Visual Representation of Linear Letter Combination

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Abstract
Experiments have been conducted describing the analysis of rapid eye movement across different platforms whether it is looking at a monitor or television to find fixation points, reacting to physical activity, or even reading a book. Eye tracking provides the ability to study how people interact with visual objects. In this paper, we present the purpose of using word search puzzles to analyze the data from the user's eye movement and determining if they can create complete words vertically, diagonally, or horizontally. The purpose is to inform and show how the visual function of eye movements can change the direction of their axes to point to a new location in an accurate and precise manner. This is important because it involves the ability to detect saccadic eye movements. This involves a range of images consisting of word search puzzles that containing letters that have either a colored background, a different colored text, or both. Spacing differentiation is also taken into account.

Keywords: word search, recognition, text styling

Introduction
When performing a word search the subject must be able to actively scan the environment while looking for a particular object among a set of other objects. The objects the subject is searching for are referred to as targets and the surrounding objects are referred to as distractors. The method of actively scanning for targets through distractors is called Visual Search. In this experiment the words being searched are the targets and the surrounding letters are the distractors.

To test if the subject's visual search is affected we will be changing the spacing of letters in the grid and the background/foreground colors. In a study using Arabic letters and E-books, Ramadan (2011) found that participants were able to read faster and with more comprehension when presented with letters in 14 pt simplified font style with a background/foreground color of white/black. This study did not use any eye tracking software but instead used a rating system. Our experiment will be using quantitative data from an eye tracker to see if letter spacing and background/foreground color has a similar effect on visual search.

Quantitative data from the Gazepoint Eye Tracker will be obtained regarding fixation points, search path, and fixation duration. Using this data we will be able to test if letter spacing in the grid and background/foreground color has an effect on the subject's visual search performance.

Background
Previous research has shown that eye movements correlates with a proportional physical movement according to Ojanpää**,** Näsänen, and Kojo (2002). In other words, the eye movements are not random and do not stray away from the focal point that people want to focus on.

In a previous study, the increase of line spacing in the experiment conducted by Ojanpää**,** Näsänen, and Kojo (2002) allowed for increase in the number of fixations. This experiment goes to show that an increase of line spacing between or around the letters in a word search puzzle can create better results for the number of fixations per search for a word. The study also showed that participants were able to view words viewed in a horizontal list better than a vertical. Number of fixations increased linearly for the search of words in a horizontal list than vertical [1].

A study conducted by Ramadan explored a subject's preference to typeface and background/foreground color with Arabic lettering. The study conducted 3 separate experiments to evaluate the best typeface to background/foreground color combination. The first

experiment was a survey to see which typeface the student found the most preferable by calculating a score for each typeface. The experiments 2 and 3 measured reading speed and comprehension with the different typeface and background/foreground combinations. Both experiments used passages for the subject to read with layout differing in each of the experiments. This study was able to show that both typeface and background/foreground color play a role in influencing reading comprehension and speed. Because of this, we expect line spacing and background/foreground color to have significant impact on the subject's fixation, fixation duration, and search path [3].

Hypothesis

These hypotheses were developed before our experiments:

Hypothesis 1: When reading white writing on a blue background, subjects will be able to identify words in a more commable way. In other words, the participants will not have to strain their eyes to look for letters. Instead, the participants will be able to pick out the letters and words at a faster rate because the letters will stand out more compared to the other foreground or background pairs. The rate at which the participant will pick out the letters will be measured using time.

Hypothesis 2: As spatial length increases between or around the letters, the users and participants will be able to have a more steady or accurate eye movement from letter to letter. This involves all three word search puzzles containing the different colors and texts. This also will increase accuracy in determining words vertically, horizontally, and diagonally by determining and comparing the fixation points.

Hypothesis 3: When reading white text on black background, users and participants' eye movement will result in a variety of fixations. In other words, the analysis will show that the eye movements were not steady in one place, instead, the eye movements were focused on every letter in the puzzle. Analysis lines will show that the fixations or points of focus were somewhere evenly distributed across all letters causing an inefficiency in collecting data for the eye tracking analysis.

Methods

Participants

Test participants were openly invited to take part in the experiment. The investigators recruited from a pool of students at Clemson University and the surrounding area between the ages of 18 and 45. Recruitment was done through email, face to face contact, and text messages. Participants had to have normal or corrected to normal vision. The purpose of the study was hidden from participants, however, their task for the experiment was explained before they started. From the total of 15 participants, 10 of the participants' data was used in the final analysis.

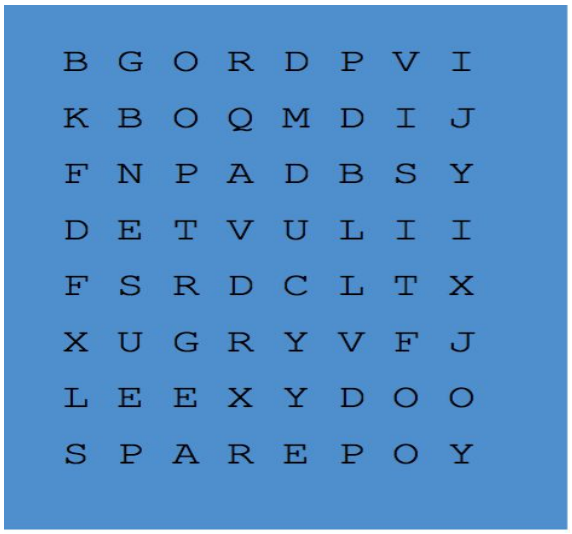

Figure 1: Stimuli black text on blue background

Stimuli

The stimuli used were a series of word search puzzles with varying properties. Each puzzle was constructed using an 8 x 8 grid as shown in Figure 1. Two words of the same length, five letters each, were added to each of the puzzles for the participants to find. Each letter had a font of 48 with the font type being Courier New. The words were randomly placed within the puzzles in order to avoid the participants from identifying a pattern that would help them solve the puzzles quicker. Three combinations of foreground/ background colors were used: white text on blue background, white text on black background, and black text on blue background. Each of these variations had a puzzle with no spacing between letters and one with spacing between letters. The color/spacing variations were created using Microsoft Word. The puzzles were generated using an online website by the Discovery Education [2]

Experimental Design

A 3 x 2 mixed factorial design was used in the study. Within subjects and between subject variables were used.Within subjects variables will be considered as the number of puzzles used. Between subjects variables will be considered as the different spacing used in the word search puzzles. The difference in spacing can be

seen in Figures 2 and 3. They are the same puzzle with differing spaces. All subjects were shown the same three word search puzzles. The three color schemes were observed by each participant. The spacing, however, was what made the study between participants. One group viewed the three puzzles with normal spacing while the other half viewed the puzzles with 1.5x the spacing between letters. In order to counterbalance the experiment, a form of the latin square design was used. The order in which the puzzles appeared to the participant was rotated one position after each experiment.

Apparatus

Participants interacted with the word search puzzles through the Gazepoint software. The puzzles were in picture format. A Dell 22" monitor with a (1920 x 1080) resolution was used. Participants were sat about 24 inches from the monitor. The GazePoint eye-tracker was mounted under the display to pick up eye movement and pupil diameter. The sampling rate is 60Hz with a latency of 16ms and an accuracy of 0.5-1.0 degrees.

Procedure

Participants were sat down in front of a monitor and given the informational letter describing the legal information, benefits, and risks. Participants were asked to answer a pre-experiment questionnaire to gauge whether the participant met the criteria to accurately perform the experiment. After answering, they were led through the five point calibration built into the Gazepoint software. The general idea of the experiment was explained but the purpose and details of the study were not told to the participant. They were told they would complete three word search puzzles while holding as still as possible to avoid corrupting the eye-tracking data. They were also told that they would look for exactly two words in each word search puzzle. Each word was read out loud to the participant. After identifying a word, the participant was supposed to gesture with a finger the start and end of the word found. The investigators knew the location of each word and were observing to ensure the participant was finding all words. After a puzzle was completed, a mouse was used to click to the next puzzle. After the experiment, a post questionnaire survey was completed to gather demographic information and to find which puzzle the participant found was the easiest to complete. The post questionnaire survey included questions about the participants demographic. It also included questions about the frequency the participant plays word puzzle games, the level of difficulty finding word combinations, and the level of difficulty of reading the letters. These questions were measured on a level from very difficult, difficult, quite difficult, neither, quite easy, easy, and very easy. The questionnaire also included a final multiple choice question asking which text color to background color combination was the easiest on their eyes. Participant personal information was not collected. Their names were replaced with ID numbers. They were then informed further of the actual purpose of the word search and any questions they had regarding the study were answered.

Results

In order to begin testing our hypotheses, we extracted data from the participants in each subgroup. This meaning, we extracted and analyzed data from the five participants who took the experiment with the word puzzles containing letters with no space and the five participants who had the word puzzles containing spaced letters.

	Spaced (seconds)	Non-spaced (seconds)
White / Blue	27.1	20.7
Black / Blue	26.7	27.2
White / Black	24.1	22.1
Total Average	74.6	70.6

Table 1: Average times per puzzle and total time

Various metrics were used to gather information from the study including time to first fixation, time to completion per color combination, and easiest color to read. We found that the word search puzzles that did not have spacing gave the more accurate and precise fixation points. Table 1 shows non-spaced puzzles were completed quicker. This was so because the participants did not have more area to look for letters. In other words, since the spacing of the puzzle change; this increased the amount of area of the puzzle. Allowing for the participant to have to look for a longer period of time around the puzzle to find the letters that they needed. Using Figure 4, we found that fixation points were either touching the AOI's (Area of Interest) or very near them. The spaced puzzles took on average 4 seconds longer to solve than the non spaced. In Figure 4 and Figure 5 we show the fixation map for both the non spaced and spaced puzzles respectively. Both puzzles feature 5 letter words and have identical sized AOI's, as seen in Figures 2 and 3.

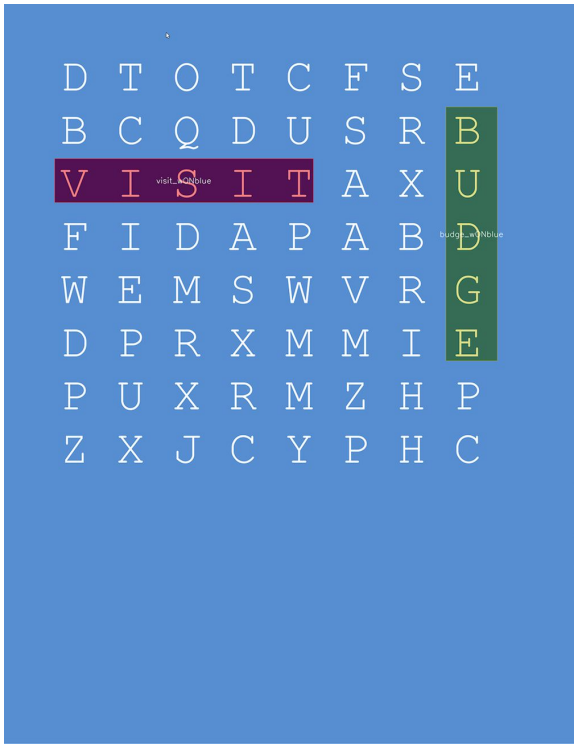

Figure 2: Non-spaced puzzle with white text and blue background

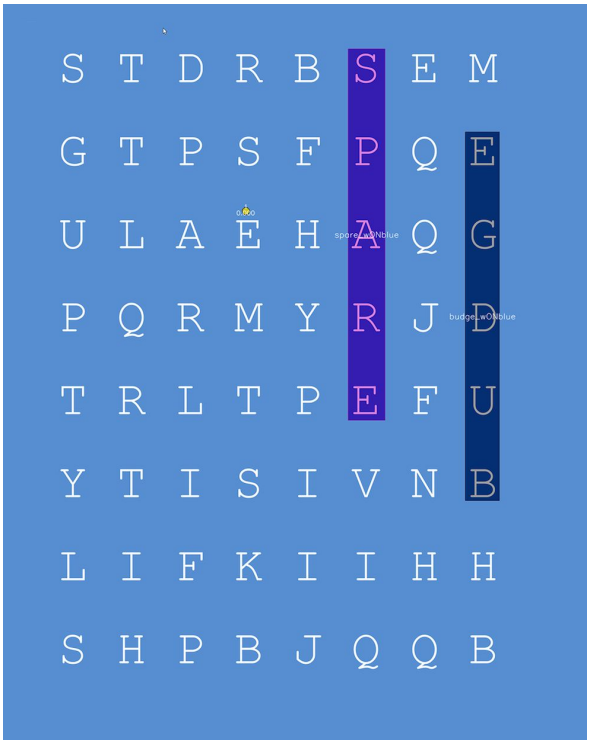

Figure 3: Spaced puzzle with white text and blue background

In Figure 4, the non spaced puzzle, the fixation count was at 28 fixations and was correlated closer to the AOI's. In Figure 5, the spaced puzzle, the fixation count was more than double the non spaced puzzle with 51 fixations. The fixations in the spaced puzzle where more sporadic and less correlated near the AOI's.

We provided the participants with a post-questionnaire containing multiple questions one of which asked, "Which textcolor and background was easiest on your eyes"? As told to the participants, the question means to ask the question of which textcolor and background allowed the participant to find the words and letters at a faster rate than the other word search puzzles containing the other text and background combinations. According to the post-questionnaire that we provided to the participants, 60% of the participants answered "White text on blue background". The fixation points were very close to the words that the user needed to find according to Figure 4. We averaged up the times that the participants took for all ten puzzles. As seen in the data of Table 1, we found that the word search puzzle with the lowest average time was the puzzle that had the white text with blue background with an average time of 20.7 seconds. This was the lowest average time with the second lowest being 1.4 seconds slower and it being the puzzle that had the white text and black background.

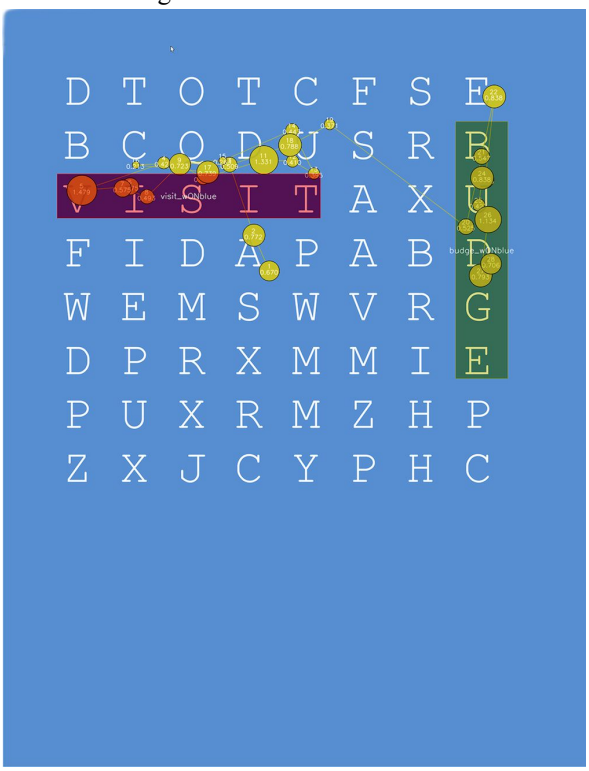

Figure 4: Non-spaced puzzle with white text on blue background with the mapping of fixation points.

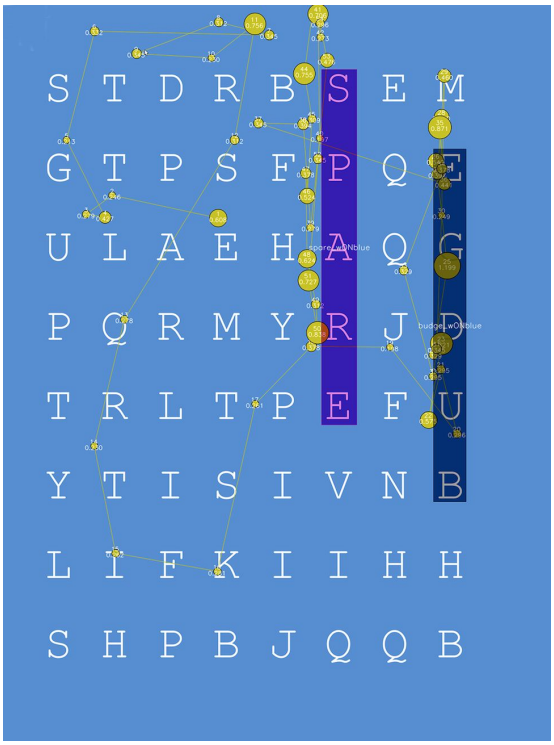

Figure 5: Spaced puzzle with white text on blue background with the mapping of fixation points.

Discussion/Conclusion

Word searches are a common activity that many people have enjoyed since their childhood. When doing a word search we don't realize the intense environmental scanning our eyes have to do to successfully complete a simple puzzle. Our goal with this study was to perform a simple experiment to see if changing the environment of the puzzle would affect the participant's ability to solve it. Our experiment was ran on a small sample size of 15 participants, 10 of each which's data was used for the final analysis. The experiment was split into two groups with 5 participants given a set of spaced puzzles and the other 5 participants given a set of non spaced puzzles.

The environment of the puzzle was changed in two ways. A participant was given a set of puzzles with narrow spacing or a set of puzzles with wider spacing. Of those two sets there were three puzzles with varying text color and background color. The three color combinations included were White Text on Blue Background, White Text on Black Background, and Black Text on Blue Background. Of the three samples, the colors with greater text/background contrast had better results. White on blue background did about as well in terms of time to complete as white on black. Black on blue however did significantly worse than the other two, by an average of five seconds. Further studies could determine if color plays a role more than purely contrast.

The spacing in letters affected participants since fixations were spread out around AOIs more in the spaced puzzles. Peripheral vision was worse on the spaced puzzles so participants had more saccadic movement. Based on the questionnaire participants determined White on Blue background was the preferred colors. This confirms our hypothesis. White on blue background was also on average quicker to complete than the others, though not by much compared to white on black background. Due to the increased fixations in the spaced puzzles and fixations spread farther around the AOIs we were not able to prove our second hypothesis that participants would have steadier and more accurate eye movements with the spaced puzzles.

References

1. Helena Ojanpää, Risto Näsänen, Ilpo Kojo, Eye movements in the visual search of word lists, Vision Research, Volume 42, Issue 12, June 2002, Pages 1499-1512, ISSN 0042-6989, http://dx.doi.org/10.1016/S0042-6989(02)00077-9. (http://www.sciencedirect.com/science/article/pii/S0042698902000779)

2. "Make Your Own Word Search with Discovery Education's Puzzlemaker!" *Make Your Own Word Search with Discovery Education's Puzzlemaker!* N.p., n.d. Web. 29 Sept. 2016. http://puzzlemaker.discoveryeducation.com/WordSearchSetupForm.asp.

3. Mohamed Zaki Ramadan, Evaluating college students' performance of Arabic typeface style, font size, page layout and foreground/background color combinations of e-book materials, Journal of King Saud University - Engineering Sciences, Volume 23, Issue 2, June 2011, Pages 89-100, ISSN 1018-3639, http://dx.doi.org/10.1016/j.jksues.2011.03.005. (http://www.sciencedirect.com/science/article/pii/S1018363911000298)

4. Paul P. Maglio and Christopher S. Campbell. 2000. Tradeoffs in displaying peripheral information. In Proceedings of the SIGCHI conference on Human Factors in Computing Systems (CHI '00). ACM, New York, NY, USA, 241-248.

5.Yarbus, A. L. Eye Movements and Vision. Plenum Press, New York, NY (1967).

6. Cutrell, E., Guan, Z. What Are You Looking For? An Eye-tracking Study of Information Usage in Web Search. In Proc. CHI 2007, 2007, 407-416

7. Ann McNamara, Reynold Bailey, and Cindy Grimm. 2009. Search task performance using subtle gaze direction with the presence of distractions. ACM Transactions on Applied Perception. 6, 3, Article 17 (September 2009), 19 pages.