ABSTRACT

PURPOSE: The aim of the study was to evaluate reading speed with increased vertical and horizontal word spacing in subjects having normal vision and low vision.

METHODS: Reading speed was measured in 23 normal and 23 low vision subjects. Data were collected using paragraph reading from laptop screen with Times new Roman font with critical print size. Stopwatch was used to measure the reading speed in word per minute (WPM). Reading speed was again measured by increasing vertical and horizontal word spacing from 1x to 5x.

RESULTS: Reading speed increases gradually with increased vertical and horizontal word spacing up to 3x and then decreases gradually in normal subjects while in low vision subjects minimal changes were observed.

CONCLUSION: An increase in vertical and horizontal spacing up to certain extent is beneficial in normal vision subjects while in low vision patients minimal changes are observed while reading.

KEYWORDS: word spacing, reading speed, low vision

INTRODUCTION: Reading speed is defined as the rate at which subject reads written text in a specific unit of time. It is generally calculated by the number of words per minute. It is important not only for reading medicine labels, newsprint or books but also important for reading road signs, driving directions, spotting words etc. Factors that significantly affect reading speed are acuity reserve, contrast reserve, field of view and central scotoma size in case of maculopathy. Other factors which affect central and peripheral reading speed are poor spatial resolution; poor eye movement control, lowercase and uppercase letters, glare and crowding phenomenon.

"Crowding" effect, is related to the difficulty of reading letters caused by the requirement of finer eye movements to read letters when they are in a tightly packed array. Crowding refers to the decrease visibility of a visual target in the presence of nearby objects so it has been suggested as a major factor contributing to decrease in reading speed. In the present study, we tried to explore whether increase in letter spacing between adjacent characters, will improve the reading speed by decreasing crowding.

METHODOLOGY: A cross sectional experimental study was performed. A total of 23 normal vision subject and 23 low vision subjects between age group of 16 and 25 years were considered. For normal vision subject, a minimum visual acuity of N8 for near without any ocular pathology was considered. For low vision subject, visual acuity greater than N18 for near without ocular
pathology which can affect visual field, ocular motility and history of head trauma were considered. All subjects underwent detailed ocular examination including history taking, anterior segment evaluation, fundus evaluation followed by objective and subjective refractive correction.

Reading speed measurement was taken in both the subject groups using a Laptop Screen of 15.6 inch. Words were rendered in Times New Roman fonts which is one type of word style used in many news-papers, magazines and books as well as it is very popular for writing. Consequently these were selected to construct the paragraph for reading. For measurement of reading speed, critical print size was considered. The critical print size is the optimal print size for reading because it is the smallest print size at which subjects read with their maximum rate. The reading text was extracted from 4th and 5th standard story book as majority of subject had English as their second language. 

For subjects with normal vision, the viewing distance was 60 cm and for low vision subject read at their habitual reading distance. Subjects with low vision who preferred to read using a specific retinal location were allowed to position the screen so that the text would fall into their preferred region of vision. Starting with the preferred print size and standard letter spacing of 1x, subjects were instructed to read each sentence, one at a time, as quickly and as accurately as possible. The letter spacing is defined as the centre-to-centre separation between adjacent letters. The standard spacing for the Times New Roman font is 1.16 times the width of the lowercase letter x, for a wide range of x-widths tested. The subjects were informed that reading speed was being measured and were asked to continue reading to the end of the sentence before correcting any reading errors they might have made. After the initial reading speed measurement the vertical letter spacing was increased from 1x to 1.5x, 2x, 2.5x, 3x, 3.5x, 4x, 4.5x and 5x and reading speed was measured using the same method. Fig.1, 2 and 3 shows vertical letter spacing of 1x, 2x and 3x respectively.

The procedure was repeated for horizontal reading. Reading speed in word per minute (WPM) was determined for each sentence as the number of standard length words read correctly, divided by the time taken to read the sentence. For data collected, the reading time was measured from the moment the sentence was revealed to the subjects until the subject finished uttering the last word of the sentence.

### RESULTS:

Table 1 and 2 shows the mean value of reading speed with horizontal and vertical word spacing in normal subjects and in low vision subjects.

**TABLE 1:**

<table>
<thead>
<tr>
<th>Word spacing</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal reading speed</td>
<td>162.04</td>
<td>166.52</td>
<td>169.52</td>
<td>172.73</td>
<td>175.69</td>
<td>172.73</td>
<td>170.47</td>
<td>169.30</td>
<td>166.60</td>
</tr>
</tbody>
</table>
Graph 1 and 2 shows comparison of reading speed with increased vertical and horizontal word spacing in normal vision subject and low vision subject respectively. The reading speed increases gradually with horizontal and vertical word spacing of 3x and then decreases gradually in normal subjects while the reading speed in low vision subject gradually decreases if horizontal word spacing increases beyond 2x and vertical word spacing increases beyond 1x.

**DISCUSSION:** In this study we compared the letter by letter crowding effect with performance measurement for recognizing a target with or without flanking objects. We had measured reading speed and in that, our target and flanking objects were word instead of single letters. It is observed that reading speed increased with increase of spacing up to 3x in normal subjects but then it gradually decreased. The increase in reading speed occurred due to decrease in crowding phenomenon. With further increase of spacing, saccadic eye movement increases which decreases the reading speed.
Mansfield JS\textsuperscript{3} measured the influence of different fonts in reading with normal and low vision and concluded for normal subjects, the differences are slighter, with an advantage in reading speed for Times. However, for print sizes close to the acuity limit, choice of font could make a significant difference in both normal and low vision reading performance. So, in the present study we used Times New Roman Font for estimating maximum reading speed of subject.

Bentley\textsuperscript{10}, Peterson and Tinker\textsuperscript{11}, examined the effect of line spacing on reading speed and concluded that increased vertical word spacing, benefits reading speed. Similar result is obtained in present study but up to a spacing of 3x

Calabrese A. et.al.\textsuperscript{15} concluded that increasing interline spacing is advisable only for very slow readers (<20 words/min) who want to read a few words (spot reading). Vertical crowding does not seem to be a major determinant of maximal reading speed for patients with central scotoma while Chung ST\textsuperscript{15} et al. concluded that increased line spacing in passages, or increased vertical separation between words in RSVP (rapid serial visual presentation), did not lead to improved reading speed in people with AMD. Rubin GS stated that line width and typeface have little influence on reading speed in people with mild to moderate sight problems. In our study, we have not considered specific group of disease but overall low vision subjects. Future studies are required in low vision subjects to assess reading speed in central and peripheral field loss separately.

**CONCLUSION:**
An increase in vertical and horizontal spacing up to certain extent is beneficial in normal vision subjects while in low vision patients minimal changes are observed in reading speed.

**REFERENCES:**


14 Sally Blackmore-Wright, Mark A. Georgeson, and Stephen J. Anderson* Enhanced Text Spacing Improves Reading Performance in Individuals with Macular Disease Published online 2013 Nov 11. doi: 10.1371/journal.pone.0080325