Analysis of Gaze on Word Search Puzzles

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ABSTRACT

Eye tracking experiments have been performed in attempts to capture eye movement patterns in a variety of different settings. Eyes tend to be drawn to certain objects and can be influenced by stimuli to focus more in a certain area as opposed to others. This study investigated if distractions similar to what the eye is searching for can create an increase in the amount of time taken to find the target. In order to test that, we used eye-tracker technology to record eye movements of a group of 13 participants (9 males and 4 females) when presented with stimulus that is distraction-free and with distractions present. Our experiment examined the speed at which a participant could find a target word in a word search puzzle based on if that word was the only valid word or there were additional valid words. We hypothesized that additional words would decrease participants search times. Based on the data collected, we were able to use key statistics such as amount of fixations and duration of fixation to determine that participants are able to more quickly find a target word in a word search puzzle if other valid words are present. Thus, disproving our hypothesis.

KEYWORDS

Gazing, Word Search, Eye Tracking, Distraction

1 INTRODUCTION

When a subject performs a word search, their eyes are constantly scanning a jumbled, unorganized environment for a specific object. In this environment this is a goal target and many distractors to the eye, these can be in the form of standalone letters or in non-goal words. This experiment labels one word as a goal word and all others as distractions.

To test to see if a subject is able to find a goal word quicker without distractions we introduced distraction words to one of the stimulus to analyze the difference. Valid words may be found quickly due to the “pop-out” effect which describes how a unique object that differs by an observable feature tends to pop-out in a visual display [7].

In this experiment a Gazepoint Eye Tracker was used to obtain quantitative data on fixation points and fixation duration. This data will allow us to determine the effects of distractions on a participants search time.

2 BACKGROUND

Word search puzzles rely on the concept of crowding, as described by Dennis Levi[6] and John Henderson[5]. This is the observation that it is more difficult to find a visual target if it is surrounded by other distraction objects. The effect is amplified if the distance between the objects crowding the target is equal and by how similar the distractor objects are to the target[6]. For instance, Henderson designed an experiment where participants were asked to find letters superimposed onto a picture of the real world. They determined that it is significantly more difficult to find words in more cluttered locations. Especially if the objects cluttering the location were very similar to each other[5]. Word search puzzles are designed to take advantage of this effect by cluttering words with fields of letters. Additionally, word search puzzles are designed so that all the letters are evenly spaced and evenly sized to increase difficulty due to crowding.

It stands to reason that this effect can also be extended to show that it is more difficult to find a word when it is crowded by other valid words compared to when one valid word is crowded by random gibberish.

The even spacing and size of letters across the word search allows us to be sure that participants eyes are not drawn to one particular location within the puzzle. This is because our eyes are drawn to locations of high contrast and edge density[1]. Because our puzzle has an even level of edge density and contrast across the puzzle, due to all English letters having similar edge densities and our letters all being black on white backgrounds, no particular location should draw the participants gaze.

Another study ran by Ojanpää, Näsänen, and Kojo[3] found that the speed with which participants can find words in a list of words is directly related to how many words they can process in one fixation. They found that when the letters in words are arranged vertically in a list, participants could find target words faster than when the letters in words were arranged horizontally. It is a fact that the human eye’s field of view is wider than it is tall. Because of this fact, it makes sense that vertical words search faster due to the participants being able to fit more words into a single fixation when the words are arranged vertically than horizontally.

This information leads us to believe that the number of fixations required to complete a word search puzzle is related to the time it takes to complete the puzzle. So, it stands to reason that the more valid words there are in a word search puzzle, the more fixation

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s r z o a u i p y m e b t w k d v q l x j h g f n c
b m i f y t o k d s u h a n l x p z g c v r e j w q
r x e v m q l f j i z c s t g b n w k p d y u a o h
g j a c v f t i u w k m d s x z r p n b y o h e q l
c p r u q e m v h t s j i x b n w y d k z a l g f o
u d c g k w q o v b p t l h r e i a m n f s y x j z
d b m q g c s t a h j r w u n v k e x i o l z p y f
t k g b j l n q f p c a u i o r m x w y h d s v z e
a c p m t k d r n q b x h z y o g s e l u w f i v j
y g j l c d p w z v f q k r t m x h o u s e b n a i
i h b d l a c j m x o p z g w y u n r v k f t q e s
m f l n b j w x e o a y q k d p z u i s c v r h g t
e z d i o x b c k a l v p m h u q f y j r g n s t w
q l h p d m r b o n x e g y s i f k t a w u j z c v
j a o e h n u l c r m f b p q k s t v w g z x y i d
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Figure 1: Stimuli control crossword puzzle with only the word "house".

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c n f g h j x l q v d k w t b e m y h a p p y z r s
q w j e r v c g z p x l n a h u s d k o t y f i m b
h o a u y d p k w n b g t s c z i j f l q m v e x r
l q e h o y b n p r z x s d m k w u i t f v c h j g
o f g l a z k d y w n b x c a t c h v m e q u o p c
z j x y s f n m a i e r h l t p b v o q w k g u d u
f y p z l o i x e k v n u w r j h a t s c g q s b d
e z v s d h y w x m r o i u a c p f q n l j b e k t
j v i f w u l e s g o y z h x b q r r d k t m p c a
i a n b e s u o b x m t r k q f v u w p d c l j g l
s e q t f k v r e u y w g z p o x i j c a l d b h o
t g h r v c s i a z p d k q y a o t x w j b n l f d
w t s n g r j y c q u h m p v l a k c b x o i d z g
v c z j u w a t h f i s y g e x n o b r m d p h l e
d i y x z g w v t s k q p b f m r c l u n h e o a j
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Figure 2: Stimuli crossword puzzle with the word "house" as well as five other distraction words.

points will be found. Therefore, the longer it will take to complete the puzzle.

Furthermore due to this fact, when comparing search times based on number of words in the word search puzzles, it is most likely best to ensure the target words are oriented the same way (either horizontally or vertically). This way, confounding variables due to words placed in certain orientations being easier to find is avoided.

Finally, Kirsten Cater[2] discusses that the fovea of the eye, that is the area of highest visual acuity, is only about two degrees or the area of about eight letters on a standard page. Or, the area of your vision your thumbnail takes up at arms length. So, words that use letters of the same size with similar lengths should take roughly the same time to process by the eye since they will take the same number of fixations to resolve. This also means that keeping a relatively wide buffer between letters in the word search puzzle, and therefore words in the, should reduce the participant's ability to process multiple words or characters within the same fixation.

3 HYPOTHESIS

When the participant is viewing the control stimulus they will find the desired word quicker due to "pop-out" effect [7], whereas the distraction filled stimulus would not be influenced by this effect and would take longer for the participant to complete. In this experiment the null hypothesis is that âĂIJpop-outâĂİ effect will not have any influence on how long the participant takes to find the target word.

4 METHODS

4.1 Participants

For this study participants were selected from a pool of Clemson University students and members of the surrounding community between the ages of 18 and 45. Volunteers were contacted through email, class announcements, and face-to-face interaction. Participants were only selected if they have normal or corrected to normal vision. We planned to recruit 15 participants to the study but ended up with 13 (9 male and 4 female) by the end of the study. While the purpose of this experiment was hidden from the participants, the task that they were expected to perform was explained prior to the experiment start.

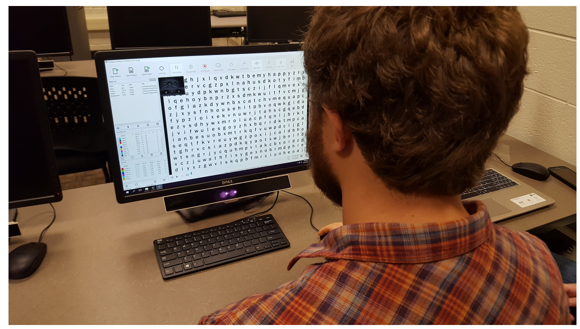

Figure 3: Participant at workstation viewing the results of the experiment. the GazePoint Eye Tracker is mounted underneath the Dell computer monitor.

4.2 Stimuli

The stimuli used were a pair of crossword puzzles. Each puzzle was constructed using a 26 x 15 grid as shown in Figure 1 and Figure 2. Each letter had a font size of 48pt with the font type being Franklin Gothic Medium and a font style of regular. A single instance of the word "house" was placed in each crossword puzzle so that its location was different from one another to avoid the participants identifying a pattern that would help them solve the subsequent puzzle quicker. In the crossword puzzle used as the control stimuli, as well in the crossword puzzle used as the experiment stimuli, the word "house" was oriented in such a way that it is read horizontally, from left to right. The crossword puzzle used as the control stimuli was designed in such a way so that it contained no English words longer than two letters except for the word "house". Five five-letter words (beach, catch, fruit, happy, and lodge) were inserted into the crossword puzzle used as the experiment stimuli. Each of these five words were oriented in such a way that they are read either horizontally, from left to right, or vertically, from top to bottom, and did not intersect the word "house". The crossword puzzles were generated using Adobe Photoshop CS4.

4.3 Experimental Design

A counterbalanced factorial design and within-subject variables were used in this study. Two different stimulus were presented to participants and each participant was presented each stimuli. Participants were shown a blank screen in between stimuli to take advantage of change blindness[2]. describes this effect by showing that participants are unlikely to notice changes to very similar scenes, such as two word search puzzles, if they are not focused on the location that changes. An example of a presented stimulus is Figure 1 and Figure 2. All participants were shown the mentioned figure and a similar stimulus with added distractions. In order to counterbalance the study the order in which the stimulus were presented was randomized.

4.4 Apparatus

Participants interacted with the word search puzzles through the Gazepoint software. The puzzles were in picture format using Photoshop picture editor. A Dell 22" monitor with a (1920 x 1080) resolution was used. The participants were seated at a distance of 24 inches from the monitor. The GazePoint eye-tracker was mounted under the display to pick up eye movement and pupil diameter. This can be seen in Figure 3. The sampling rate is 60Hz with a latency of 16ms and an accuracy of 0.5-1.0 degrees.

4.5 Procedure

The participants were first greeted and asked to sit down in front of the computer monitor and eyetracker. Participants were informed on the procedure of the experiment. Then they were given an informational letter describing possible risks, benefits of the study, and legal information. We then asked the participants to answer a questionnaire to gather demographic information about their age, occupation, and gender. The personal information about participants was not collected and their names were replaced with ID numbers.

After gathering this information and giving the participant the informational letter, we went through the process to setup the eye-tracker. This process included positioning the eye-tracker so that it was centered on the participants pupils. Then, calibration was performed by getting the participant to look at five to nine points on the screen while the eye-tracker tracked their eye movement. A common error when performing this calibration process was that the calibration dots were not positioned correctly on the screen, throwing off the calibration of the eye-tracker. This error can be corrected by selecting the correct display size on the GazePoint software. The overall process of calibration took about five minutes.

After this portion of the setup process is completed we began the experiment. An initial blank page was shown on the screen to make sure that the participant did not see the crossword puzzle before the eye-tracking software had been initiated or before they were ready to begin. Once ready to begin, the first stimuli was shown on the screen and the participant was asked to find the word "house" in the word search. The eye-tracker followed the participants gaze as they completed the word search puzzle.

After the participant completed the puzzle and the eye-tracking data was collected, a blank page was shown. This blank page prevents the word on the first puzzle from drawing attention to the words on the second puzzle by taking advantage of change blindness[2].

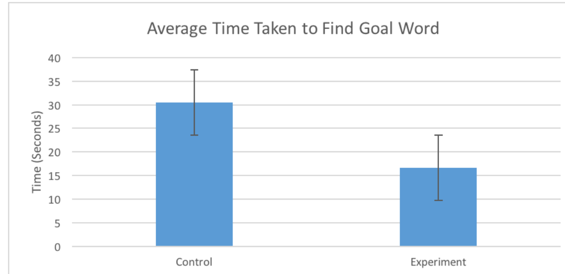

Figure 4: The average time take to find the goal word.

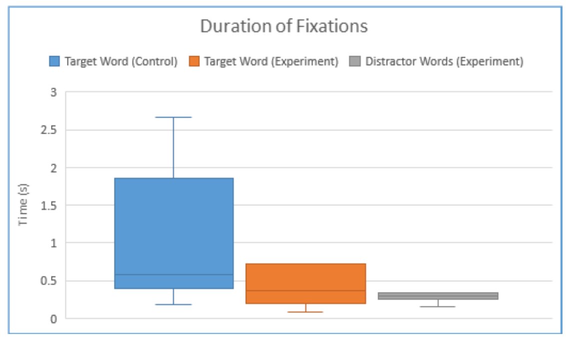

Figure 5: Box and whisker plots of the participantsâĂŹ duration of fixation for each portion of the experiment

After the participant looked at the blank page and was ready to continue, the second stimuli was shown on the screen. Participants were asked to search for the same word, "house" which was now surrounded by other distractor words. After the experiment, participants were informed of the actual purpose of the word search and any questions they had regarding the study were answered.

5 RESULTS

Eye movement data that was collected by the Gazepoint Analysis software was exported as a .csv file and examined for statistical significance. The data was analyzed with metrics for amount of fixations on the goal word, how long the duration of gaze was on the goal word, and when the participant found the goal word in order to uncover additional information from the study.

Figure 4 shows that participants were able to locate the goal word much quicker in the experimental word search puzzle than the control word search puzzle. On average the seek time in the control was 30.5347 seconds and the experiment seek time was 16.675 seconds. This increased speed can be explained by the participants becoming familiar with word search environment[5].

Figure 4 illustrates that distractor words had a very short median fixation duration of 0.2913 seconds. In comparison to the actual goal words median fixation duration 0.5750 seconds in the control it appears that participants were not hung up for long by the distraction words planted in the word search.

Table 1 above shows that it took participants on average 2.2658 seconds of fixation time to recognize the goal word. When viewing the experimental word search it took the same group of participants

	Avg. Number of Fixations	Avg. Time to Recognize Goal Word	Avg. Time of Fixation on Goal Word
Control	2	2.2658	1.1329
Experimental	1.4615	0.7491	0.5126

Table 1: Shows the average number of fixations, average time to fixate on the goal word, and the average time to fixate any word.

on average 0.7491 seconds of fixation time to find the same goal word. This data set takes into account times that they fixated on the word and did not recognize it to be the goal. An unpaired t test was performed on the fixation times shown above are significantreturning (p = .0042). , which indicates that there is a significant difference between our two fixation times. This p value means that we will reject our null hypothesis. Our null hypothesis would be that there is no correlation between the distraction words and the time it takes to find the target word.

6 DISCUSSION

The results from our study do not support the hypothesis that words in the control stimulus would be found quicker due to “pop-out” effect, whereas the distraction filled stimulus would not be influenced by this effect and it would take longer for the participant to complete. This could be due to participants growing familiar with the format of our word search puzzle and therefore performing better on the second puzzle which, for all participants, was our experimental stimulus containing the target word âĂIJhouseâĂİ and the five additional distraction words. This phenomena is explored by John Henderson[4] where he describes that the consistency of objects within, the coherence of, and the participants familiarity of the scene improves their search efficiency of that scene. The first puzzle, our control, takes more time because the format of the puzzle is novel to the participant but, since the second puzzle, our experimental stimulus, looks extremely similar, the participants new found familiarity increased their efficiency.

With this in mind, we believe always presenting the stimuli in the order of control followed by the experimental introduced a confounding variable to the experiment. Therefore, future work into this subject could focus on randomly selecting the order of stimulus to show participants to see if the results are the same as what we found. If they are, that would be a strong indication that we are able to identify words faster in a crossword containing other valid words than one containing only one valid word. Otherwise, it would show that the order of our stimulus did indeed introduce a confounding variable into our experiment.

Our results could also be explained by the findings of Ojanpää, Näsänen, and Kojo[3]. They found that the speed at which words can be found increases when multiple words can be processed in a single fixation. In our experimental stimuli the goal word “house” is located near enough to the distractor word “catch” that they both could potentially have been viewed in a single fixation. This may have introduced another confounding variable by increasing the participants chance of finding the word “house” if they found the word âĂIJcatchâĂİ first.

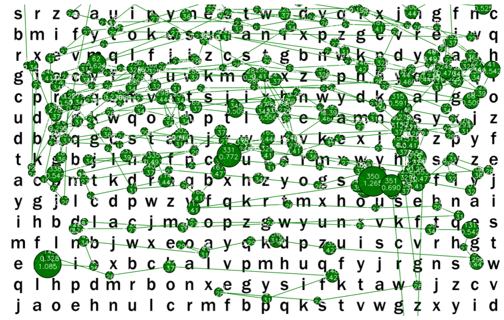

Figure 6: Participant 7 used a rigid search pattern when attempting to find the specified word. This method resulted in a long seek time to find the goal word.

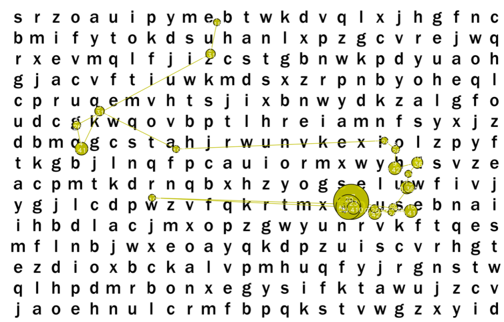

Figure 7: Participant 2 used a random search pattern to find the specified word. This method resulted in a short seek time to find the goal word.

Future work could be done to test the search speed of crossword puzzles based on the target words proximity to other valid words. That is, the search speed of a participant finding the the target word when it is surrounded by distraction words within 10 characters of itself vs the speed when all words are as far away from the target word and each other as possible. Research into this would be especially interesting due to the fact that while our results indicate that moving distraction words further from the target word could potentially decrease search speed it goes almost directly against Henderson[5] who states that clutter, that is moving the distraction words closer, should decrease search speed.

We also noticed two distinct search patterns from our participants. Figure 6 and Figure 7 show two of the different approaches that the participants took to find the goal word. From the recordings that were obtained, we found that participants that did not use a recognizable search pattern, such as participant 2 in Figure 7, found the word faster than ones that did. We believe this means that the target word did have a “pop out” effect for these participants but not for the others who who used rigid search patterns, such as Participant 7 in Figure 6. This could be due to the goal word being oriented closer to the middle of the word search where most of the participants that showed random searcher patterns began at as opposed to near the top or bottom where the participants that showed rigid search patterns typically began.

Another aspect of this project to consider is that the overall sample size was 13 participants with the majority of them being male students between the age of 18 and 28. In order to further confirm our results a larger sample size would be required to explore the trends uncovered by the data that was collected. If possible, we would like to even up the amount of male and female participants to ensure no gender bias in the results.

7 CONCLUSIONS

Based on the results of this experiment, there is no indication that the "pop-out" effect has any influence on how easy it is for a participant to find a word in a word search. The opposite was shown to be true by this experiment. It took less time for words to be found when distraction words were introduced but this can also be explained participant familiarity with the environment. It also was found that it took the participant more fixations on the goal word in the control stimulus to "find" it.

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