Using Eye Tracking to Examine Subconscious Human Eye Activity

by
Christian Barnes

A thesis presented to the Honors College of Middle Tennessee State University in partial fulfillment of the requirements for graduation from the University Honors College.

Fall 2020

Using Eye Tracking to Examine Subconscious Human Eye Activity

by Christian Barnes

APPROVED:

____

Dr. Salvador Barbosa
Computer Science

____

Dr. Chrisila Pettey
Computer Science

____

Dr. Rebekka King,
University Honors College

Abstract

Eye tracking is quickly becoming a novel medium of entertainment and research. Many avenues have been explored in forensics with eye tracking. The goal of this paper is to further explore forensic applications of eye tracking and also pave the road for future forensic techniques. Specifically, the question this paper addresses is this: when presented with an image, do people tend to prioritize their gaze on a personal point of interest? This paper will explore this question and explain the implications of the results.

Table of Contents

Terms

***Key Image* –** The main image of a virtual room of which this study revolves.

Near-infrared – An invisible spectrum of light in between the visible light spectrum and infrared.

API (Application Programming Interface) – A package of pre-written code to save time and make performing a variety of tasks through a standardized interface.

Game engine – A set of tools to provide a starting point for game development, i.e., 3D rendering, collision detection, scripting tools, etc.

Raycast – A method used in 3D applications to collect spatial information, by sending out a "laser" from a single point to obtain information about objects in front of that point.

Control scheme – The method by which something is controlled, especially a video game.

Hardware – Physical components of a computer system.

Software – A set of computer instructions to control a piece of hardware.

Asset – A media component of a piece of software such as images, sounds, 3D models, etc.

Heat map – A colored representation of the amount of activity in an area of an image over any given time frame.

***XML* –** A markup language to organize information easily readable by a computer.

***C#* –** A programming language.

Introduction

Researchers have been examining the movement of the human eye at least as far back as 1908, when the psychologist Edmund Huey examined that the way humans read is not associated with a smooth eye movement from one side of the page to the other. In actuality, the human eye tends to dart quickly across small portions of text at a time in movements called "saccades," and shortly pauses on points of the text between saccades. These pauses are called fixations (Huey 16). These observations were made without any computers, using a very intrusive analogue device of Huey's creation. Although the conclusions Huey made were cobbled together through rather crude means, his conclusions have since been demonstrated with precision using actual eye tracking hardware and computer software (Rayner).

This primitive form of eye tracking was an important precursor in the formation of a new avenue of research. It was roughly thirty years after Huey's experiments before eye tracking could be conducted non-intrusively. Guy Buswell was the first to do this in 1935.

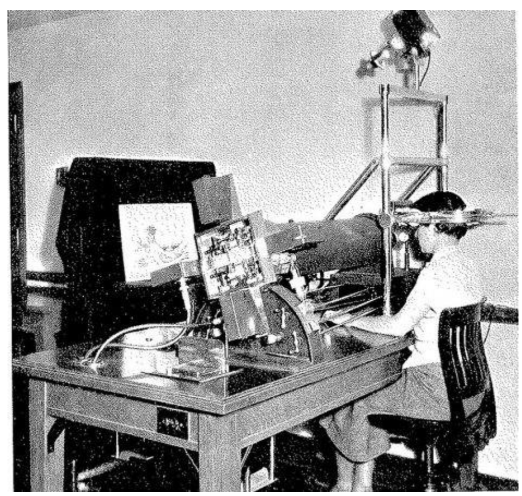

Figure 1. The first unintrusive eye tracker in use from: Buswell, Guy T. How People Look at Pictures. A Study of the Psychology of Perception in Art. University of Chicago Press, 1935.

Buswell conducted a study examining how people look at images. To do this, he used light rays and used a camera to record the reflections on the eye (Buswell 11). This method is remarkably similar to the method used today, if not identical. The only major changes that have been made to this method of eye tracking is the size and portability of devices that can achieve it.

It's been well over a century since the first studies were done with eye tracking. Needless to say, the hardware has improved considerably since then and the amount of research being done has exploded. One of the earliest examples of modern eye tracking research was a 1994 study that examined how adolescents respond to tobacco product advertisements. The researchers were specifically looking at the amount of time the subjects spent observing the health warnings on the advertisements. The study was meant to show the efficacy of newly developed health warnings as opposed to old health warnings. The study found that the newer warnings were in fact more effective (Krugman).

The areas of research that can be explored with modern eye tracking equipment is not just limited to advertising, however. If we consider research within the last ten years, the areas of study are quite diverse. From helping people with disabilities communicate (Al-Kassim and Memon) to forensics (Mansour and Flowe), it is clear that eye tracking is a very versatile technology that will continue to grow for years to come.

The question to be answered in this paper is this: When presented with an image of a room, do humans subconsciously allocate most of their gaze to a personal point of interest? The research hypothesis is yes, they do. If the hypothesis is correct, the implications could have applications in forensics and psychology.

In the study done for the basis of this paper, forty subjects participated in this experiment. Each was placed in front of an eye tracker while a piece of software developed for the experiment was running on a screen in front of them. The subjects were shown a series of images, before and after a personal point of interest was established for one of the images. To establish this personal point of interest, the subjects were asked to interact with the software to place an object anywhere in a virtual room (which was one of the images). The place the subject decided to put the object was then marked as their personal point of interest. This personal interactive experience with the virtual environment is enough to establish enough personal bias to answer the research question.

The goal for the thesis is to pave a road for future forensic techniques. If a personal point of interest has any effect on the way a person examines an image, then it should be possible to record a pattern in the change of behavior. If this change in behavior can be characterized, it can be applied in forensics, for example when showing a criminal suspect an image of a crime scene they might be associated with. By being able to identify this characterization in their gaze, it could be possible to relate patterns in their gaze with already known positional information regarding the crime committed to find correlation between the suspect's behavior and the crime.

As stated before, forensic applications of eye trackers are not completely unheard of. A 2016 article outlines how researchers are using eye tracking to evaluate eyewitnesses when they are presented with a suspect lineup (Mansour). Another 2013 study uses eye tracking to detect the frequency of blinking in individuals during a concealed information test in order to uncover crime related memories (Peth).

The eye tracker used for this thesis is called the "Gazepoint GP3." It uses a near-infrared light source to illuminate the surface of the eye. A physical eye-tracking accessory is used to do this, and then a built-in camera receives the reflections created. Software is used to interpret the reflections on the surface of the eye into tangible information regarding at what point on a screen a user is looking, usually to a relatively high degree of accuracy ("Eye Tracking - Learn More About Eye Tracker Technology").

This whole process is entirely harmless in healthy adult individuals without epilepsy or infrared-dependent medical devices (“Safety Guidelines”).

Eye tracking in its current state is also very accurate and reliable. A 2014 study that assessed the same eye tracker used for this thesis found that the amount of error regarding the accuracy of the eye tracker was about 1.05cm (Zugal). According to the paper, this is well within the realm of accuracy to conclude that the Gazepoint GP3 is viable for academic research.

Methodology

The engine used to build the software is called the Unity game engine (http://www.unity.com). While this platform is generally utilized to create video games, it can easily be used to create software and include 3D visuals. This engine provides an extremely large variety of tools perfectly suited for this project. Data analysis and manipulation, 3D rendering, user interaction, etc. are all possible and provides what is necessary for the proposed approach.

In addition to Unity, the Gazepoint GP3 eye tracker was used. This eye tracker is designed for research, with a complete license to aggregate and analyze data. The manufacturer has designed and published a very flexible API that streams information about the current state of the eye tracker from a local XML server. Using a simple library to interact with XML servers in C#, it is possible to interface with this data in the Unity game engine. However, the server only feeds text strings that hold the data, so methods to parse and organize the information were created for this project.

The 3D models used in the software largely came from free assets downloaded from the Unity Asset Store. Users of the Unity game engine can create and share assets to the store for others to use. This was supremely helpful in reducing time for creating 3D models.

Other general tools include Microsoft Visual Studio Code for writing scripts and Microsoft Excel to analyze the data collected.

Using Unity, a scene that resembles a library was created. A script that interfaces with the eye tracker to send out a ray cast and obtain a constant stream of information regarding where exactly in this 3D room the user is looking at any point in time, was developed.

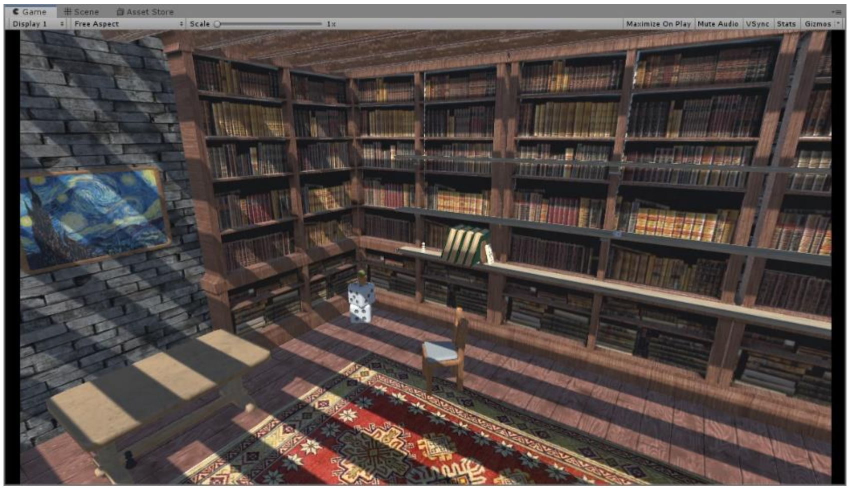

Figure 2. The Virtual Room Constructed in Unity

For demonstration purposes, a red dot is plotted in 3D space to represent where the user is looking as Figures 2 and 3 demonstrate.

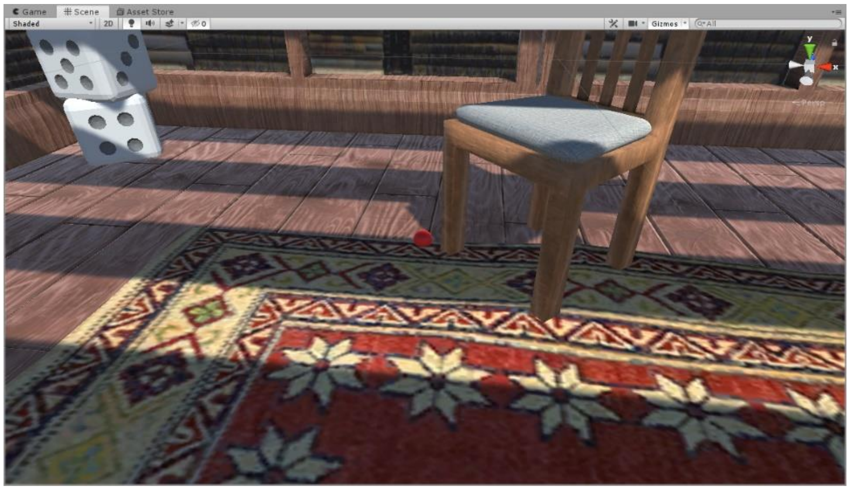

Figure 3. Location of Red Dot When Looking Next to The Chair

It is notable that the eye tracking hardware can theoretically cause seizures to those with epilepsy and interfere with medical augmentations that rely on infrared ("Safety Guidelines"). So, precautions were taken to ensure that no one with these conditions participated in the study. Approval to perform the experiment had to be obtained from the IRB (Institutional Review Board) to formalize the process. Subjects were not only verbally asked to confirm that they didn't have epilepsy or medical augmentations that rely on infrared, but they also had to sign a consent form that also confirmed the absence of these conditions in the individuals participating.

A series of forty subjects were asked to confirm that they do not have epilepsy and/or medical augmentations before beginning the experiment. Subjects were asked to sit down at a computer to perform a set of actions to assess the research question. Initially, as each subject sat down, the eye tracker was calibrated to them. After calibration, the subjects were shown a series of 4 images for 5 seconds each. Unbeknownst to the subject, the fourth image is the key image of the experiment, being the virtual room built in Unity. While the images were being shown, the software took note of the subjects' eye activity for each image, to be assessed later in the experiment. The data collected up to this point is control data in order to examine how their behavior changes after they perform the interactive part of the experiment.

The interactive stage of the software then begins. The subjects were asked to place an object wherever they wanted in the virtual room using the mouse. This was to establish a personal point of interest with the room and the image. After each subject did this, the software constructed a grid of "cells," centered on where the object was placed, which was invisible to the subject. These cells are all the same size, and are square designations of screen real estate that is sensitive to the gaze of the subject. The size of the cells is dependent on depth: the apparent size of the object they placed based on the distance “into” the room. The cell correlated with the position of the object was noted, as well as all cells adjacent to it.

At this point, each subject was shown the same assortment of images in sequence as before. When each image was shown, the software took note of the amount of gaze time each individual cell in the grid accumulated for each image. Each cell kept note of the cumulative number of frames it has the subject’s gaze, as well as a list of exactly what frame numbers it had the gaze.

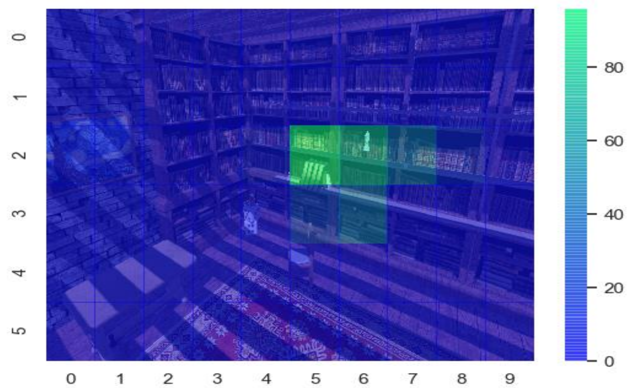

Figure 4. Example of a heat map visualization shows the size of cells

Once this was complete for the test set of images, the software then “replayed” the control data taken earlier and also took note of the accumlated gaze time of each cell for each image, as well as the other data points noted earlier. Once this was completed for every subject, the data was organized into a set of forty Excel spreadsheets (one sheet per subject). The data was then extracted from the generated spreadsheets and visualized and analyzed using Python. The data was examined to see if any discernible difference existed between the amount of time the subject spent looking at the point where they placed the object when shown an image of the room ***before*** a personal point of interest was established, and the amount of time they spent looking at that same point ***after*** the personal point of interest was established.

Specifically, for each of the eight image reveals shown to the subjects, the cell data was analyzed to see if the **key image** reveal (image of the virtual room after the personal point of interest was established) exhibited the most gaze time on the cell associated with the position of the established point of interest, among any image reveal. This was done for every participant of the study to extrapolate a percentage of the volunteers this was true.

To further explain this, take note of the following graphs. These graphs represent all image reveals for a single subject. Each graph is one image reveal. The bottom 4 graphs are the control image reveals, and the top 4 are the test image reveals. The top-rightmost graph represents the key image reveal (image reveal of the virtual room after the personal point of interest was established). The graphs retain this format for the entirety of the data analysis discussion.

Figure 5. Example of image reveal graphs of a single volunteer

Each line represents one cell of the image reveal. The red line represents the cell associated with the position of the point of interest. The green lines represent the cells adjacent to it. The faded blue lines represent every other cell. The X axis represents the total number of frames that have passed since the image reveal. The Y axis represents the cumulative number of frames that a cell has been gazed upon.

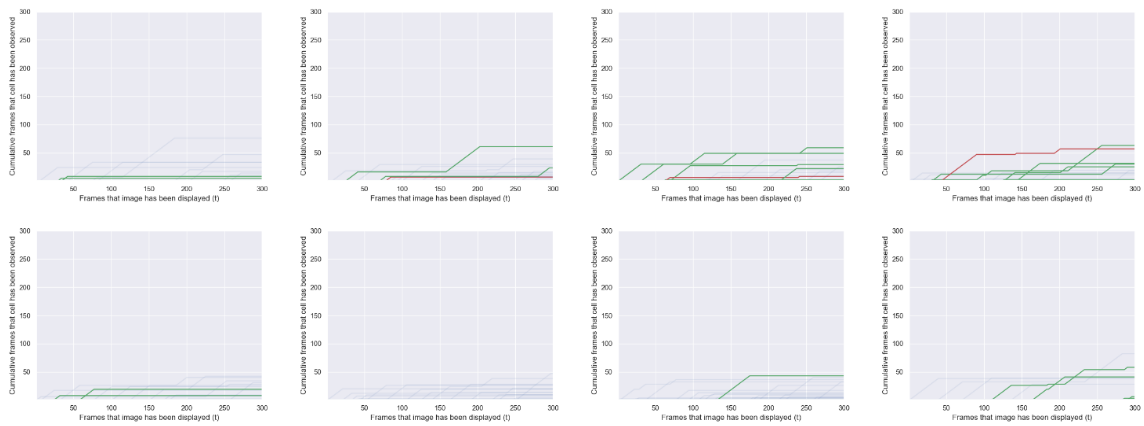

Figure 6. An example of a subject that had the most gaze on the point of interest on the key image reveal

Above is an example of a subject of which the key image reveal exhibited the most gaze time on the cell associated with the position of the established point of interest than any other image reveal. Notice the final Y position of the red line is the highest in the top right image reveal.

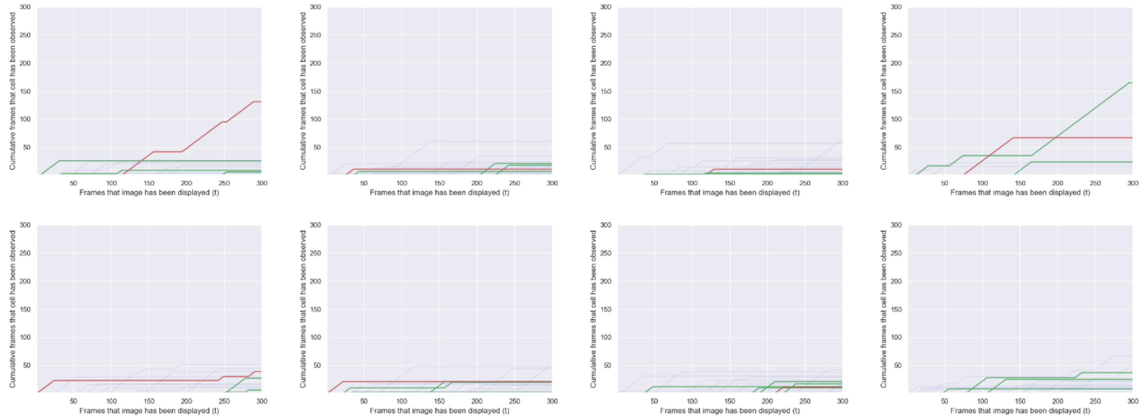

Figure 7. Example of a subject that did not focus as strongly on the point of interest

Above is an example of a subject who does not fit the previously described criteria. In this instance, the top left image reveal had the highest final location on the Y axis of the red line. Comparing the number of subjects whose graphs reflect the previously described criteria and the number of subjects whose do not will extrapolate a percentage.

This same exact principle was applied to the control key image (bottom right graph) to extrapolate another percentage to find the general chance that the control key image will boast the most gaze time on the point of interest by chance, without any prior exposure to the image. This percentage can then be compared to the test key image percentage.

However, that is only gaze time. Other percentages were compared such as what percentage of the volunteers had the ***test*** key image exhibit the *earliest* initial gaze of the point of interest of any of the images, and what percentage of the volunteers had the ***control*** key image exhibit the *earliest* initial gaze of the point of interest of any of the images. Lots of interesting aspects can be extrapolated with this principle and were explored.

On top of these percentage figures pulled from this data, some basic intuitive analysis was also performed on the mean dwell time that the key test image received on the point of interest versus the control images.

Results

As stated before, the main results extrapolated from this experiment are those of percentages. These percentages are extrapolated by counting the number of times a certain criterion is true for some image reveal across all forty subjects and dividing that number by the number of subjects.

The format of results will be in the form of sections. These sections will be the different criteria discussed above. The corresponding results and a brief explanation will be provided for each section.

1. Total cumulative dwell time on point of interest is highest among all image reveals

The total cumulative dwell time for every cell in an image reveal was recorded for every image reveal for every subject. The data points of interest are the percentage of subjects that spent the most amount of time looking at their point of interest during the test key image reveal and the percentage of subjects that spent the most amount of time looking at their point of interest during the control key image reveal.

The percentage of subjects that spent the most amount of time looking at their point of interest during the *test* key image reveal was 62.5%. On the other hand, **the percentage of subjects that spent the most amount of time looking at their *later*-defined same point of interest during the *control* key image reveal was 12.5%.**

The latter percentage represents the chance that a subject will spend the most time looking at their point of interest while looking at the key image **before any prior exposure to the image.** This makes the extrapolated probability that the point of interest will receive the most gaze time *after* a point of interest is established for an image ***five times more likely*** than without any prior exposure to the same image.

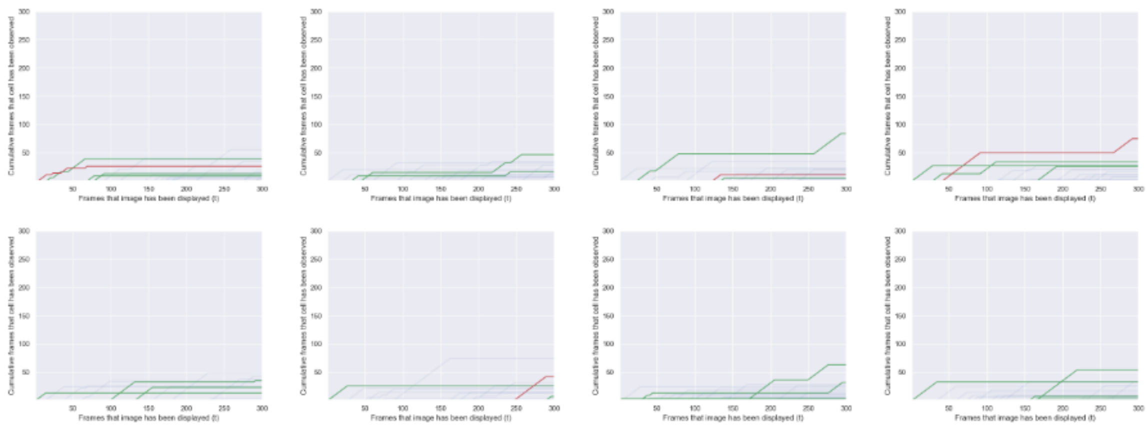

Figure 8. An example of a subject that contributed to the first percentage

The figure above shows a prime example of a subject that spent the most time dwelling on the point of interest in the test key image reveal. The top right graph clearly exhibits the most activity with the red line denoting the cell that corresponds with the point of interest.

The images to the right are heat maps generated from the test key image reveal (top) and the control key image reveal (bottom) of this subject.

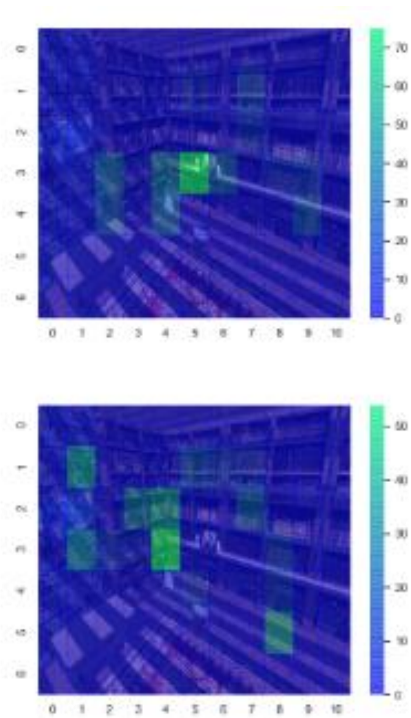

Figure 9. Generated heat maps

From the heat map figures, it is clear that the subject's gaze is much more centralized and focused in and around the point of interest in the key image reveal. The object that they placed in the room is the white chess piece on the shelf towards the center of the image. You can see the relative amount of gaze each cell accumulated by the intensity of the shade of green.

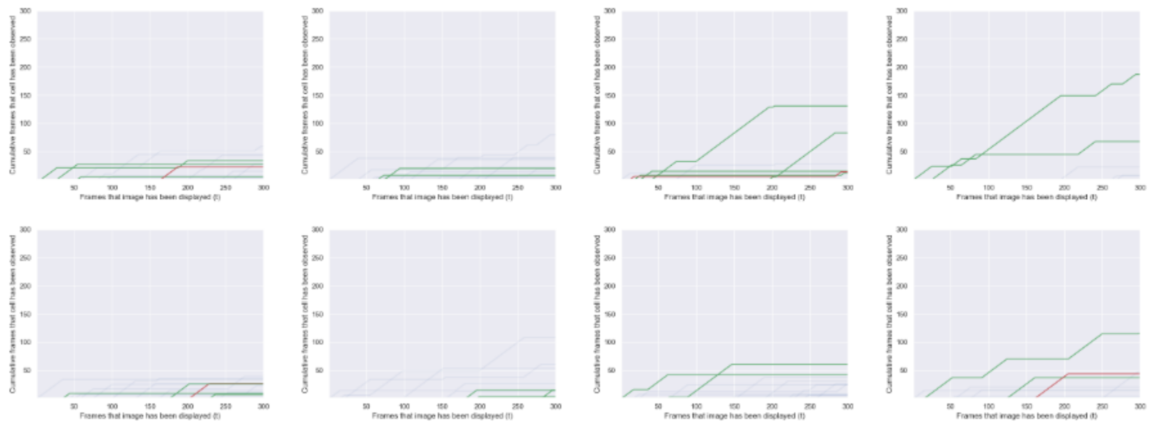

Figure 10. Example of a subject that contributed to the second percentage

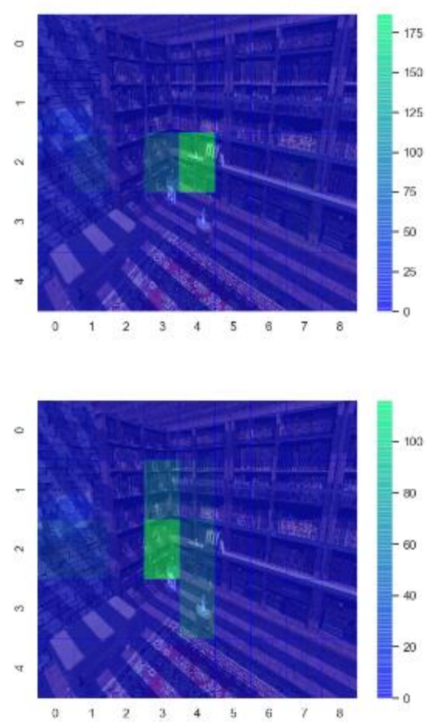

Figure 11. Generated heat maps

To counter this, above is an example of a subject that contributed to the second percentage. That is, the key image exhibited the most gaze on the point of interest before it was even established. This is obviously an example of a subject whose behavior is counter to the research question, which only happened in 12.5% of subjects, as stated before.

To the right is again a set of generated heat maps, this time representative of the counter example subject's behavior. This subject chose to place the white chess piece on top of the chair in the middle of the floor. The top heat map reflects that as seen in the top right graph; the point of interest has no total gaze time during the duration of the test key image reveal. However, the bottom heat map that represents the control key image reveal shows that *some* gaze was captured on the point of interest before it was established.

2. First instance of dwell time on point of interest is earliest among all image reveals

Every frame that a cell was being gazed upon was noted for every cell in an image reveal for every image reveal for every subject. The data points of interest are the percentage of subjects that exhibited the earliest instance of looking at their point of interest during the test key image reveal and the percentage of subjects that exhibited the earliest instance of looking at their point of interest during the control key image reveal.

The percentage of subjects that exhibited the earliest instance of looking at their point of interest during the *test* key image reveal was 40%. On the other hand, **the percentage of subjects that exhibited the earliest instance of looking at their *later*-defined same point of interest during the *control* key image reveal was 20%.**

The latter percentage represents the chance that a subject will exhibit the earliest instance of looking at their point of interest while looking at the key image **before any prior exposure to the image.** This makes the extrapolated probability that the point of interest will receive the earliest gaze time *after* a point of interest is established for an image ***twice as likely*** than without any prior exposure to the same image.

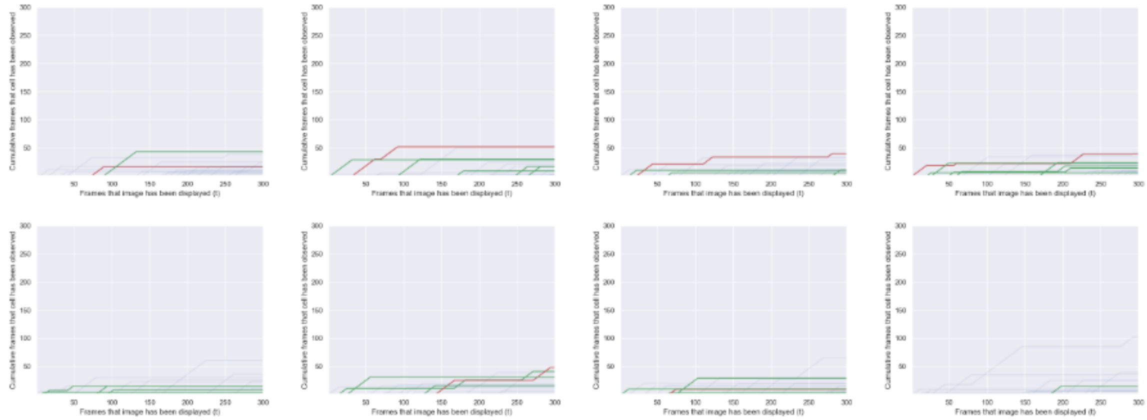

Figure 12. Example of a subject that had a very quick response to their point of interest

Above is an example of a subject whose behavior fits this section’s criterion for the test key image reveal. Heat maps are not necessary because they represent no temporal data. As seen in the graphs, the test key image reveal exhibited the earliest occurrence of gaze on the point of interest for this subject. This occurred in 40% of cases, as stated before.

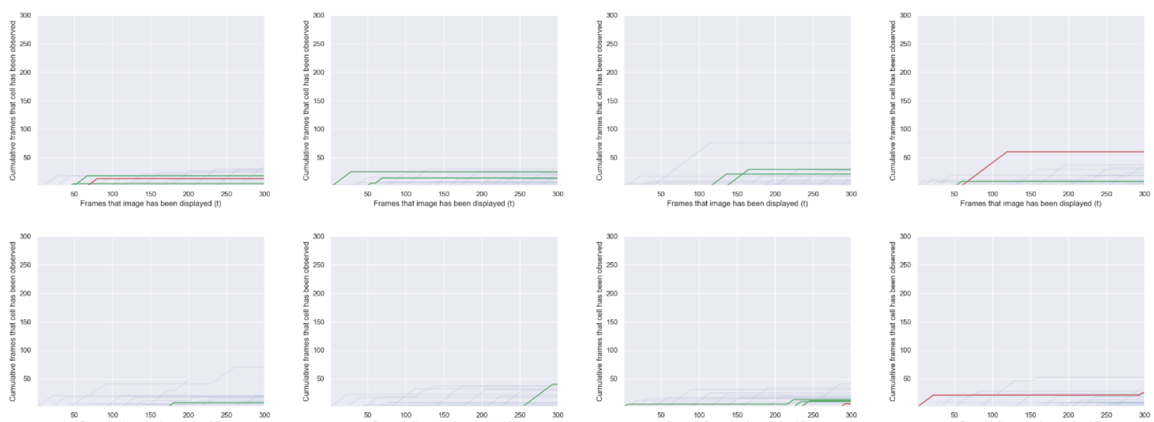

Figure 13. Example of a subject that contributed to the second percentage

In contrast to this, above is an example of a subject in the 20% of instances where the *control* key image reveal exhibited the earliest instance of gaze on the point of interest. Notice how in this particular case that the *test* key image reveal still exhibited the highest *cumulative* gaze time on the point of interest despite this.

3. Comparing mean cumulative gaze

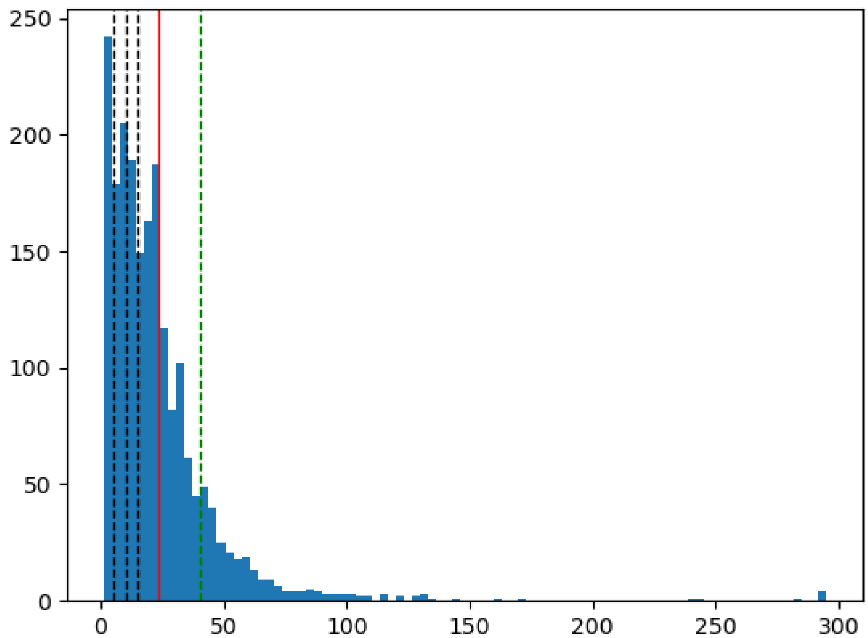

Figure 14. Histogram of control cell gaze times

Above is a histogram of every cell of every image reveal of the control phase of the experiment for every subject. The main histogram only regards cells that received at least *1 frame* of gaze time during the image reveal. A very large number of cells go without ever being gazed at, so including 0 interferes massively with the readability and significance of the data. In short, the main histogram represents the distribution of the number of frames every control cell was looked at, but only *if it was looked at.*

The X axis represents the cumulative number of frames that a cell has been looked at, and the Y axis represents the total number of cells that exhibited gaze times within each range. The solid red line represents the mean of the histogram data set.

Each dotted line represents the average number of frames that a subject gazed at their point of interest during each test image reveal. The green dotted line represents the test *key* image reveal and the other three lines represent the three images that are not the key image reveal. The dotted lines come from the test portion of the experiment, so they are not extrapolated from the histogram in any way, but instead they are overlaid on top of it to easily compare the means from the control and test data sets.

The means represented by the dotted lines include 0, that is, it includes image reveals from subjects where the point of interest was not gazed at whatsoever. That is in contrast to the main histogram which omits cells that were not gazed at. The black dotted lines – i.e. the test image reveals that were not the key image – fell below the average of the main histogram because of this. However, despite this, you can see that the average gaze time for the test key image reveal is still *almost double* (from **23.22** to **40.55**) that of the histogram average.

This means that the average number of frames that a personal point of interest is gazed upon when viewing the test key image is 1.75 times more than the average number of frames that any gazed-upon point is looked at before an established point of interest.

Discussion

The percentages extrapolated for the data strongly suggest that the thesis question was proven in the affirmative. Given a personal point of interest, the gaze data *does* show bias towards that point of interest. The differences in the probability that the point of interest will receive the most cumulative gaze time is remarkable. The noted **62.5%** of subjects having the most gaze time on their point of interest after it was established, as compared to **12.5%** before they had their point of interest established, suggests a **500% increase** in probability. This fact alone provides a reasonable basis to confirm the research question, but that was not the only percentage looked at.

While not as remarkable, the **doubling** in probability that *the point of interest will have the earliest instance of gaze time after a point of interest is established* is still a very valuable point to note. An increase in probability of **20%** to **40%** was noted. While total cumulative gaze time is important, the quickness of the initial gaze on the point of interest suggests eagerness and priority. When a subject suggests that the point of interest was highest on their priority list during the test key image reveal, it adds merit to the confirmation of the research question.

The investigation into the average cumulative gaze times of the different image groups also suggested a confirmation of the research hypothesis. While the average cumulative number of frames of gaze time for any given cell that was looked at during the control images was **23.22**, the average number of frames that the point of interest was looked at during the test key image reveal was **40.55**. This marks a sizable **175% increase** in the average. Also, this increase does not seem to be caused simply by the fact that the point of interest is usually near the center of the screen, as the average point of interest gaze time was much lower among the test images that were not the key image. Only specifically under the circumstances that a point of interest on an image has been established, and then being shown that same exact image show a positive difference between the average gaze time on that point of interest and the average amount of gaze time any given cell among the cells that were looked at in the control image group received. This circumstance is exactly what the research question was looking to assess, and it appears to be decidedly in accordance with the hypothesis.

From what data is available to analyze in this study, it appears the research question is confirmed. Every result looked at suggests a trend that a previously established point of interest does, in fact, lend itself to some reasonably strong biases within the eye tracking data. The implications of this in forensics could be profound if investigated further. Knowing what the results of this paper have revealed, there may be merit in investigating how criminal suspects react to visual stimuli. If a criminal has some pre-disposition to a picture of a crime scene (knowing what evidence is significant, knowing where the crime took place, etc.), then these points of interest could reveal themselves as such if the suspect is observed with eye tracking hardware.

Using eye tracking to evaluate a subject's gaze patterns when shown a picture of a crime scene is not completely unheard of in research. A 2017 study examined how investigators observe a crime scene and how efficiently they pick out evidence (Watalingam). However, this study was using investigators as subjects and did not look into anything about pre-established points of interest and how they affect the data.

A combination of this experiment and this thesis's experiment would be the logical first step in developing any techniques from the results of this paper.

Future Works and Limitations

As just stated, the next logical step to follow up this thesis would be an experiment with real pictures that people look at other than virtual rooms. Due to time limitations this experiment was unable to extend past virtual means. Subjects were only able to look at the key image from one point of interest, and in turn only able to establish their point of interest from one point of view. An interesting revision of this experiment would be to have subjects actually hide an actual item in an actual room letting them explore the room and hide their item with more creativity. They would be shown a picture of the same room before and after they hid the actual item, similar to this experiment.

An interesting challenge that this would create would be integrating where the subjects hid their item within the software. A possible solution would be to have an operator monitor the room through a camera feed from the same point of view as the image they will be shown and input manually the point on the screen that the subject hid the item.

Another thing to note is that in this experiment, the subjects were simply told to place object wherever they wanted on the screen. The introduction of telling the subjects to *hide* an item in the room means that they need to be creative. The notion of *hiding* something could add some "mischievousness" factor to more closely emulate association with the point of interest and the "guiltiness" of the subject.

Thinking even further ahead, to actually develop these findings into any forensic techniques, trials will have to be conducted with suspects of actual crimes. Case studies will have to be performed to see if the patterns found in this study are actually correlated with the guiltiness of a subject. A group of suspects could be monitored via eye tracking when shown an image of a crime scene in question, then the researchers could compare the presence of visual biases towards the assumed point(s) of interest with the number of subjects proven guilty by other means and see if there is any correlation.

Also, a revision to the eye tracking setup and hardware would be ideal for any follow up experiments. Due to financial restraints, a fairly cheap eye tracker was used. While the eye tracker used was accurate enough to extract meaningful data, the calibration process was cumbersome and may have led to some variability in the data. The eye tracker only provided accurate measures when subjects were within very specific positions in relation to it, taking some of their focus away from the experiment as they were trying to stay within the strict bounds of the eye tracking hardware. Other eye tracking solutions exist that are more flexible when it comes to subject positioning as well as being more accurate and easier to calibrate. This is important, because this research question relies very heavily on the fact that the subject acts *completely* naturally without any distractions.

The data was recorded in a crowded area which also caused distractions for the participants. Future experiment could eliminate any of the variability caused by this by performing the procedures in a more secluded area. Although this experiment had some limitations, the end result has still laid out a good framework for future studies to investigate the findings further.

Conclusion

Eye tracking has a rich and interesting history. It is astonishing that researchers have been able to track the minute moving of the human eye since at least 1908. It was only inevitable that this technology would evolve rapidly and open avenues of research over the following century. With advertising being first to make the leap into eye tracking research, many more areas followed. In the modern day, eye tracking is becoming increasingly popular among gamers with peripherals hitting the market to allow gamers to interact with virtual worlds using their eye.

This technology was a very fun topic to explore for an honors thesis. The amount that was learned during the entire process of programming, researching, and writing for this thesis is staggering. Getting the eye tracking hardware to interface properly with the Unity game engine was challenging. Not much documentation was available for the eye tracker that was used, so a lot of work went into researching the technologies that the eye tracker used to communicate to the computer.

On top of this, coming up with an experiment that actually accurately addressed the research question was a foreboding task. Many things have to be considered before an experiment is executed because a lot of the time it can only be executed once under strict deadlines. There has to be absolute certainty in the values that are collected and the significant information that can be extrapolated out of them. It is difficult when there is no one to say if what is being done is the correct thing to do or not. Absolute trust has to be placed in the initial plan, and the weight of the sense of responsibility that creates is fatiguing.

When presented with an image, do people tend to prioritize their gaze on a personal point of interest? This was the initial research question, and after executing the experiment it is clear that yes, people *do* tend to prioritize their gaze towards a personal point of interest when shown an image. Out of the three main sections in the data analysis, all of them had a conclusion that correlated with a confirmation of the research question. After a point of interest was established, the probability that the key image reveal would boast the highest cumulative gaze time on the point of interest *went up by five times,* The same probability regarding the earliest instance of gaze time *doubled,* and the average view time of the point of interest cell was 1.75 times that of any given control cell.

It is unmistakable that the research question is confirmed, and the new forensic techniques that this paper could lead to are exciting. The goal of this thesis was to prove an inkling about human gaze prioritization in order to inspire other researchers to take that inkling further. Although the experiment had some limitations and some challenges had to be overcome in order to achieve a finished product, the results found here pave the road for a new line of research to enhance the world of forensics.

Citations

"Eye Tracking - Learn More About Eye Tracker Technology." Gazepoint, https://www.gazept.com/eye-tracking/.

"Safety Guidelines." *Tobii Eye Tracking Support*, https://help.tobii.com/hc/en-us/articles/212372449-Safety-guidelines.

Al-Kassim, Zeenat, and Qurban Ali Memon. "Designing a low-cost eyeball tracking keyboard for paralyzed people." *Computers & Electrical Engineering* 58 (2017): 20-29.

Buswell, Guy Thomas. "How people look at pictures: a study of the psychology and perception in art." (1935).

HUEY, Edmund Burke. *On the Psychology and Physiology of Reading... A Thesis... Reprinted from the American Journal of Psychology*. Clark University, 1908.

Krugman, Dean M., et al. "Do adolescents attend to warnings in cigarette advertising? An eye-tracking approach." *Journal of advertising research* 34.6 (1994): 39-53.

Mansour, Jamal K., and Heather D. Flowe. "Eye tracking and eyewitness memory." *Forensic Update* 101 (2010): 11-15.

Peth, Judith, Johann SC Kim, and Matthias Gamer. "Fixations and eye-blinks allow for detecting concealed crime related memories." *International Journal of Psychophysiology* 88.1 (2013): 96-103.

Rayner, Keith. "Visual attention in reading: Eye movements reflect cognitive processes." *Memory & Cognition* 5.4 (1977): 443-448.

Watalingam, Renuka Devi, et al. "Eye tracking to evaluate evidence recognition in crime scene investigations." *Forensic science international* 280 (2017): 64-80.

Zugal, Stefan, and Jakob Pinggera. "Low–cost eye–trackers: Useful for information systems research?." *International Conference on Advanced Information Systems Engineering*. Springer, Cham, 2014.