The Effects of Word Isolators and Text Size on Reading Speeds in Patients with Age-Related Macular Degeneration

Abstract

Age related Macular Degeneration (AMD) is a retinal disease causing distress to the Macula, a critical area for vision. The Macula is crucial for central vision, image resolution, as well as fine detail. The prevalence of AMD among the visually impaired is high; however, there is no known cure for this disease (Khandhadia *et al*., 2012). Reading speeds of these patients are significantly reduced. The objective of the experiment was to analyze the relationship between word isolation and reading speeds in those pre-diagnosed with AMD. An additional objective was to identify a correlation between varying text size and reading speed. 25 participants were asked to read a page from 3 different books that varied in text size. The first time, when participants read a page from the three different books, the surrounding words were visible. The second time, the participants were asked to read a different page from the same 3 books, but this time surrounding words were covered by an index card. Findings of this experiment showed that there was a positive correlation between text size and reading speeds ($R^2 = 0.92$ without isolator and $R^2 = 0.97$ with isolator.) With the addition of the index card to block out surrounding words, 92% (23/25) of the test subjects had experienced stimulated reading levels. In order to improve this study, we will use a wider variety of text sizes to find out which is optimum for patients with Age-related Macular Degeneration.

Word Count: 241

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Introduction

Age related Macular Degeneration (AMD) is a retinal disease causing distress to the Macula, a critical area for vision (Khandhadia *et al*., 2012). The Macula is crucial for central vision, image resolution, as well as fine detail because it receives a vast amount of focus of incoming light. The anatomy of the retina includes two layers; the first of which is the inner neurosensory retina and the outer retinal pigment epithelium (RPE), which is the second layer (Khandhadia *et al*., 2012). The outer choroid consists of a network of fenestrated capillaries, known as the choriocapillaris layer. The role of the choroid is to remove waste from the retina, as well as to bring nutrients and oxygen to the retina, especially at the Macula. This choroid is separated from the RPE by the Bruch's membrane (BM) (Khandhadia *et al*., 2012).

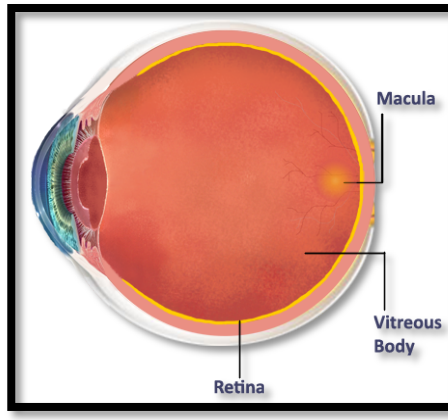

Figure 1 Depicts the Macula and the Retina of a human eye

http://www.retina-consultants.com/images/anat01.png

AMD is the principal source of central vision impairment, in those above the age of 50 (Cheong *et al*., 2008). In the developed world, AMD is the leading cause of blindness, accounting for approximately 50% of all known cases. The prevalence of AMD among the visually impaired is high; however, there is no known cure for this disease (Khandhadia *et al*., 2012). There has been no successful treatment for the disease until the recent introduction of anti-vascular endothelial growth factor. Anti-vascular endothelial growth factor (A-VEGF) is injected into the patient. Even this helps only a small percentage of patients and the drugs may lead to a rapid decrease in retinal thickness, which is detrimental (Meyer *et. al*., 2008). Vascular endothelial growth factor (VEGF) is a glycoprotein, an endothelial cell mitogen that stimulates the growth and regeneration of blood vessels. However, when this occurs in the retina, the vessels do not form properly. This leads to damaging results in the Macula (Penn *et al*., 2008). As a result, A-VEGF needs to be injected into the patient to reduce the affects of the VEGF. Results of this procedure vary between patients, depending on many factors. The majority of AMD patients are not benefited by A-VEGF injections (Khandhadia *et al*., 2012). Therefore, most patients suffer from the disease without any positive drug-related assistance for AMD.

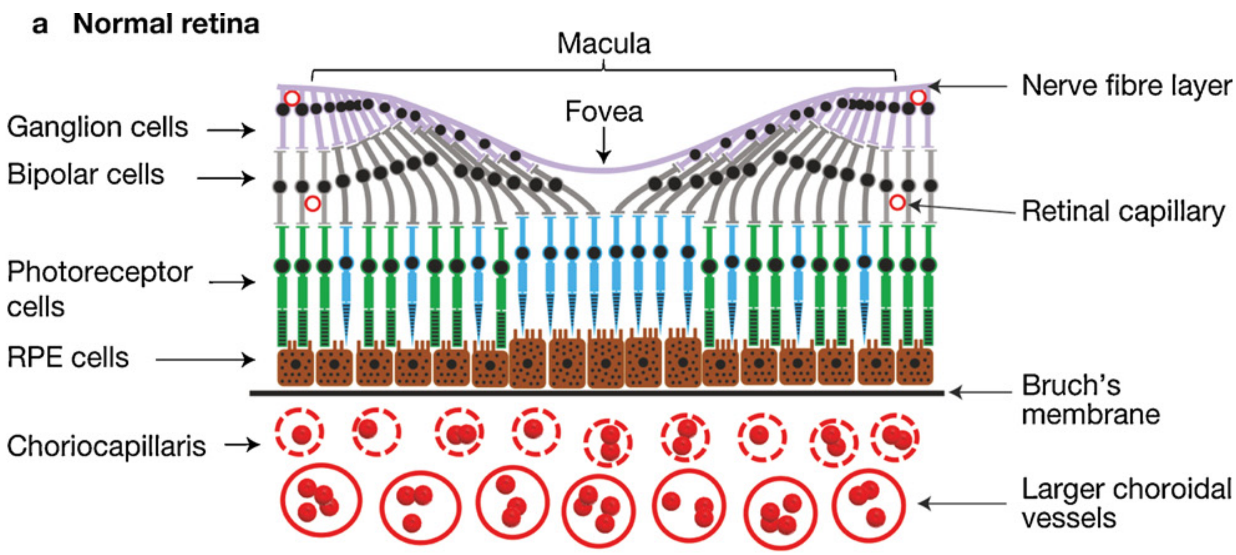

Figure 2. A diagram of a normal retina.
All anatomical features are in place and functioning. The blue lines show the direction of the central vision. It is facing one direction which means that there is no distortion in central vision.

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AMD can occur in wet form or dry form. Initially, AMD occurs in the dry stage (Figure 3), where alterations in the RPE occur. Drusen builds up and causes the deterioration of RPE cells. Choriocapillaris deficiency occurs in the dry form, as well. Subsequently, the wet form can occur later due to drusen accumulation (Chiou, 2011). Drusen are tiny yellow/white extracellular build-up between the RPE and BM, which is normal with age. However, too much build up is connected with the occurrence of AMD. In the wet form of AMD (Figure 4), defective choroidal neovascularization (growth of new blood vessels) occurs and they start to enter the area containing RPE cells and move them, causing subretinal hemorrhage. As a result, retinal distortion occurs and the central vision becomes heavily impaired which causes trouble reading and focusing on objects (Khandhadia *et al*., 2012). 90% of patients have the dry form of AMD. Yet, there is no single drug available for the treatment of dry AMD. Genes play a significant role in the development of dry AMD (Chiou, 2011). Early AMD often has no symptoms but is detectable when there is too much drusen and pigmentary irregularities in the retina, by examination.

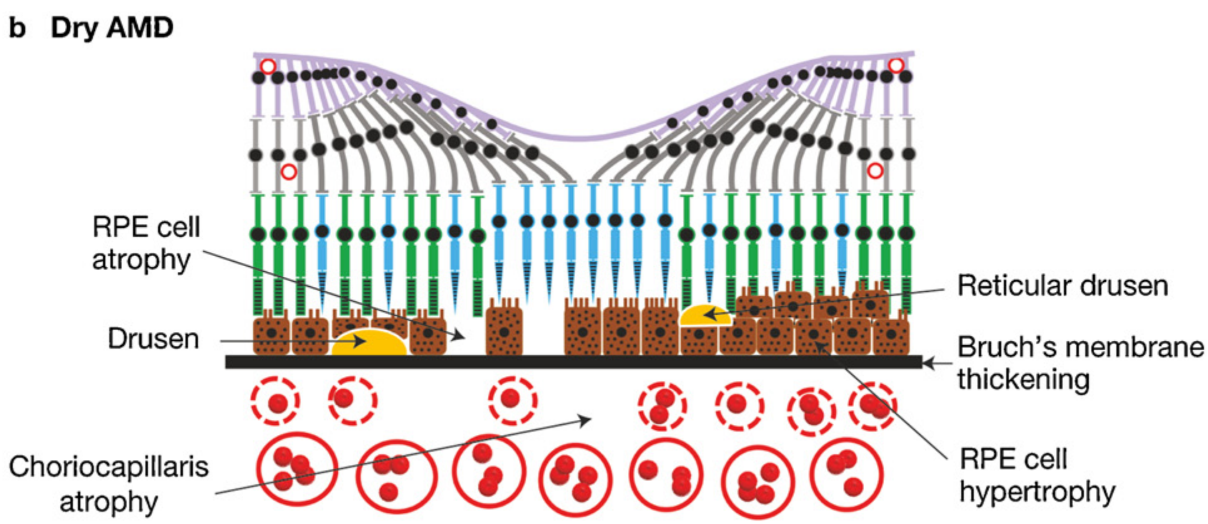

Figure 3. A Diagram of retina with dry AMD.

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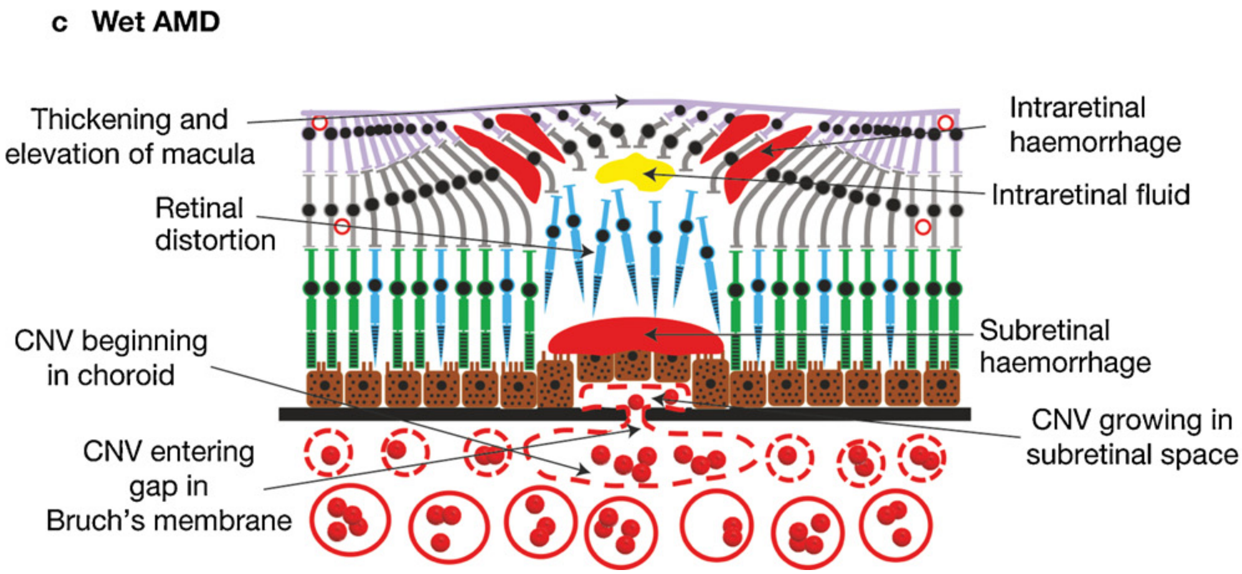

Figure 4. A diagram of the retina with wet form of AMD.

. The arrows are no longer straight as they were in a normal retina, which means there is retinal distortion. The Macula becomes elevated, as well.

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Central vision field loss, a result of AMD, causes reading difficulty. Many AMD patients read slowly despite prescribed a visual magnifying aid (Cheong *et al*., 2008). Reading speeds of these patients are significantly reduced. Suggested factors for these reduced reading speeds include impaired oculomotor control, shrinkage of the visual span, and slower temporal processing of letter information (Cheong *et al*., 2008). Our study looks at a possibility of word crowding as a factor for lower reading speeds. Crowding of words is when many words are clustered together, or grouped with similar patterns. According to the laws of Gestalt psycholuman eye sees objects in their entirety before perceiving their individual parts. Patients with AMD have minimal capability to perceive individual parts of clustered letters of the same design and color. As expected, the smaller the text is, the more difficult it becomes for the

Macula to establish separation between words. Thus, reading speeds usually become increasingly depressed with a decreasing size text (Levi, 2008). In crowding, a letter or word that is easily recognized when isolated becomes unrecognizable if it is surrounded by other letters or words. Very few studies have analyzed the effects of crowding on reading speeds (Levi, 2008).

Studies have looked at the effects of crowding on dyslexic patient's reading efficiency and found some evidence linking crowding and reading speeds in dyslexic patients (Levi, 2008). However, most of these studies about crowding have not analyzed effects of crowding on AMD. We believe that by unveiling only one word at a time in a text and obscuring surrounding words, patients with AMD would experience less crowding, and therefore have accelerated reading speeds. With increased text size, crowding would be reduced and reading speeds would increase. A combination of the large text-sized book and the surrounding-word isolator would yield optimum reading speed in patients with AMD.

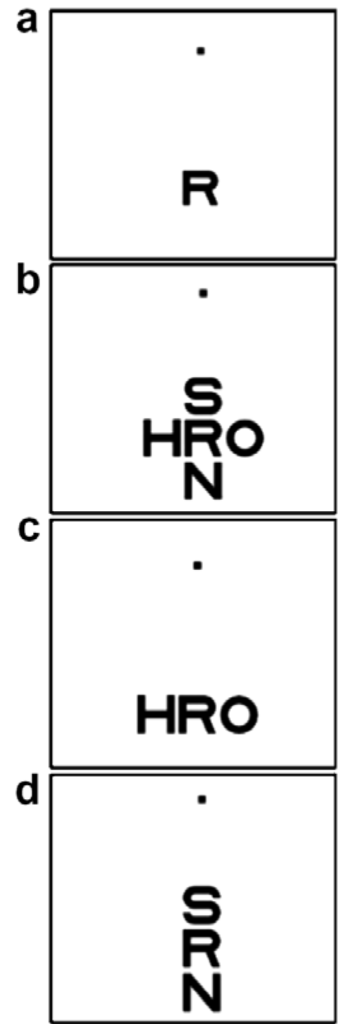

Figure 5. Crowding of letters

A person, especially one with AMD will have a hard time naming a single letter in B, C, and D while having their eyes only fixated on the dot. However, it is an easier task to name a single letter in isolation while staring at only the dot (A).

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Methodology

This experiment tested 25 people between the ages of 45-75 years old. Each participant who partook in this experiment was previously diagnosed with Age-Related Macular Degeneration. Test subjects of this experiment were found at the Jewish Guild for the Blind. All participants of this experiment signed a consent form that informed them about the goals and risks of this experiment and all participation was voluntary. The objective of the experiment was to analyze the relationship between word isolation and reading speeds in those who suffer with Age-Related Macular Degeneration (AMD). An additional objective was to identify a correlation between varying text size and reading speed. Participants were warned about the minimal risk testing might have had. The minimal risk included straining the eyes. Participants were also informed that they would be able to opt out of the experiment at any given time if they chose to do so. Participants' data was kept anonymous and all data was saved in a rescue CD.

In examining the relationship between text magnitude and reading speed, participants were asked to read a page from 3 different books that varied in text size. We used three popular books in this experiment to serve as an accurate representation of the most common text sizes people encounter. The first book chosen was Stem Cells for Dummies by Lawrence S.B. Goldstein. Each participant read page 177 from this book. The average length of each word on the page read of this book was 11 millimeters and the average height was 2 millimeters. This book was identified as small text since its font size was tiny compared to the other books used in this experiment. Participants were asked to begin reading once the timer began. After a minute, participants were instructed to stop reading. The number of words that they read out loud within that minute was their reading speed in wpm (words per minute). Next, the participants were asked to close their eyes for two minutes in order to allow any strain that might have been inflicted previously from reading to subside. When time expired, participants were asked to continue on and read page 307 from the novel Twilight by Stephenie Meyer. The average word length in this book was 12 millimeters and the average height was 3 millimeters. This text size was identified as medium. Just as in the first book, the subject's reading speeds was calculated and recorded in wpm. Participants had to rest their eyes for another two minutes before moving on to the final book. The final book was The Kite Runner by Khaled Hosseini. This book was identified as large size text because the average length of a word was 16 millimeters and the average height was 4 millimeters on page 223. The participants' reading speeds were calculated and recorded after the 60 seconds they read for this book.

Next, we tested the second objective of the experiment. The second goal of this experiment was to identify if word isolation would increase reading speeds. In order to test this factor, the three books previously used were repeated in this second trial. Participants were asked to read afresh, however, participants were instructed to read a different page to keep the data from being skewed if they were to remember the words they previously read. This time around, surrounding words were blocked with an index card. Index cards were cut out in the middle to the dimensions corresponding to the average length and height of the words on the selected pages, and were specific to each book. The first index card was cut at 11mm×2mm. This index card was used to sequestrate the focused word and cover all other words in the book Stem Cells for Dummies. The second index card was cut at 12mm×3mm in its center and was used for Twilight; the third index card was cut at 16mm×4mm, and was used for The Kite Runner. Each participant had to read page 171 from the small text for one minute. When the participant finished reading one word, they were instructed to slide the index card to the right (or to the next line) to unveil the following word. After one minute of reading, the number of words read out loud was recorded. Participants were asked to close their eyes for two minutes to reduce any strain that may have been caused from reading once again. The same procedure was followed when participants read page 137 in Twilight, except the 12mm×3mm index card was used to block out the surrounding words. Likewise, the same procedure was followed when participants read page 193 from The Kite Runner, except the 16mm×4mm index card was used to block surrounding words.

Data was organized and analyzed using Microsoft Excel 2007. Each participant was identified as a number for the purpose of keeping their information confidential. Data collected displayed the trends in reading speeds of each subject as the text size augmented in the order of the 3 books (S, M, and L). Data collected was also organized to expose the relationship between isolating words with an index card and the resulting reading speeds.

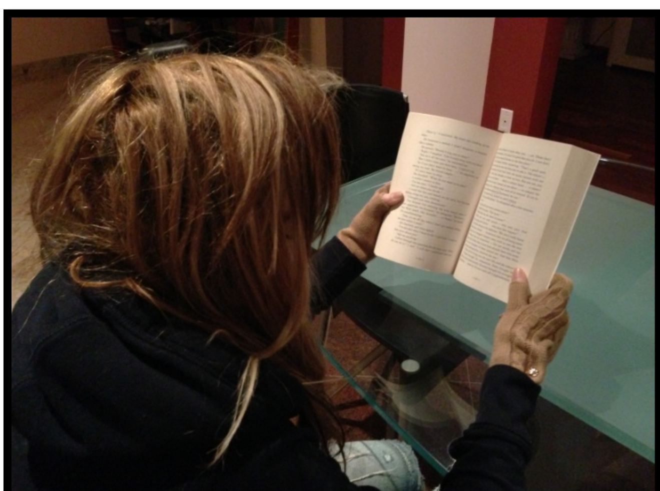

Figure 6. A Participant with AMD reading a page from a book with medium sized text without an index card isolator. (Photo Credit: K. Blidy)

Figure 7. A Participant with AMD reading a page from a book with medium sized text with an index card to isolate words. (Photo Credit: K. Blidy)

Results & Discussion

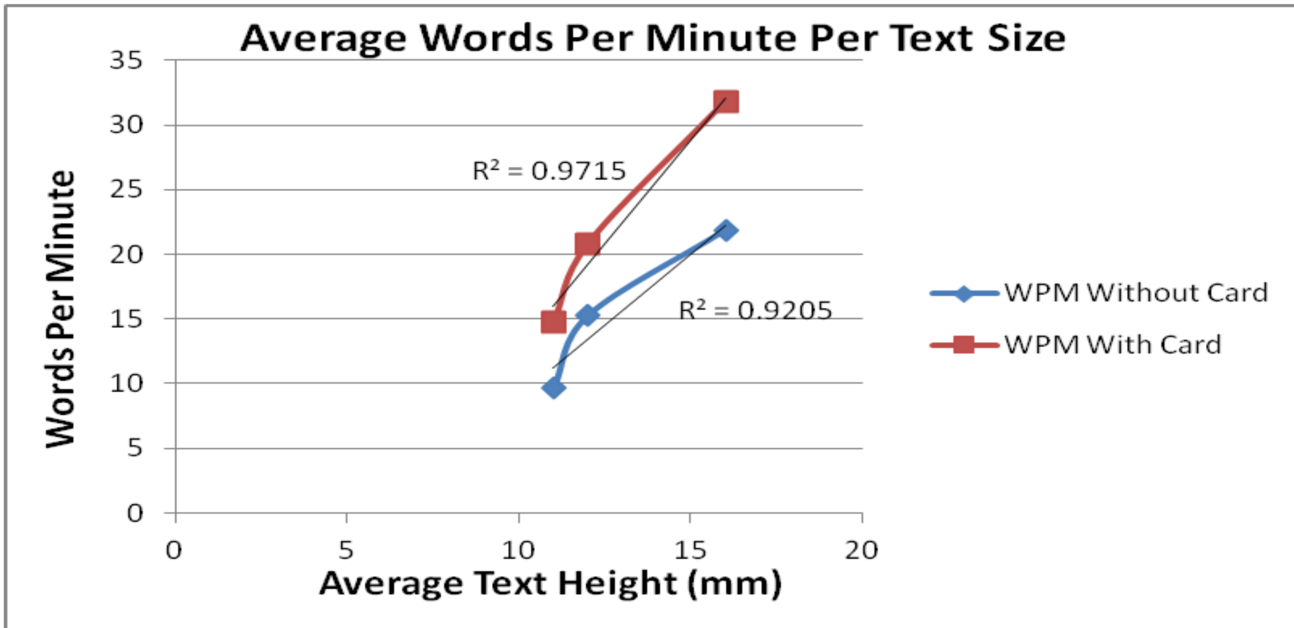

Figure 8. This graph displays the correlation between text height and words per minute for both with the card and without the card. The correlation coefficient for average text height and words per minute without the card is 0.92 and the correlation coefficient for average text height and words per minute with the card is 0.97 which means that in both cases there was a strong positive correlation between average text height on the page and words per minute.

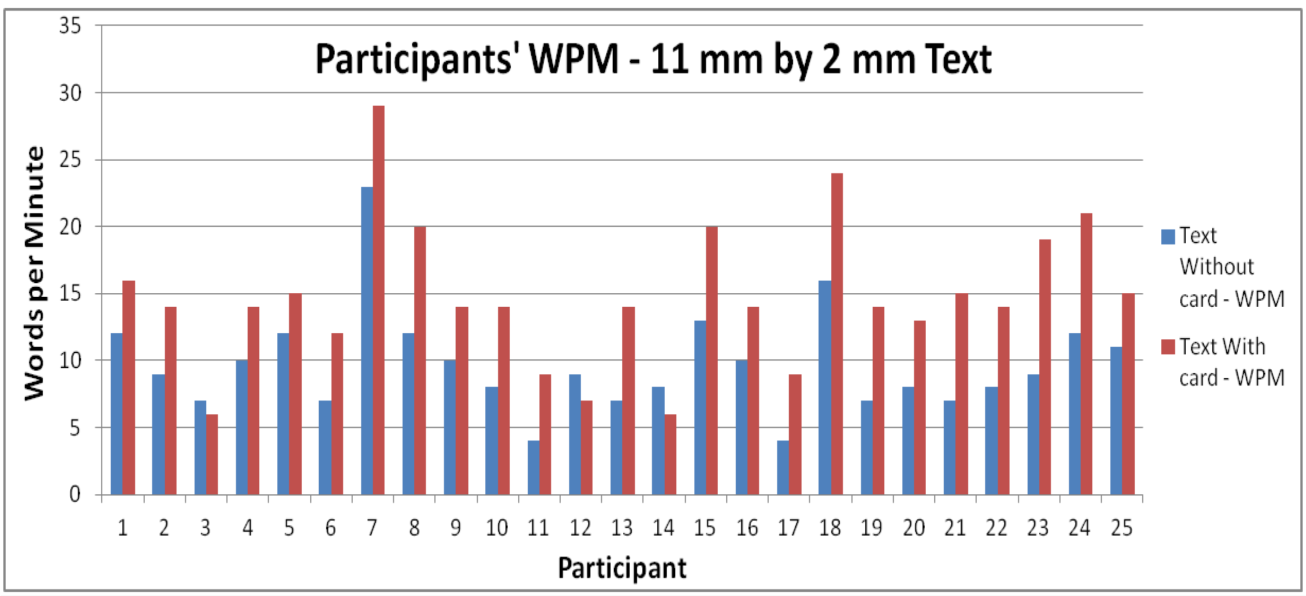

Figure 9. The Words Per Minute total for each of the 25 participants with and without the card, reading a book with small sized text with average words of 11 mm height by 2 mm length.

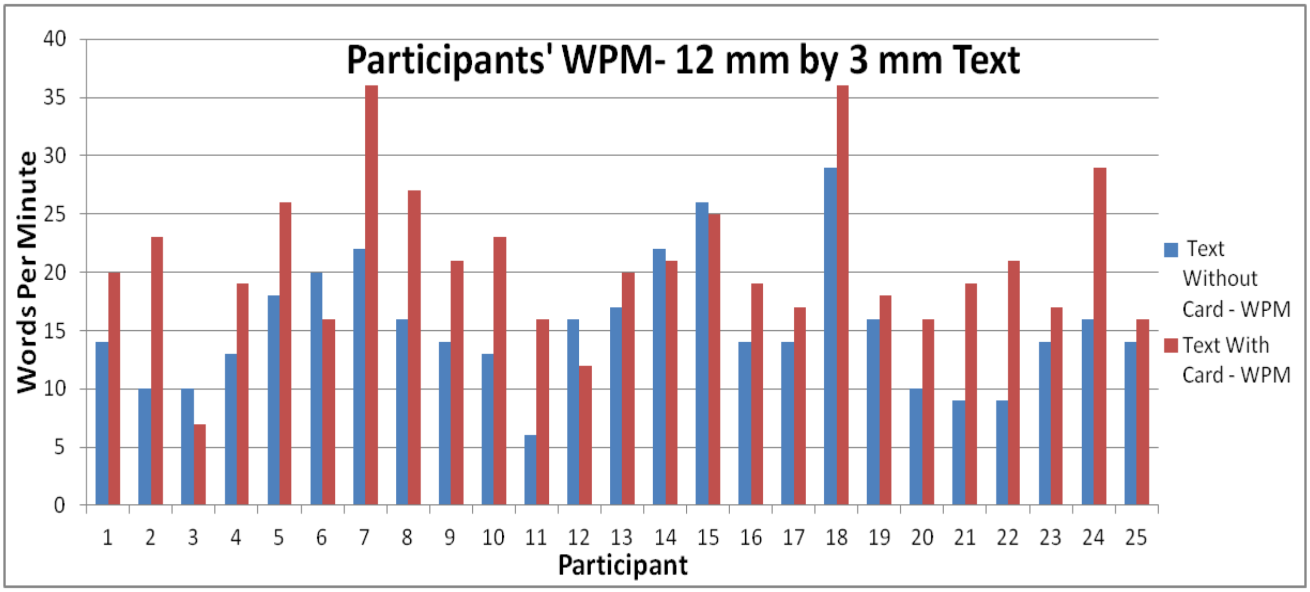

Figure 10. The Words Per Minute total for each of the 25 participants with and without the card, reading a book with medium sized text with average words of 12 mm height by 3 mm length.

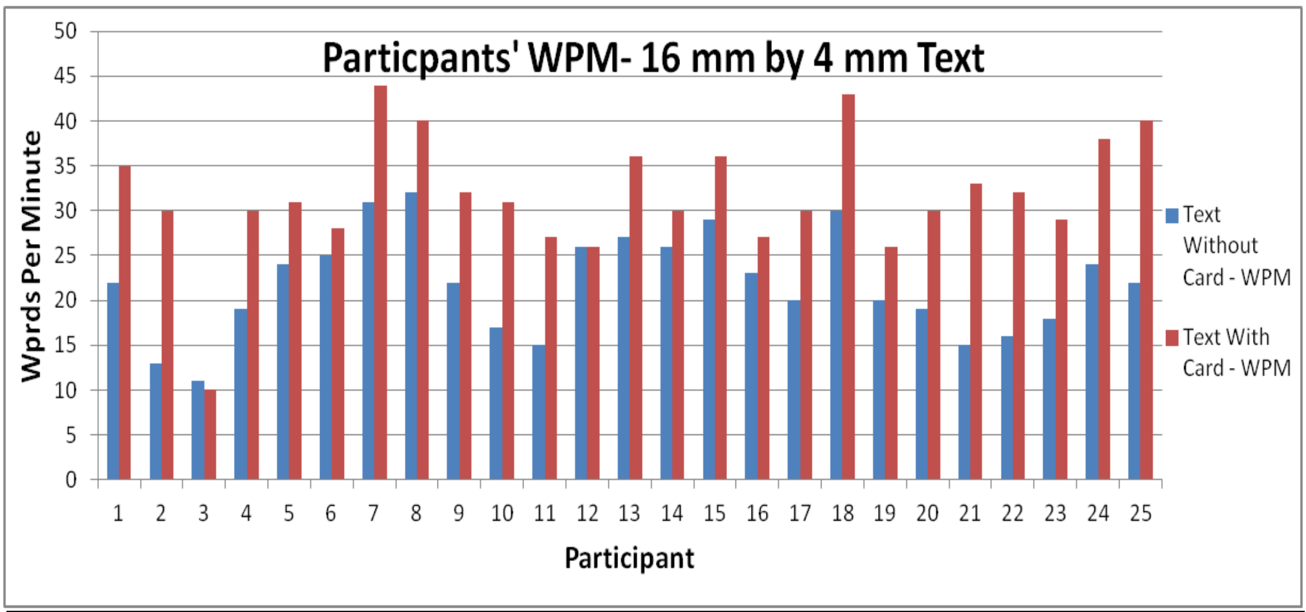

Figure 11. The Words Per Minute total for each of the 25 participants with and without the card, reading a book with large sized text with average words of 16 mm height by 4 mm length.

According to the above data, it is clear that there is a direct relationship between text size and reading speeds. More specifically, when the text size increases, the reading speeds generally increase. Although this is almost always true, there was a strange pattern in the case of the 7th subject's performance without the card. The 7th test subject seemed to have decreased reading speed by 1 wpm when text size increased from the small to medium font size. This may have happened due to the straining of the eyes from previously reading the small text. The break of 2 minutes between each reading may have been insufficient for this particular test subject.

Test subject number 18 also seemed to produce skewed results. This subject consistently read at much higher rates than the others. We speculate that this reader probably was aided by the use of glasses that he/she had to wear due to an overlapping eye condition. It is also very likely that this subject may have a less deteriorated macula than many of the other test subjects.

After the tests were finished, we calculated the percent (average) increase from reading without the card to reading with the card. The equation is as follows:

$$\frac{(S_{\text{w/card}} + M_{\text{w/card}} + L_{\text{w/ card}}) - (S_{\text{w/o card}} + M_{\text{w/o card}} + L_{\text{w/o card}})}{S_{\text{w/o card}} + M_{\text{w/o card}} + L_{\text{w/o card}}} \times 100\ \%$$

Where S is average WPM for small text size book, M is average WPM for medium text size book, and L is average WPM for large text size book.

The percent increases are a sound indicator of the extent of change there was between reading speeds exhibited with and without the use of the surrounding-word-blocking card. The results calculated are very shocking. It seems that 92% (23/25) test subjects did in fact experience stimulated reading levels with the addition of the word blocker. The results indicate that there was a great variation between how much the addition of the card helped the readers with AMD. According to table 1, the range was between -17.86% and +116.13%. For the most part, all the readers read quicker and minimized the amount of lines they skipped when transitioning from one line to the next. The total average percent change from all the readers was 46.89%.

Table 1.

Participant	Percent Increase or Decrease	Participant	Percent Increase or Decrease
1	47.92%	**14**	1.79%
2	109.00%	**15**	19.12%
3	-17.86%	**16**	27.66%
4	50.00%	**17**	17.37%
5	33.33%	**18**	37.33%
6	7.77%	**19**	34.88%
7	43.40%	**20**	59.46%
8	45.00%	**21**	116.13%
9	78.95%	**22**	103.03%
10	78.95%	**23**	58.54%
11	108.00%	**24**	69.23%
12	-11.76%	**25**	51.06%
13	37.20%		

Table 1 shows the average percent increase or degrees in WPM speed after using a surrounding-word isolator for all 25 subjects. 23/25 subjects had a positive increase and subjects 3 and 12 have a slightly lower speed after using the isolator, as indicated by a negative percent increase.

Table 2: Participants' WPM for Different Text Size without Word Isolation and With Word Isolation

Participants	Small Text 11mm×2mm (w/o card)	Small Text 11mm×2mm (with card)	Medium Text 12mm×3mm (w/o card)	Medium Text 12mm×3mm (with card)	Large Text 16mm×4mm (w/o card)	Large Text 16mm×4mm (with card)
1	12 wpm	16 wpm	14 wpm	20 wpm	22 wpm	35 wpm
2	9 wpm	14 wpm	10 wpm	23 wpm	13 wpm	30 wpm
3	7 wpm	6 wpm	10 wpm	7 wpm	11 wpm	10 wpm
4	10 wpm	14 wpm	13 wpm	19 wpm	19 wpm	30 wpm
5	12 wpm	15 wpm	18 wpm	26 wpm	24 wpm	31 wpm
6	7 wpm	12 wpm	20 wpm	16 wpm	25 wpm	28 wpm
7	23 wpm	29 wpm	22 wpm	36 wpm	31 wpm	44 wpm
8	12 wpm	20 wpm	16 wpm	27 wpm	32 wpm	40 wpm
9	10 wpm	14 wpm	14 wpm	21 wpm	22 wpm	32 wpm
10	8 wpm	14 wpm	13 wpm	23 wpm	17 wpm	31 wpm
11	4 wpm	9 wpm	6 wpm	16 wpm	15 wpm	27 wpm
12	9 wpm	7 wpm	16 wpm	12 wpm	26 wpm	26 wpm
13	7 wpm	14 wpm	17 wpm	20 wpm	27 wpm	36 wpm
14	8 wpm	6 wpm	22 wpm	21 wpm	26 wpm	30 wpm
15	13 wpm	20 wpm	26 wpm	25 wpm	29 wpm	36 wpm
16	10 wpm	14 wpm	14 wpm	19 wpm	23 wpm	27 wpm
17	4 wpm	9 wpm	14 wpm	17 wpm	20 wpm	30 wpm
18	16 wpm	24 wpm	29 wpm	36 wpm	30 wpm	43 wpm
19	7 wpm	14 wpm	16 wpm	18 wpm	20 wpm	26 wpm
20	8 wpm	13 wpm	10 wpm	16 wpm	19 wpm	30 wpm
21	7 wpm	15 wpm	9 wpm	19 wpm	15 wpm	33 wpm
22	8 wpm	14 wpm	9 wpm	21 wpm	16 wpm	32 wpm
23	9 wpm	19 wpm	14 wpm	17 wpm	18 wpm	29 wpm
24	12 wpm	21 wpm	16 wpm	29 wpm	24 wpm	38 wpm
25	11 wpm	15 wpm	14 wpm	16 wpm	22 wpm	40 wpm
Average	9.72 wpm	14.72 wpm	15.28 wpm	20.8 wpm	21.84 wpm	31.76 wpm
Standard Deviation	±3.9 wpm	±5.5 wpm	±5.5 wpm	±6.6 wpm	±5.8 wpm	±6.7 wpm

(Green) Indicates reading speed of each participant among the various text sizes in which words weren't covered with index card

(Blue) Indicates reading speed of each participant among the various text sizes in which words were isolated with index card

Table 3.

Text Size	Avg. speed without card	Avg. Speed with card
S	9.72 WPM ± 3.9 WPM	14.72 WPM ± 5.5 WPM
M	15.28 WPM ± 5.5 WPM	20.8 WPM ±6.6 WPM
L	21.84 WPM ± 5.8 WPM	31.76 WPM ± 6.7 WPM

Clearly represented by the data in Table 2, in almost all cases, word isolation improved WPM speed. The combination of blocking surrounding words and large print text proves to be the prime conditions for those with AMD.

According to the Foundation of the American Academy of Ophthalmology, 1.75 million Americans are estimated to suffer from Age-Related Macular Degeneration. Since the data seems to be so convincing that reading speeds can be altered for the people's benefit, we believe that surrounding-word blockers should manifest and be sold along with books. Moreover, we believe that the opening of the surrounding-word blocker should be magnified so that even small text sizes appear to be larger. If this were to happen, we would essentially achieve the highest possible reading speeds and thus, achieve a facilitated reading experience.

Other errors that may have skewed the data were the test subject's degree of scarring to the Macula from AMD, the test subjects having different variations of the disease (wet form vs. dry form), and the number of trials we tested. Since the Jewish Guild for the Blind only holds meetings two times a month for patients with Macular Degeneration, and many people show up infrequently, it is nearly impossible to test on a person more than one time.

Conclusions

Ultimately, it becomes explicit that when text sizes increase, reading speeds do as well. There is a positive correlation between WPM and increased text size with $R^2 = 0.92$ when subjects did not use a word isolator. There is also a positive correlation between WPM and increased text size when using a word isolator with $R^2 = 0.97$. The experiment also proves that the addition of the surrounding word blocker also increases reading speeds at an average of near 50% compared to reading without it. Both of these results validate the earlier stated hypothesis that a combination of the large text-sized book and the surrounding-word isolator would yield optimum reading speed in patients with AMD.

Future Work

In order to improve this study, we aim to minimize the source of error we encountered this time. In the future works, we will run trials more than once on each person, use a wider variety of text sizes to find out the optimum text size, test people with only the dry (or wet) variation of AMD, and perhaps test on a larger sample size.

Acknowledgements

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We also give a special thank you to all the participants of the experiment.

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