the stage and read aloud random words of equal difficulty viewed on a Closed Circuit Television (CCTV) screen. Reading speeds for normal and remapped text were obtained. Reading rates were determined for both free viewing and with stabilization of the position of the screen relative to the eye rotations. Results of these experiments are discussed.

Keywords: Low vision, remapping, reading, warping of image

1. INTRODUCTION

Ocular diseases or traumas to the retina can frequently cause visual field defects. Diseases such as Stargardt's Disease, Toxoplasmosis, Age Related Macular Degeneration as well as solar burns to the fovea can destroy the central vision. The fovea is the sensitive part of the retina which has high resolution and is used for fixation. The visual information falling on these destroyed parts of the retina is not seen by the observer. These patients have difficulty with daily tasks such as reading, domestic chores and facial recognition.

Most patients with visual field defects (scotomata) request assistance in reading. Reading is a complex task requiring recognition of details, stability of retinal image (visual fixation stability) and control of eye movements. The nature of the text such as contrast\textsuperscript{2-3}, type of font, spacing of letters, luminance, field of view\textsuperscript{4-5} and presentation (e.g. scrolling, Rapid Serial Visual Presentation [RSVP]\textsuperscript{6}, jumping of text) are essential for the ability to recognize the text. Many of these elements required for reading are lacking or inferior in persons with central visual defects.

NASA Johnson Space Center has developed an electronic remapping system called the Programmable Remapper that can warp an image from one coordinate system to another.\textsuperscript{1} The Remapper was initially developed for the space program. We are using this device to attempt the specification of an effective low-
price low vision aid. The Remapper can warp and redistribute information falling onto the visual field defects to the still functioning parts of the retina.

Wensveen et al. (1995) investigated reading rates of people with artificial central scotomata of 2°, 4°, and 8° using the electronic Programmable Remapper. The image on a monitor screen was stabilized relative to the eye using the SRI Purkinje eye tracker. This stabilization kept the artificial scotoma at the same retinal position relative to eye movements. They observed that spatial remapping produced a small but significant increase in reading rate for 4° and 8° artificial scotomata when compared with the unremapped control condition.

Harris et al (1985) compared near visual acuity with a 'full field E' chart (a chart covered with identical Snellen E's) and normal clinical Snellen chart. Twenty three out of twenty seven ARMD patients demonstrated better visual acuity (V.A.) with the 'full field E' test. This was even true for patients with bilateral ARMD. They concluded that ARMD patients did not naturally use the area of the retina with the best visual resolution and might not have stable fixation.

The purpose of our study was to determine if the reading rate improved when the text was remapped out of the scotomata but as close as possible to the central retina of patients with natural central scotomata. Patients with ARMD and Stargardt’s disease who exhibited central field defects were used in this study. Unlike the technique of Legge et al. (1985 a, 1985 b) and Wensveen et al. (1995) where the speed of the text was controlled by the investigator for their reading experiments, text in this experiment was scrolled by the subjects at their own speed to simulate the natural way of using the Closed Circuit Television (a low vision magnifying device that consisted of a video screen, a camera system and a stage for the reading material).

2. READING RATES WITHOUT STABILIZATION

2.1. Remapping system
The primary measure of this study was the reading speed of each subject for normal and electronically remapped texts on the Telesensory Closed Circuit Television. The camera system of the CCTV was connected to the Programmable Remapper and the remapper was interfaced to the CCTV screen. Normal text could thus be transformed into remapped text. Two types of remapping algorithms were used: “Gausflow” and “Radial Eccentric”. The “Gausflow” algorithm tilted the text around the scotoma without distorting the shape of the letters. The size of the text was slightly reduced. The “Radial Eccentric” algorithm stretched the text out of the scotoma, expanding the size and distorting the shape of the text. Wensveen et.al. (1995) compared unremapped text and “Radial Eccentric” remapped text for subject with simulated scotomata. We earlier reported a variety of warping methods. In the tests reported here, we used the “Radial Eccentric” algorithm to compare with what Wensveen et.al. (1995) did. The “Gausflow” algorithm was used because the shape of the letters do not distort.

2.2. Subjects
A total of three subjects were recruited from patients of the University of Houston/ Lighthouse of Houston Vision Rehabilitation Clinic. A female, 71, and a male, 81, had ARMD and a male, 35, had Stargardt’s disease. The subjects had near visual acuities of 20/200, 20/275 and 20/125 respectively and scotoma sizes between 6 and 10 degrees of arc in at least one eye. Only patients with a central scotoma with a diameter between 4 and 10 degrees and near visual acuity between 20/100 and 20/400 in at least one eye were selected. Subjects whose scotomata were larger than 10 degrees or visual acuity worse than 20/400 were not included in this study because of the limited field of view. Subjects had to be able to view at least four characters at a time to be able to read with ease. Subjects with recent onset of ARMD were chosen, so that they had not yet developed eccentric fixation.
Table 1: Data of subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Eye</th>
<th>Gender</th>
<th>Age</th>
<th>Medical condition</th>
<th>Size of central scotoma</th>
<th>Near V.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.H.</td>
<td>O.S.</td>
<td>Male</td>
<td>35</td>
<td>Stargardt's</td>
<td>-7°</td>
<td>20/125</td>
</tr>
<tr>
<td>E.W.</td>
<td>O.S.</td>
<td>Male</td>
<td>81</td>
<td>ARMD</td>
<td>-7°</td>
<td>20/200</td>
</tr>
<tr>
<td>B.L.O.S.</td>
<td>O.S.</td>
<td>Female</td>
<td>71</td>
<td>ARMD</td>
<td>-6°</td>
<td>20/275</td>
</tr>
</tbody>
</table>

In accordance with the University of Houston Committee for Human Subjects, the letter of consent was read to the subjects, a copy of the consent was given to the subjects and oral consent was obtained.

2.3. Preliminary assessment
Before measuring reading rates, preliminary assessments of the visual function of each subject were obtained. Visual acuity at 40 cm was measured to determine the sizes of the letters to be used for the study. The subject read monocularly the smallest letters possible on the Lighthouse Near Chart at 40 cm. The position and the size of the central scotoma were measured in each subject. To determine the size and the location of the central scotoma, the Amsler grid and kinetic perimetry were used.

2.4. Choosing the optimal letter size
The subject monocularly read random words on the CCTV at two, three, four and five times larger than the subject’s best near visual acuity. For example, if the subject’s best near visual acuity was 20/20, two times the acuity would be 20/40, three times the acuity was 20/60, four times the acuity was 20/80 and five times the acuity was 20/100. We used the New York lower case font. The subject sat at a distance of 40 cm in front of the CCTV that had a moving stage. One of the sets of random high contrast, printed words of equal difficulty selected from the English dictionary was mounted onto the stage. A single line of text was scrolled by the subject from right to left across the Closed Circuit Television screen. The subject read aloud and was audio recorded on a cassette recorder. The smallest letter size at which the subject obtained the highest reading speed was used as the optimal letter size for the study. Legge et al (1985b) observed that reading rate reached a broad maximum at a print size much larger than the acuity limit for both normally sighted and low vision subjects. However, reading rate fell again if the print size became too large because of the limited number of letters in the field of view. Using letter sizes up to a maximum of 24 degrees, Legge et al. (1985 b) observed that subjects with central visual field loss benefited from ever increasing magnification, at least up to character size of 24 degrees. Whittaker and Lovie-Kitchin (1993) analyzed data from Legge et al (1985 a), and found that normally sighted subjects had a sharp rise in reading rate to a peak when the character size was between six and eight times greater than the acuity threshold. The smallest letter size at which the subject obtained the highest reading speed was used as the optimal letter size for the study instead of the suggested magnification because of the limited field of view of the CCTV screen.

2.5. Training
Before the actual reading-speed experiment, the subject was familiarized with the operation of the CCTV and the remapping programs. Two types of remappings called “Gausflow” and “Radial Eccentric” were used. The subject was trained to look consistently at one position in order to place and hold the central scotoma area on the CCTV screen so that the remapped letters would be visible outside the scotoma.

2.6. Reading experiment
A set of high contrast, optimal size random words of equal difficulty was mounted onto the stage. The subject was instructed to read the random words aloud as fast and as accurately as possible. The subject viewed the CCTV screen monocularly at a distance of 40 cm. The subject moved the stage and read aloud. When reading normal unremapped text, the subject was allowed to move one’s eye to any position on the CCTV screen. This was to simulate the subject’s own strategy when reading. When reading the electronically remapped text, the subject had to look consistently at one position on the CCTV screen in order to place and hold the central scotoma area so that the electronically remapped letters were visible outside the central scotoma.
2.7. Results of reading experiment without stabilization

The subjects did not read significantly faster when the text was electronically remapped. The two Sample t-tests were used to analyze the difference in reading rates of normal and electronically transformed text for each subject. Subject J.H., a Stargardt's disease patient, did not show a significant difference in reading speeds between normal text and "Gausflow" remapped text (p-value > 0.4; diamond symbol in Graph 1). He read the "Radial Eccentric" text significantly slower than the normal text (p-value ≤ 0.0005; circle symbol in Graph 1). Subjects E.W. ("Gausflow", p-value ≤ 0.0005; "Radial Eccentric", p-value ≤ 0.0005; diamond and circle symbols in Graph 2) and B.L. ("Gausflow", p-value ≤ 0.0005; diamond symbol in Graph 3) read significantly slower with the electronically remapped texts when compared to normal text. (see Table 2 for p-values).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean and Stdv Normal (words/min.)</th>
<th>Mean and Stdv Gausflow (words/min.)</th>
<th>Mean and Stdv Radial Eccentric (words/min.)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.H. (Stargardt's)</td>
<td>138.3 ± 26.0</td>
<td>136.9 ± 19.8</td>
<td></td>
<td>&gt; 0.4</td>
</tr>
<tr>
<td>J.H. (Stargardt's)</td>
<td>136.2 ± 22.9</td>
<td></td>
<td>104.3 ± 21.9</td>
<td>≤ 0.0005</td>
</tr>
<tr>
<td>E.W. (ARMD)</td>
<td>47.3 ± 4.8</td>
<td>36.4 ± 3.7</td>
<td></td>
<td>≤ 0.0005</td>
</tr>
<tr>
<td>E.W. (ARMD)</td>
<td>47.0 ± 3.2</td>
<td></td>
<td>37.3 ± 3.2</td>
<td>≤ 0.0005</td>
</tr>
<tr>
<td>B.L. (ARMD)</td>
<td>24.6 ± 3.6</td>
<td>16.8 ± 2.2</td>
<td></td>
<td>≤ 0.0005</td>
</tr>
</tbody>
</table>

Table 2: Reading rates for normal text and electronically transformed text, Gausflow and Radial Eccentric, without stabilization of the text.

The possible explanation for no difference and slower reading rates for remapped text could be the different strategies employed by the subjects to read normal and electronically remapped text. The subjects could move their eyes freely when reading normal text but have to keep looking at one point when reading the remapped text. This additional task of keeping the eyes still at one point could have distracted the subjects' concentration in the reading task. Therefore, an experiment was derived to eliminate eye movements by stabilizing the image the subjects viewed.

3. READING WITH STABILIZATION

3.1. Reading experiment

The eye of the subject to be tested was aligned in the SRI Purkinje Eye Tracker. Through the eye tracker, the subject viewed the CCTV screen. The "gain" of the eye tracker was adjusted so that the image on the CCTV screen moved perceptually simultaneously with eye movements. Therefore, a position on the screen would always be projected at the same position on the retina. The eye tracker perceived eye rotations as eye movements. Eye translations (moving the head without changing gaze position) was not perceived as eye movements. The central scotoma of the subject was mapped out using kinetic perimetry before the experiment.

The central scotoma of the subject was aligned to the image warping by two different settings. The settings were:

a) The scotoma was aligned to be above or below the line of normal text. The alignment of above or below depended on where the subject normally viewed (above or below the scotoma).

b) The scotoma was aligned within the central region of the electronically remapped text so that the line of text flowed around (above or below) the scotoma. This depends on the subject. We tried to split the text line above and below the scotoma, but the subjects could not recognize the letters.
3.2. Results of reading experiment with stabilization

For the reading rate data with stabilization of image (Table 3), subjects J.H. ("Gausflow, 0.1 < p ≤ 0.375; "Radial Eccentric", 0.1 < p ≤ 0.375; triangle and square symbols in Graph 1) did not show any significant difference in reading rates between unremapped text and remapped texts. Subject E.W. did not show significant difference in reading rates between normal text and “Gausflow” remapped text (0.05 < p ≤ 0.1; triangle symbol in Graph 2) but read significantly faster with the “Radial Eccentric” remapped text compared to normal text (0.0005 < p ≤ 0.005; square symbol in Graph 2).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean and Stdev Normal (words/min.)</th>
<th>Mean and Stdev Gausflow (words/min.)</th>
<th>Mean and Stdev Radial Eccentric (words/min.)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.H. (Stargardt's)</td>
<td>109.8 ± 14.0</td>
<td>114.2 ± 12.6</td>
<td></td>
<td>0.1 &lt; p ≤ 0.375</td>
</tr>
<tr>
<td>J.H. (Stargardt's)</td>
<td>109.8 ± 14.0</td>
<td>111.8 ± 13.1</td>
<td></td>
<td>0.1 &lt; p ≤ 0.375</td>
</tr>
<tr>
<td>E.W. (ARMD)</td>
<td>30.8 ± 5.2</td>
<td>33.3 ± 6.3</td>
<td></td>
<td>0.05 &lt; p ≤ 0.1</td>
</tr>
<tr>
<td>E.W. (ARMD)</td>
<td>30.8 ± 5.2</td>
<td>35.9 ± 6.0</td>
<td></td>
<td>0.0005 &lt; p ≤ 0.005</td>
</tr>
</tbody>
</table>

Table 3: Reading rates for normal text and electronically remapped text, Gausflow and Radial Eccentric, with stabilization of the texts.

Graph 1: Graph shows the reading rates of subject J.H. The reading rate of nonstabilized "Gausflow" is not significantly different from the nonstabilized normal text (diamond). The reading rate of "Radial Eccentric" nonstabilized remapping is slower than nonstabilized normal text (circle). The reading rates of stabilized remappings (triangle and square) are faster (not significant) than normal stabilized text.
Graph 2: Graph shows the reading rates of subject E.W. The reading rates of nonstabilized "Gausflow" and nonstabilized "Radial Eccentric" remappings are slower than nonstabilized normal text (diamond and circle). The reading rates of stabilized "Gausflow" remapping (triangle) is not significantly different from stabilized normal text. The reading rate of stabilized "Radial Eccentric" remapping is significantly faster than normal stabilized text (square).

Graph 3: Graph shows the reading rates of subject B.L. The reading rate of nonstabilized "Gausflow" remapping is slower than nonstabilized normal text (diamond).
4. DISCUSSION

The results of the three subjects indicated that remapping of text did not aid their reading performance without stabilization of text. In most instances, they read more slowly than with no remapping. Without stabilization, subject J.H. did not show any significant difference in the reading rates between normal and the “Gausflow” remapped text. Otherwise, the reading rates of the normal text were significantly faster than the remapped texts for all subjects. This may be due to the different strategies employed by the subjects for normal versus remapped text. For normal text without stabilization, a subject could view the text by moving his eye around on the CCTV screen. For electronically remapped text without stabilization, the subject was instructed to view the text by looking at one spot on the CCTV screen at all times. A subject had the freedom of moving his or her eye freely when viewing the normal and transformed texts with stabilization, because the image on the CCTV screen moved simultaneously with the eye. Thus, with this eye movement variable controlled, a better comparison could be made.

The reading rate of the normal text dropped when the text was stabilized. This is a strong indication that the difference in strategy when reading normal and remapped without stabilization caused the difference in reading speed. With stabilization of text, subject E.W. read significantly faster with the “Gausflow” remapping algorithm. Subject J.H. and E.W. showed a trend of reading remapped texts faster. This trend suggests that remapping of text does have the potential of improving reading rate. More subjects are needed to confirm this. Subject B.L. did not participate in the second experiment.

There are still some hindrances that may cause the reading rate of the remapped text to be slower in the natural condition. Wensveen et. al. (1995) used normal subjects with simulated scotomata. They found an increase in reading rate with the remapped text. The visual function of their subjects are normal around the scotomata. The scotomata of our subjects were not regular and could not match exactly the remapped region on the CCTV screen. Also, the visual function of the region of the retina around the scotomata may not be normal. There may be visual distortions and/or relative scotomata.

This method of reading with remapped text was also novel to the subjects and different from everyday experience. Therefore, more practice may be required to achieve a faster reading rate. Perhaps, we have not found the suitable algorithm of remapping for these subjects. All of the subjects preferred the “Gausflow” algorithm to the “Radial Eccentric” algorithm. Subjects E.W., J.H., and B.L. reported that the “Gausflow” algorithm was easier to read and more comfortable.

These preliminary results indicate that there is potential in the Programmable Remapper if some of the problems stated above are resolved. Further runs on new subjects will give a more concrete indication of the advantages and disadvantages of remapping as a low vision aid.

5. ACKNOWLEDGEMENTS

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6. REFERENCES


