Effects of Time Pressure on Fixation Clustering During a Seek and Find Game

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ABSTRACT
This paper examines the effects of time pressure on fixation clustering during a seek and find game. Participants will search busy images for a particular target. Data is obtained using a Gazepoint eye tracker with software that will measure the participant's fixations while they are searching the image for the specific target.

INTRODUCTION
Visual search is something that humans do everyday subconsciously. Whether they are reading a newspaper or walking down a busy street, humans scan objects to try to gather information. When people know that they are on a time limit to do a task, they tend to become frantic. Since visual search occurs naturally, the question of whether a time limit changes the way that humans use visual search can be investigated. This can be explored through the use of fixations, which occurs when the eyes dwell on one location for an extended period of time. By calculating the average distance from one fixation to its nearest neighbor, conclusions can be drawn about the visual search patterns.

Being able to determine if time-pressure alters a person's visual searching methodology was the main motivation for this study. The experiment is conducted using an infrared eye tracker and a timer to analyze if the added pressure of being timed affects search patterns. The results are determined based on the nearest neighbor index (NNI). The nearest neighbor index is a tool used to measure the spatial distribution of a sample and determine if is regularly dispersed, randomly dispersed, or clustered.

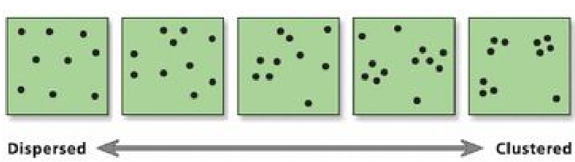

Figure 1: From left to right, the values range from NNI > 1 to NNI < 1 [Delaitre]

Values of NNI range from less than 1 to greater than 1. If the value is less than 1, then the fixations are clustered around each other. An NNI equal to 1 means that the fixations are randomly distributed, while an NNI above one means that they are uniformly distributed.

BACKGROUND
The experiment was inspired by the paper *Statistical Patterns of Visual Search for Hidden Objects* [Credidio] published in 2012. In this paper, they tested how the eye moves during a visual search and gathered data showing erratic eye movements when the image is busy or distracting. They started the experiment with having the participants find the number '5' amongst a long series of '2's in a formatted image. From this first iteration of the experiment, visual patterns were seen to be very linear, due to the arrangement of the image. The second iteration of the experiment used images from Where's Waldo, which produced much more erratic eye movements along an image and better represented an actual visual search in real life. This experiment picks up where they left off, but instead gets its data from eye movements using the nearest neighbor index. Waldo will be replaced with an alternate target, Patrick Star.

Further motivation for including the nearest neighbor index was from a paper that used PC games of variable difficulty [Nocera]. The games tested the distance to a fixations' nearest neighbor as a measure of mental workload. The experiment aimed to collect fixation data based on the PC game's difficulty. The game was lengthy and sometimes exhausted the participant throughout the testing levels. The model used in this experiment aims to undercut an exhausting search with just 3 different images of equal difficulty.

The formula to calculate the nearest neighbor index is based off two main variables, $\overline{r_A}$ and $\overline{r_E}$. $\overline{r_A}$ is the mean of the summation of the measurements of distances to each fixation's nearest neighbor. $\overline{r_E}$ is the average distance to a nearest neighbor expected with an infinitely large random distribution of density rho. The NNI (R) is the ratio of $\overline{r_A}$ to $\overline{r_E}$.

$$\bar{r}_A = \frac{\sum r}{n} \qquad \bar{r}_E = \frac{1}{2\sqrt{\rho}}$$

$$R = \frac{\bar{r}_A}{\bar{r}_E} = \frac{2\sqrt{\rho} * \sum r}{n}$$

Figure 2: How to calculate NNI [Clark]

RESEARCH HYPOTHESIS

The purpose of this study is to see how time pressure changes the length of time that the participant's eyes remain fixed on one location. The hypothesis predicts that the NNI for when the participant has a counting down timer will be be around 1, while the NNI will be less than 1 when the participant does not have a timer. An NNI of about 1 means that the fixations are randomly distributed, and an NNI less than 1 means that the fixations will be clustered.

This hypothesis stems from the fact that the participant will have different time limits for the three trials. The participant will feel that they can take their time when there is no timer, so they are more likely to scan the image in a logical manner. Because of this, they will have bigger fixations that are close to each other; their fixations will be clustered. Clustered fixations leads to an NNI less than 1. But, when there is a timer, the participant will feel rushed to find the target image. They will not take their time; their eyes will jump from place to place on the image, trying to cover as much ground as possible in a short amount of time. Their fixations will be more randomly distributed throughout the image, causing their NNI to be around 1.

METHODOLOGY

Apparatus

The participant's eye movements are recorded using the GP3 Desktop Eye-Tracker developed by GazePoint. The GP3 tracks where the user is currently looking on the screen as well as the distance of the eyes from the screen. It has an accuracy of half a degree to a degree, which is between 50 and 100 pixels. It has a sampling rate of 60Hz. The Eye-Tracker must be calibrated to each new participant before the study can begin. The monitor is a Dell P2213 22" LED LCD monitor with a native resolution of 1680 x 1050 at a 60Hz refresh rate.

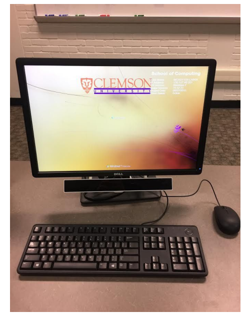

Figure 3: The apparatus

Stimulus

The main stimuli are three "busy" images with a specific target image hidden within the busy images.

Figure 4: Target Image

The participant will be presented with a blank image with a dot in the center. This will set the participant's focus in the center of the screen before transitioning to the first busy image.

Figure 5: Example of a busy image [Connguy]

The stimulus is designed to take the participant up to two minutes to complete. After successfully finding the target image in the first collage, the participant will again be presented with a blank screen with a dot in the middle to reset their focus. They then move on to the next busy image. This is repeated once more for the third image.

Experimental Design

The study was done using a within-subject design. Participants will be given an image and asked to locate the target image within it. The process will then be repeated with a second and third image. The second image will be shown with a time limit of 90 seconds, and the third image will be shown with a time limit of 30 seconds. There will be no visual timer, since this would interfere with the participant's search patterns; the time remaining will instead be read out by the supervisor in 15 second intervals. If the participant is unable to locate the target image before the time is up, the screen will automatically return to the blank screen with a dot in the center to re-establish the participant's focus. The images are counterbalanced into three separate groups, A, B, and C. Each group displays the images in a different order, giving each image a trial with 90 seconds, 30 seconds, and unlimited time. An equal number of participants were assigned to each group.

Subjects

The study will require approximately 20-25 participants. The participants will be college undergraduate students, graduate students, and faculty at Clemson University. The expected age range is 18-70.

Procedure

The eye tracker will be calibrated between each participant. This will consist of the user using the Gazepoint calibration until there is minimal error between each of the focus points. The participant will then be shown their target image that they will be searching for in the upcoming image collages. Once the participant has the image memorized, they will be presented with a blank screen with a dot in the middle to return focus to the center of the screen.

The first collage will then be shown, and the participant will not be timed while searching for the target image. Once the participant has found the target, another blank image with a dot in the middle will be displayed for the participant. The participant will be informed that the next trial will be similar, except with a 90 second timer.

Once the participant is ready, the next collage will be displayed on the screen with the time remaining being read by the supervisor. Once the participant has discovered the target image or the time limit is reached, the participant will once again be shown the blank image with a dot in the middle to reset their gaze. The participant will be informed that the next trial will have a 30 second timer.

When the participant is ready, the final collage will be displayed. The study will end when the participant finds the final target image, or when the participant runs out of time.

RESULTS

There were a total of 24 experiments run (8 for each project type A, B, and C). The visualization of the results can be seen in figure 6, where the initial hypothesis was mainly disproven. Image1 was the only image that reflected the hypothesis, because the NNI grew closer to 1 as the amount of time given to find the target image decreased. This means that the participant's searching patterns became more randomized and less clustered under time pressure. Image2 and Image3, however, did not show any strong tendencies towards this behavior. Both images had a higher NNI for the untimed trials than the 90 second trials, but while the NNI for 30 seconds for Image2 had an even lower NNI, the 30 seconds trial for Image3 had a much higher NNI.

Because the shapes of the lines for each image were not consistent, it shows that conclusions about the effect of time pressure on search patterns cannot be drawn. It appears that the timer did not affect people consistently. Some people were more frantic in their searching, but it did not change some people's searching at all.

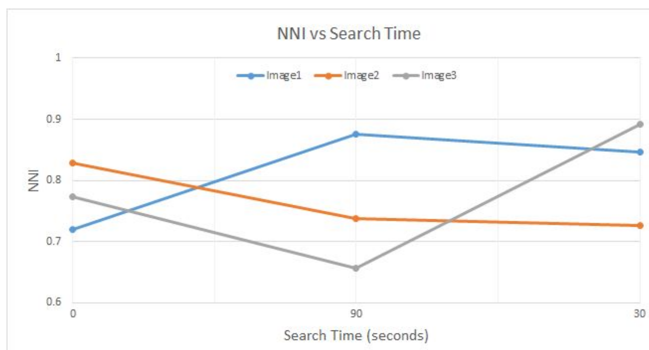

Figure 6: NNI results based on image and time. 0 Seconds represents unlimited amount of time to find the target image. Higher NNI means less clustered search patterns.

Search Time (seconds)

	0	**90**	**30**
Image1	0.719851	0.875697	0.846742
Image2	0.828825	0.737886	0.656915
Image3	0.772928	0.656915	0.891392

Figure 7: Average NNI results for each image.

The data above has little to indicate that time had a factor in NNI. The range of the values for each image are all under .25 NNI, so there is no significant difference in the NNI between when the image was untimed and when it was timed. The biggest outlier was Image3. When it was untimed, it's NNI was .77. It then jumped down to .66 when it had a 90 second timer, then went straight back up to .89 for 30 seconds. The other two images had both of their timed trials either below (Image2) or above (Image1) the untimed NNI.

DISCUSSION

The inclusion of a timer when first designing the experiment proved to be an unexpected hurdle. The experiment was initially going to include a physical timer, but this changed when participants began looking at it periodically, causing their gaze to leave the computer screen. This caused major fluctuations in the fixations on the image, thus altering the NNI. This led to the transition into a busy still image with verbal reminders of the participant's remaining time.

Some participants were able to find the target image in only a few seconds. This led to tests with very little useable data. This problem could have been fixed by using more complex images, or ones made without the inclusion of the target image altogether. A collage lacking the target image would guarantee the maximum amount of time spent searching and would likely induce the "stress" factor being sought after.

Search patterns among the participants varied, but a common search pattern was "reading" the page. They started in the top left corner of the image, then scanned from left to right, line to line. This has more to do with personal preference, but it may have to do with the natural feeling that comes from reading left-to-right. Some participants used a random search pattern. This led to them looking at the same place multiple times, decreasing their likelihood of finding the target image quickly. One of the more unique search patterns was when the participant started in the middle of the screen and searched using a spiral pattern.

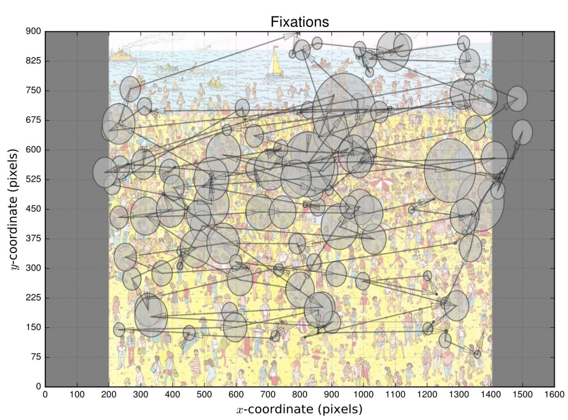

Figure 8: Example of "reading" the page. The participant was not able to find the image in the allotted time

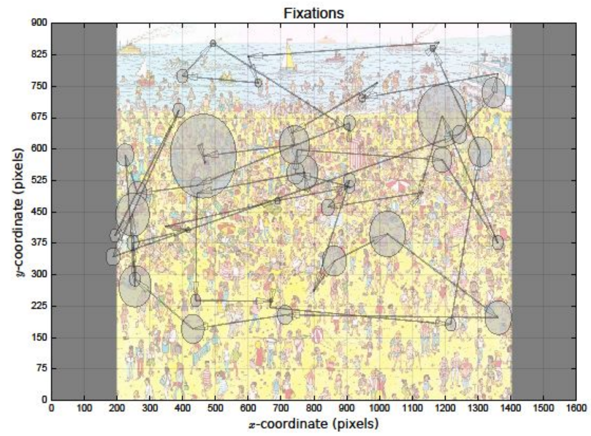

Figure 9: Example of a random search.

External stress was not explored. The experiment could have had other elements to increase stress, such as loud noises or distracting lights. It is possible that these external factors combined with the timer would have led to results more in line with the hypothesis.

CONCLUSION

This experiment set out to see if there is any relationship between visual searching and time pressure. The nearest neighbor index was chosen to try and find this relationship. It was hypothesized that the NNI would be below 1 when the participant did not have a time limit, and around 1 when they did.

Results varied greatly between participants, with some taking the entire duration without finding the target image, and others finding the target instantly. Some of these could be countered with more complex images, or images that did not contain the target. Some common visual search patterns included "reading" the image and randomly searching the image. External stress could also be introduced to see if that would influence the NNI.

The experiment showed that the hypothesis was incorrect. While there was one image that had a lower NNI for the untimed trial then the timed trials, the other two images did not have this same distribution. The data shows that there was not enough evidence to show that the introduction of a timer caused the NNI to be around 1.

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