# Analysis of Words Per Minute Correlated to Fixation Length While Searching

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## ABSTRACT

Previous studies have shown that average fixation duration is different depending on what task a person is performing. Our goal was to find out whether or not one's reading speed would affect their average fixation duration during a visual search. We collected data on 11 different participants, first measuring reading speed, measured in words per minute (wpm), by having them read a sample passage, then putting them through three different visual search tasks ranging from easy to very difficult to find the target. We hypothesized that faster readers would have shorter average fixation length, due to their ability and practice gathering information quickly during reading. Results do not support this hypothesis, however, as there seems to be no correlation between reading speed and fixation length at all. Based on this, we can conclude that people process information gathered by their eyes very differently depending on the source and goal of their task.

## KEYWORDS

Eye Tracking, Fixation Length, Picture Search

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## 1 INTRODUCTION

Reading is something people do on a day-to-day basis, whether it be road signs, books, articles, or anything in between. Different people have different reading speeds. Some can read large quantities of data very quickly, and some take more time to process and think about each word they read. This seems very closely related to visual searching, which is something else people constantly do. This refers to scanning anything and everything to gather information about our surroundings or a particular piece of media.

After hearing about studies where participants were tested on reading speed and fixation duration, we wanted to see if those statistics would have any impact on fixation duration during a visual search. Average fixation duration, or how long our eyes dwell on a single area, seems to be something that is different from person to person and even different depending on what a person is currently looking at. One's fixation time may be longer if he/she is trying to carefully scan through something and not miss any information, while it may be shorter if someone is "skimming" through an article or document to get a general idea of what is going on.

Our group aims to use a reading speed test to gather average fixation duration for a participant, then see if that information is helpful in determining how fast that person will complete a visual search, and if their average fixation duration is similarly faster or slower during the search as it was in reading.

### 1.1 Background

Our experiment was originally inspired by a host of research papers. First, Visual Memory Augmentation: Using Eye Gaze as an Attention Filter [1] sparked the idea of using a Where's Waldo picture search as stimuli. In the experiment conducted, they used eye tracking to augment memory for a visual search. The experimenter developed an application that would display "burn marks" where the subject fixated for a significant period of time. Their hypothesis that darkening the area that the subject already searched thoroughly would make it safe to rule out unsupported data. However, since their study concluded that a Where's Waldo picture search can yield viable data, our research team decided to implement Where's Waldo as our stimuli.

While exploring for a paper on fixation length of searching, we stumbled across a study that measured perceptual span or region of effective vision during eye fixations in reading. Eye movements, the perceptual span, and reading speed [5] concluded that reading speed in words per minute has an impact on perceptual span and fixation. With both the resources of Where's Waldo and reading speed, we wanted to test if the words per minute of a subject's reading speed is correlated with their fixation length while completing a visual search. In an earlier paper, Rayner discussed differences


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in eye movements during several different tasks, including reading silently, orally, and visual search [5]. This study showed that fixation duration during visual search is longer, on average, that during reading.

Lastly, a paper that we found very useful in generating our ideas correlating to fixations was Discerning Ambient/Focal Attention with Coefficient K [2]. In this paper, Duchowski introduces the K coefficient. K is measured by using fixation durations, which is what we heavily use in our experiment, and saccade amplitudes which are then translated into a z-score. Although our paper does not measure saccade amplitudes, this paper inspired us to use fixation durations and use a part of this measure to translate our data into a z-score and then focus our attention on the p value.

$$K_i = \frac{d_i - \mu_d}{\sigma_d} - \frac{a_{i+1} - \mu_a}{\sigma_a} \text{ such that } K = \frac{i}{n}\sum_{n} K_i$$

The equation above illustrates the formula used to calculate the K coefficient. Mu d and Mu a are the mean fixation duration and saccade amplitude and sigma d, sigma a are the fixation duration and saccade amplitude standard deviations.

In the paper, Duchowski conducted two studies. The one we focused particular attention on was the one that was used to validate the K coefficient using visual search. They concluded that during the search, according to Nothdurft [3], the focus of attention always moves to the target both in serial and parallel searches. We kept this in mind throughout our experiment and decided that before each stimulus was presented, we would present the participant with a black dot in the middle of the screen to shift his/her focus of attention back to the center of the screen before his/her new visual search began.

### 1.2 Hypothesis

The purpose of this experiment is to see how reading speed is correlated to fixation length while performing a visual search. We hypothesize that faster reading speeds will correlate to faster fixations and overall shorter visual search completion times.

Our hypothesis derives from the assumption that the patterns from gathering visual information will be similar in reading and visual searching. The faster the person reads the quicker fixations therefore allowing the subject to search and process the stimulus more efficiently with quicker fixations.

## 2 METHODOLOGY

### 2.1 Experimental Design

The type of experimental design used in the investigation was a within-subjects design. Participants were given a "Where's Waldo?" image and asked to locate Waldo in an unlimited time frame with the GazePoint software tracking the time it takes to find Waldo. Once the participant finds Waldo, he/she will indicate he/she has found him with the mouse pointer and then be introduced to a blank image to restart the process all over again. This will then be repeated for the next two images. Each participant will look at the stimulus in random order for unbiased purposes and to reduce fatigue. The independent variable / the fixed factor is the words per minute of the participant. The dependent variable is the fixation speed and time being searched for Waldo. The words per minute

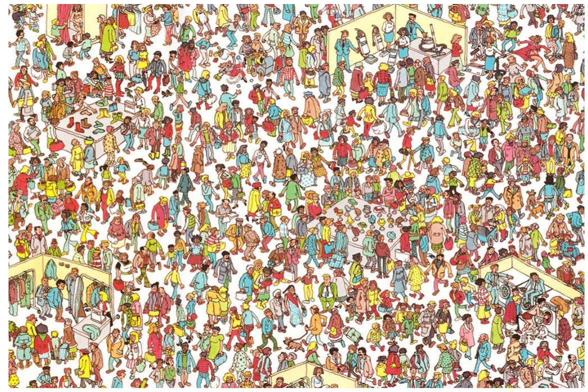

**Figure 1: Fairly easy Where's Waldo Search.**

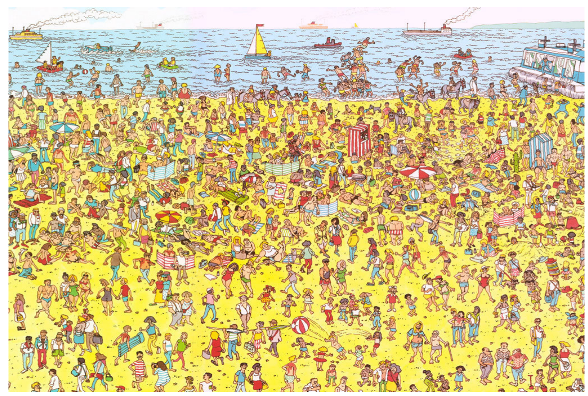

**Figure 2: Moderately difficult Where?s Waldo search.**

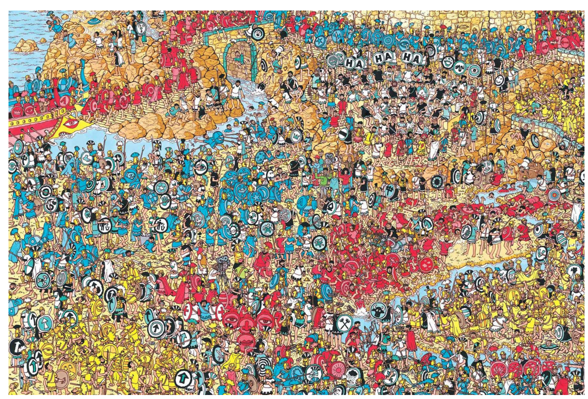

**Figure 3: More difficult Where?s Waldo search.**

variable in the experiment will indicate that there is a change in how quickly the participant finds Waldo. The GazePoint software will track the length of time each participant takes to find Waldo.

### 2.2 Stimulus

The main stimuli of the experiment is the three "Where's Waldo?" images with Waldo hidden within the busy image.

To begin, the participant will be directed to look at an image with a dot in the center in order to have the participant's focus before going on to the next step. Once Waldo is found within the busy image, the participant will be asked to focus on another image with a dot to regain his/her focus before going on to the next image. This process will then be repeated for the last image. In order to rule out the participant lying about finding Waldo, the experimenters will ask the participant to indicate if he/she has found Waldo with their mouse pointer to where he is located.

## 2.3 Apparatus

The monitor used for the eye tracking experiment is a Dell P2213 22" LED LCD monitor with a resolution of 1680 x 1050. Eye movements are tracked by using the GP3 Desktop Eye-Tracker created by the company GazePoint. The sampling rate of the participant's eyes is 60Hz and has a visual angle accuracy of 0.5-1 degrees. The GP3 tracks participants eye movements, fixations, and the amount of distance between the participant's eyes and the screen.

## 2.4 Procedure

For the procedure, participants were first introduced to the experimenters in an environment-friendly computer laboratory surrounded with eye trackers. The participants were then asked to be seated near one of the monitors with the eye tracker. Participants were given an informational letter containing an accurate account of what the experiment is about, such as the risks involved in the experiment, the potential benefits, protection of the participants confidentiality, the experimenters' contact information, and lastly letting the participant know that this is a voluntary participation and he/she is welcome to opt out of the study. Once the participant gave consent, the experimenter provided clear and accurate instructions on what to do in a verbal manner. First, the participant was asked questions regarding demographics such as age, gender, and occupation. Then the participant conducted a words per minute speed test by using an online application that makes him read multiple paragraphs timed and eventually calculates a WPM. The participant was asked to give a sentence summary to make sure he/she truly read the paragraph, as well as to prevent false data. Then the participant began by fixating on the targets given on the screen to first calibrate the GazePoint software. Next, the participant was presented with a blank image and a dot and then the screen was switched to the test stimuli and instructed to find Waldo. The participant was timed on how long it took him/her to find Waldo during each stimulus. Once he was found, the participant notified us and moved the mouse to Waldo so the experimenter knew he had been found. After the first stimuli, the experimenter presented the participant with the blank image again. Then, the second stimuli was shown until the participant found Waldo. This process was completed once again with the last stimuli.

## 2.5 Participants

The study consisted of 11 participants. The participants were undergraduate students from Clemson University and ranged from people with perfect vision to people with corrected vision. The age range of the participants was 18-27, including 5 males and 6 females.

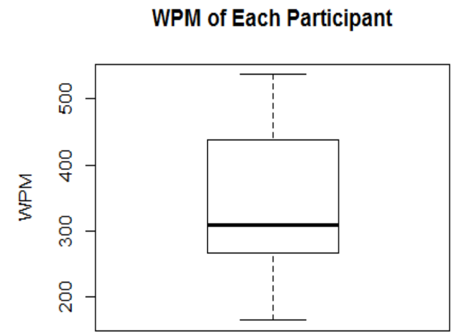


**Figure 4: A boxplot of the WPM for all participants.**

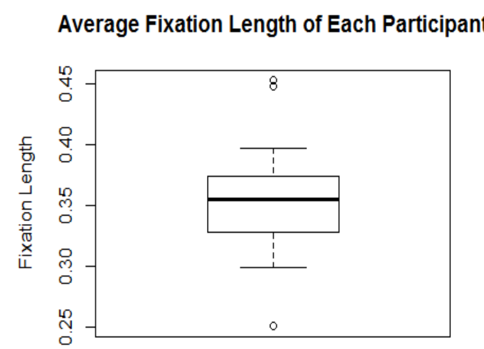


**Figure 5: A boxplot of the Average Fixation Length for all participants.**

## 3 RESULTS

As stated in our hypothesis, we predicted that there would be a correlation between a user's WPM and the fixation lengths during a picture search. The experiment was conducted on 11 participants, and each of them were presented with a reading test as well as three Where's Waldo stimuli. Words Per Minute were manually recorded in an excel sheet and the fixation length was recorded in Gazepoint. The data was taken and collated, then processed through R in order to get a statistical analysis.

First, we had each participant complete the reading test that calculated WPM. In figure 4, the WPM is shown for all participants. Next, we found each of the participant's Fixation Point of Gaze Duration (FPOGD), which showed the length of each of the different fixations a user had during a trial. In figure 5, the average fixation length for each user is shown. Using this data, the statistics were calculated to determine if a correlation could be found between the

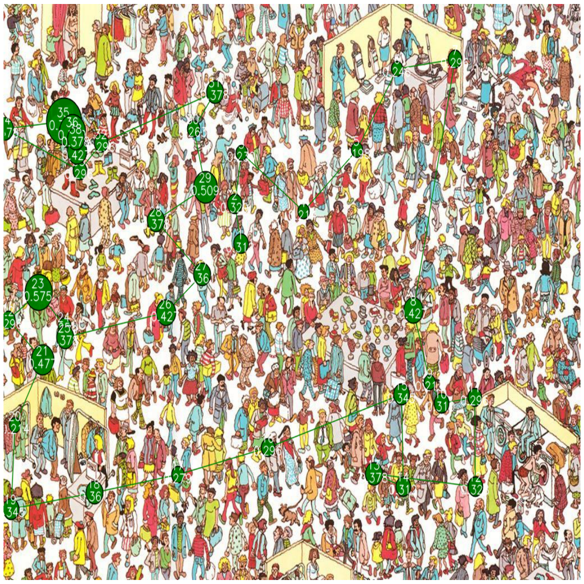

**Figure 6: Fairly easy Where's Waldo Search with a fixation map example overlaid.**

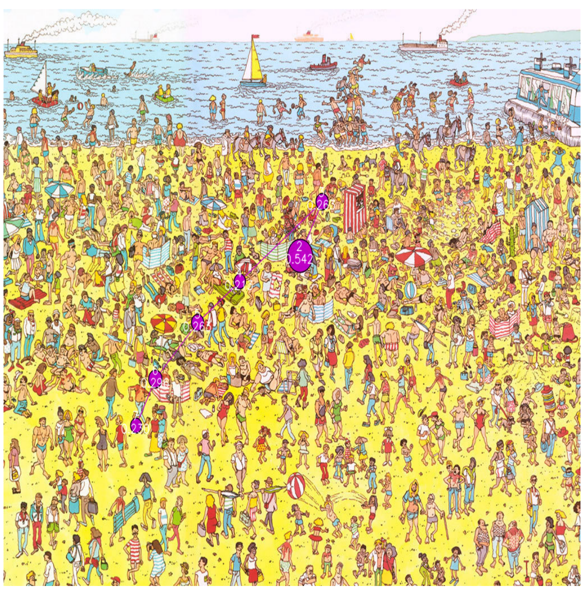

**Figure 7: Moderately difficult Where?s Waldo search with a fixation map example overlaid.**

measurements. The data was processed in R, and we discovered our p-value of 0.8058 and a correlation of 0.0444.

Each of the participants was presented with three stimuli of different difficulty for the Where's Waldo picture searching segment of the experiment. The main differences in the data regarding difficulty levels were that the more difficult the stimulus, the more total fixations by the participant. This showed that the time it took to find Waldo increased as the difficulty increased. Even though

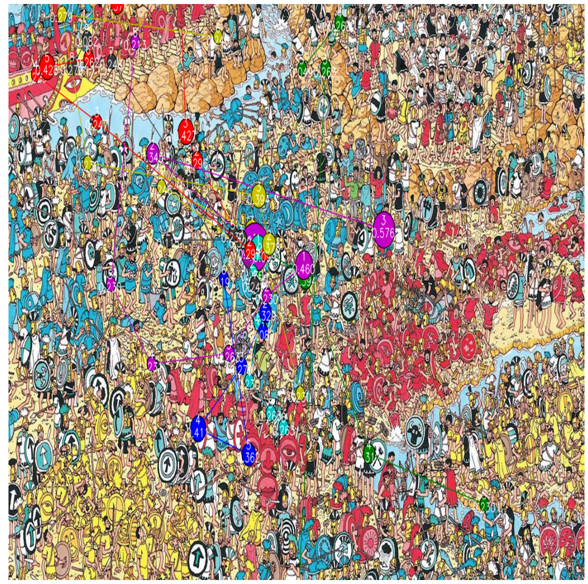

**Figure 8: More difficult Where?s Waldo search with a fixation map example overlaid.**

the amount of fixations increased, the length of fixations stayed generally the same. For the Easy stimulus, the average number of fixations for the participants was 38, for Medium 100, and for Hard 146. This helped us justify that each of the stimuli was labeled with the correct level of difficulty. From these results, we concluded that our hypothesis was not able to be proven.

## 4 DISCUSSION

Based on the results stated above, we saw that there was no correlation between words per minute and fixation length of participants. Our p-value was much greater than 0.05, with a value of 0.8058, showing that there was not enough evidence to support our hypothesis. This means that we have to accept the null hypothesis stating that there is no correlation between WPM and fixation lengths. In the scatterplot shown below in figure 9, there is no visible positive or negative correlation. The data is scattered everywhere, so no relationship can be established. In addition to that, our correlation value of a 0.0444 also told us that there could not be correlation between WPM and fixation length.

### 4.1 Further Research

If we were to take this experiment to the next phase, there would need to be some changes. First of all, there would definitely need to be a significant increase in our study size. In our data, there were many instances of outliers that could have significantly affected our data since our study size was so small. Also, we would need to create our own stimuli so that images could be created specifically for this experiment. This way we could manipulate the images in order to create clearer results. This would allow us to also manipulate the levels of difficulty of each of the stimuli.

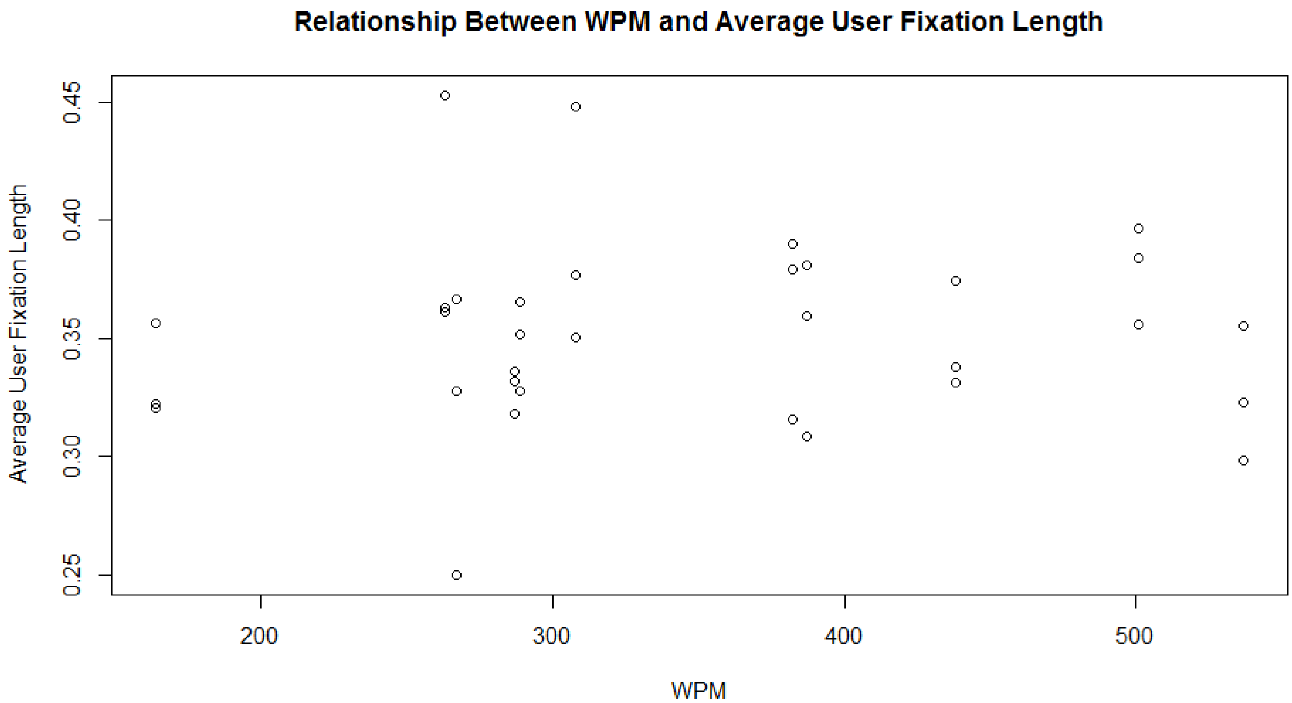


**Figure 9: A scatter plot of the (lack of) correlation between WPM and average fixation length of participants.**

## 5 CONCLUSION

Learning about the correlation between reading speed and fixation duration during visual search could have many implications regarding the importance of improving one?s ability to gather information quickly. If the results of this study showed that reading speed was directly correlated to visual search fixations, we could reasonably conclude that improving one's reading abilities would have impacts on other types of information gathering. While improving one's ability to read quickly will be beneficial in the long run, especially to students and researchers that must read lots of information on a regular basis, this shows that it won't necessarily benefit them in gathering information from other sources.

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