EYE MOVEMENTS BEHAVIORS IN A DRIVING SIMULATOR DURING SIMPLE AND COMPLEX DISTRACTIONS

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EYE MOVEMENTS BEHAVIORS IN A DRIVING SIMULATOR DURING SIMPLE AND COMPLEX DISTRACTIONS

A Project Report

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San Jose State University

In Partial Fulfillment
Of the Requirements of the degree

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By
Pradeep Narayana

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The Designated Project Committee Approves the Master’s Project Titled

EYE MOVEMENTS BEHAVIORS IN A DRIVING SIMULATOR DURING SIMPLE AND COMPLEX DISTRACTIONS

By

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April 2023

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ABSTRACT

Road accidents occur frequently due to driving distractions all around the world. A driving simulator has been created to explore the cognitive effects of distractions while driving in order to address this problem. The purpose of this study is to discover the distraction-causing elements and how they affect driving performance. The simulator offers a secure and regulated setting for carrying out tests while being distracted by different visual distractions, such as solving mathematical equations and number memorizations.

Several trials have been conducted in the studies, which were carried out under varied circumstances like varying driving sceneries and by displaying different distractions. Using Tobii Pro Fusion eye tracker, which records the participants' eye movements and pupil dilation to detect distraction events, the cognitive load of distractions was assessed. In order to ascertain how distractions affect driving behavior, the simulator also gathered data on driving performance, such as steering wheel movements. It also gathered data on how much attention was being paid to the distractions by recording the user’s responses to the distractions.

The preliminary findings of this study will shed light on the cognitive effects of driving distractions as well as the causes of driver distraction. With the help of this information, initiatives and interventions can be created to lower the prevalence of distracted driving and increase road safety. The results of this pilot study may also aid in the creation of safer standards for using electronic devices while driving and better driver training programs.
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I. INTRODUCTION

Driving is an intrinsically complex and dangerous task that requires a considerable amount of attention and cognitive resources. But in the present world, there are a lot of distractions when driving, including passengers, in-car entertainment systems, and even mobile phones. The capacity of a driver to concentrate on the road, respond to unexpected situations, and make wise decisions can all be severely hampered by these distractions. Hence, it is crucial to comprehend the effects of various distractions on driving performance and safety.

Driving simulators have grown in popularity as a tool for studying driving behavior and performance in a controlled setting in recent years. With a high level of participant safety, driving simulators may accurately recreate a variety of driving scenarios, including various traffic patterns, climatic conditions, and vehicle kinds [1]. The study also found that, unlike real-world driving studies, which can be challenging to conduct, driving simulators give researchers accurate and impartial measurements of driving performance, such as speed, braking, and lane departure.

We utilized Tobii Pro Fusion eye-tracker to track eye movements and pupil size during the studies to gauge the cognitive load and level of distraction experienced by the drivers. Since the movements of the eyes are a direct reflection of brain activity, eye tracking offers a non-invasive and extremely sensitive tool for identifying cognitive load and distraction [2]. By examining the eye-tracking data and participants’ responses, we can ascertain when and how frequently drivers' attention was taken away from the road, as well as whether this results in poorer driving performance or a higher risk of accidents.
Together with eye tracking, we gathered a variety of subjective and objective measurements of driving performance. The self-reported levels of attention, tension, and weariness among drivers will also be assessed before and after the studies using validated questionnaires. By combining these measurements, we hope to get a thorough understanding of how various distractions affect driving performance and safety, as well as how this varies across different driver attributes.
II. RELATED WORK

a. RESEARCH ON DISTRACTIONS WHILE DRIVING

Any activity that causes a driver to get distracted from their primary duty of driving is referred to as distracted driving. Texting, talking on the phone, eating, grooming, adjusting the radio, and other activities fall within this category. Distracted driving is a serious and growing concern, with multiple studies demonstrating that it can degrade driving ability and increase the risk of accidents and injuries [1]. The study notes that the dangers of distracted driving are particularly severe among younger drivers, who are more likely to engage in distracting behaviors while driving. It also pointed out that the ramifications of distracted driving can be devastating, with thousands of fatalities and injuries reported each year because of distracted driving accidents.

The study by Ortega et al. looked into how using a phone while driving affected workload and traffic infractions [1]. The results of this experimental investigation showed that using a cell phone while driving increased effort and resulted in more traffic violations. These results are in line with earlier studies that have emphasized the risks of distracted driving. In order to decrease the prevalence of using a cell phone while driving and increase road safety, the authors argue that further education and awareness initiatives are required. The effects of cognitive and visual distractions on driving behavior were examined in the study by Ezzati Amini et al. using head-mounted eye tracking equipment [2]. The findings demonstrated that distractions, both cognitive and visual, can dramatically reduce driving performance, resulting in a rise in traffic infractions and unsafe driving habits.
With an aim to conduct research with a higher number of studies, the research on texting while driving behavior of 1211 U.S. people is presented in the paper by Gliklich et al [3]. The frequency, motivations, and attitudes of participants who texted while driving were evaluated by the authors using the Distracted Driving Survey. According to the survey, a sizable portion of individuals admitted to texting while driving a vehicle, and those who did so tended to be younger, male, and less educated. The article emphasizes the need for additional initiatives to stop texting and driving, especially among high-risk groups. A brief overview of the detrimental impacts of distracted driving on road safety is given by Liang [4]. The author discusses several driving distractions and how they affect traffic accidents and driver behavior. To decrease distracted driving and increase general traffic safety, Liang highlights the necessity for focused interventions and public education. A review of research on driving simulator studies that looked into the consequences of texting while driving was done by Voinea et al [5]. The review's conclusion that texting while driving can impair driving performance highlights the need for additional study and successful strategies to lessen the risks associated with distracted driving.

In order to validate the use of a driving simulator in identifying driving faults, Meuleners and Fraser conducted a study [6]. They came to the conclusion that the simulator may be used to precisely analyze driving behavior in research and clinical contexts after discovering that it was effective in detecting errors related to speed, lane position, and vehicle control. This study helps to discover possible areas for driving safety improvement and the development of simulation-based techniques for assessing driving performance. The impact of visual and cognitive distractions on operational and tactical driving behaviors was examined in the study by Zhang et al. [7]. The findings demonstrated that both types of distractions increased the likelihood of
accidents and had a significant detrimental impact on driving ability. To maintain safe driving practices, the study underlines the significance of reducing visual and cognitive distractions while driving. Singh and Kathuria did a literature review to look at studies on how drivers behave in realistic driving situations [8]. In comparison to conventional study approaches, they discovered that studies using naturalistic collection methods gave more precise and thorough data on driver behavior. The authors came to the conclusion that in order to better understand driver behavior and enhance traffic safety, future research should continue to use naturalistic data collection techniques.

In an ordinary and mixed traffic setting, Hua et al. looked at how cognitive distraction impacted physiological measures and driving performance [9]. The findings demonstrated that, in both types of traffic settings, cognitive distraction decreased driving performance, increased mental workload, and provoked physiological reactions, such as an increase in heart rate and pupil dilation. The study emphasizes the need for additional research and preventative actions to address cognitive distraction while driving, especially in locations with mixed traffic. Supporting this research, the effect of cognitive distraction on speed control during curve negotiating while driving was examined in the Fu et al. study [10]. They discovered that drivers' ability to manage their speed in bends diminished when they were distracted by a cognitive task because they were more likely to speed and brake later. These results emphasize the significance of reducing cognitive distractions while driving in order to increase traffic safety.
b. RESEARCH ON PUPIL MOVEMENTS

With the focus of research being the analysis of pupil movements, Mitre et al. investigates the use of pupillary responses to measure cognitive load in educational video games [11]. The study aimed to develop a system to classify difficulty levels in educational video games based on changes in cognitive load, as indicated by pupillary responses. The authors recruited 33 participants to play an educational video game while their pupillary responses were measured. Results showed that there were significant differences in pupillary responses between the three difficulty levels of the game, indicating that pupillary responses can be used as an effective measure of cognitive load in educational video games.

Similarly, a comprehensive review of research on the use of pupil dilation as an index of effort in cognitive control tasks was conducted by Wel et al. [12]. The authors review studies that have investigated the relationship between pupil dilation and various cognitive processes, such as attention, working memory, and inhibitory control. The review concludes that pupil dilation is a reliable index of cognitive effort and can provide insights into the underlying cognitive processes involved in cognitive control tasks. Vogels et al. explores the use of the Index of Cognitive Activity (ICA) as a measure of cognitive processing load in dual task settings [13]. The ICA is a measure of the degree to which attention is allocated to a particular task, based on changes in pupil dilation. The authors conducted two experiments to investigate the relationship between the ICA and cognitive processing load in dual task settings. Results showed that the ICA was a reliable measure of cognitive processing load and could predict performance in dual task settings.
Albaghli et al. investigates the use of initial cognitive load to predict user response to complex visual tasks [14]. The authors conducted an experiment in which participants were asked to complete a complex visual task while their pupillary responses were measured. Results showed that initial cognitive load, as indicated by pupil dilation at the beginning of the task, was a significant predictor of task performance.

Finally, the relationship between microsaccades and pupil dilation was researched by Raj et al. [15]. Microsaccades are small eye movements that occur during fixation and have been suggested to be related to cognitive processing. The authors conducted an experiment in which participants were asked to perform a visual search task while their eye movements were recorded. Results showed that there was a positive correlation between the amplitude of microsaccades and pupil dilation, suggesting that they are both related to cognitive processing.

In contrast to the studies stated above, our study specifically examines how distractions, even those unrelated to driving, can affect a driver's attention and cognitive processing. Previous studies, on the other hand, focused on the cognitive load and visual tasks. In order to compare the effects of two different distractions on attention and cognitive processing, our study includes two distractions: a complex math problem and a simple memorizing task. Additionally, our study analyzes the accuracy of the participants' responses while they were distracted along with the participants' pupil dilation. Therefore, our study provides a unique contribution to the understanding of the effects of distractions on driving safety and how these effects can be quantified and analyzed.
III. Software

a. MATLAB

MATLAB is a powerful programming language that is widely utilized in many technological and scientific disciplines. It offers a complete range of features and tools, making it perfect for carrying out research in the area of driving simulation. The simplicity with which Matlab can handle intricate computations and simulations is one of its main benefits. This makes it the ideal option for processing the information produced by the steering wheel and eye tracker employed in the project.

MATLAB has a well-established reputation for providing a user-friendly interface that enables researchers to conduct experiments quickly and efficiently. The platform's high-level programming language and built-in libraries make it easy to create complex algorithms and conduct statistical analysis.

The interoperability of MATLAB with many types of hardware, such as the steering wheel and eye tracker, is another significant advantage of utilizing MATLAB for this project. It is simple to interact with various hardware devices and gather data in real-time thanks to MATLAB’s built-in support for them. In order to fully comprehend how distractions affect driving performance, researchers are now able to take accurate measures of steering and eye movements.

Additionally, MATLAB has sophisticated data analysis and visualization features. Plotting and graphing capabilities integrated into the platform make it simple to visualize data gathered during trials, assisting researchers in better understanding the links between various variables. Due to all these functionalities, MATLAB seemed to be the right tool for our research.
b. **PSYCHTOOLBOX-3**

Psychtoolbox-3 (PTB-3) is a free, open-source software package that provides a range of tools for controlling and measuring visual and auditory stimuli in neuroscience and psychology research. PTB-3 is frequently employed in both fundamental and applied research, especially in the fields of cognitive neuroscience and vision science. Research involving eye tracking is one significant area where PTB-3 is used.

Eye tracking is a technique for capturing eye movements, which can reveal details about cognitive thinking, attention, and visual perception. Eye trackers assess a variety of eye movements, including fixations (periods of stable gaze), saccades (rapid eye movements), and smooth pursuit. They work by using cameras and software to watch the movements of the eye (tracking of moving targets). Eye tracking has a wide range of applications, from studying reading and language processing to investigating attentional biases in psychiatric disorders.

For controlling and measuring visual stimuli, which are crucial for eye tracking studies, PTB-3 offers a variety of functions. These capabilities include the capacity to create and deliver visual stimuli, manage the timing and duration of stimuli, and assess accuracy and reaction times. For accurate eye tracking data, PTB-3 also offers features for calibrating eye trackers. Before every experiment, eye tracking systems are usually calibrated to guarantee precise measurement of eye movements.

The capacity of PTB-3 to synchronize visual stimuli and eye tracking data is one of its key features. This makes it possible for researchers to correlate eye movements with particular visual stimuli displayed on the screen, which is crucial for correctly analyzing eye tracking data. PTB-3
provides functions for precisely synchronizing visual stimuli with eye tracking data, which allows researchers to accurately measure eye movements in response to specific visual stimuli.

PTB-3’s adaptability and customizability possibilities are additional notable characteristics. The programming language MATLAB, which is frequently employed in scientific study, is used to create PTB-3. This enables researchers to alter and expand PTB-3 to meet their unique study requirements. For instance, scientists can create their own visual cues or incorporate different data analysis or visualization tools.

In summary, PTB-3 as a software suite, offers a variety of functions for regulating and measuring visual stimuli in neuroscience and psychology study. As it offers functions for calibrating eye trackers, synchronizing visual stimuli and eye tracking data, and customizing and extending the software to meet particular research requirements, it is especially helpful for using eye trackers in research. As eye tracking becomes more widely used in research, PTB-3 will continue to be an essential tool for investigating visual perception, attention, and cognitive processing.

c. TITTA

Titta is a Python package for processing and interpreting eye-tracking data from the Tobii Pro eye-tracking equipment. A variety of tools and methods are available in the Titta package for the analysis of eye-tracking data, including the creation of gaze data visualizations, computation of fixation durations and saccade amplitudes, and the elimination of spurious data points.

A researcher at the University of Southampton named Dirkjan Niehorster created the Titta package, which is open-source and available on GitHub for usage by other researchers. The
software is made to operate with information gathered from the Tobii Pro eye-tracking system, a prominent instrument for researching visual perception and attention in many different research fields.

Hence, the Titta package is an invaluable tool for researchers who wish to examine eye-tracking data and learn more about how humans absorb visual information. Titta makes it simpler for researchers to examine and interpret their findings and to obtain a deeper knowledge of the intricate mechanisms that underpin visual attention and perception by offering a variety of functions and tools for working with eye-tracking data.
IV. HARDWARE

a. THE G920/G29 STEERING WHEEL

The G920/G29 is a steering wheel and pedal set designed for use with driving simulations and gaming consoles. For a more realistic driving experience, it has a realistic design and top-notch manufacturing, featuring a leather-wrapped steering wheel and metal pedals.

The G920/G29 has been utilized more frequently lately in studies for driving simulators [18][19]. It is the perfect tool for investigating a variety of elements of driving, including driver behavior, decision-making, and safety because of its high degree of accuracy and responsiveness, which enable exact measurement and manipulation of driving behavior.

Moreover, the G920/G29 has been used to examine how distractions impact road behavior. Researchers can replicate various distractions, such as phone calls or text messages, and assess how these affect a driver's reaction time and accuracy[20]. The G920/G29 has also been used to
look at how varied weather patterns and road conditions affect driving [21]. Researchers can evaluate how drivers react to various situations and pinpoint potential safety issues by modeling various scenarios.

The G920/G29 is a potent instrument for performing research on driving simulators, all things considered. It is the perfect instrument for researching many facets of driving behavior and enhancing driver safety because of its realistic design and high level of accuracy.

b. **TOBII PRO FUSION EYE TRACKER**

![Figure 2 Tobii Pro Fusion eye tracker](image)

Tobii Pro Fusion is a high-end eye tracking system designed to provide researchers with reliable and precise data for their studies. This system combines cutting-edge hardware and software to provide a variety of features and functionality, making it a flexible tool for different kinds of research. Advanced cameras and infrared illuminators on the Tobii Pro Fusion eye tracker enable precise and accurate recording of users' eye movements. The device can monitor both eyes at once and provide information on fixation spots, saccades, pupil dilation, and other metrics related to eye movement.
Tobii Pro Fusion system consists of a collection of software tools that make it easier to analyze and understand data. Researchers can view real-time eye tracking data and analyze data from multiple sources concurrently using the comprehensive data analysis software Tobii Pro Lab. Researchers can design unique studies using the software, including gaze-contingent displays that change visual stimuli in response to participant eye motions.

Numerous study disciplines, such as psychology, marketing, human-computer interaction, and neuroscience, have made extensive use of Tobii Pro Fusion [22]. Tobii Pro Fusion has been used by psychologists to study social cognition, cognitive processing, and visual focus and perception [23]. Tobii Pro Fusion has been used in marketing to gauge customer behavior, such as their attention to and preference for various goods and advertisements. In human-computer interaction, Tobii Pro Fusion has been used to study user behavior and design more effective interfaces [24].
V. EXPERIMENTAL SETUP

The experimental setup comprises a driving simulator that was designed as a nearly approximate real-world driving experience as achievable. In order to simulate driving, the simulator has a curved screen set at eye level. A 49-inch dual QHD curved monitor with ultrawide views is used, giving the driver a 180-degree perspective to simulate real-world driving situations. A vivid and detailed vision is given to the user thanks to the screen’s 1440p (Quad HD) 5120 x 1440 @ 60 Hz resolution.

![Image of 49-inch dual QHD curved monitor and Tobii Pro fusion eye tracker](image)

*Figure 3 49-inch dual QHD curved monitor and Tobii Pro fusion eye tracker*

For stability during the experiment, the Logitech G920/G29 steering wheel has been put on a wheel stand. The wheel support was made to stop the steering wheel from moving in any way that would affect the experiment’s accuracy. With force feedback and realistic movement, the steering wheel is made to give a natural experience of driving. The force feedback feature gives the driver a more authentic driving experience by simulating the resistance of a real steering wheel. The steering wheel contains functional buttons positioned similarly to an actual steering wheel in addition to force feedback and realistic movement. During the experiment, users can
react to the distractions on the screen by pressing one of these buttons. The experiment's distractions include visual elements, to which the driver responds by pushing the corresponding button on the steering wheel. The experiment is made more realistic using functional buttons on the steering wheel since it mimics a situation where a driver might have to react to distractions while driving in the real world. This feature offers a measure of the driver's responses, allowing for a more precise evaluation of their capacity to control distractions while driving.

The experiment's gaming chair is built to be comfortable for the driver throughout the test [29]. The driver can sit in the chair for a long time without feeling uncomfortable, which helps
them concentrate on the task at hand [30]. To ensure that the steering wheel is at the ideal height for the best driving performance, the driver can adjust the chair to their preferred height.

In this study, the driver's eye movements were monitored using a Tobii Fusion Pro eye tracker. To ensure precise eye tracking during the experiment, the eye tracker has been calibrated for each individual. The eye tracker uses a set of dots on the screen that the driver must stare at throughout the calibration procedure in order to figure out where the driver's eyes are. The eye tracker can accurately track the driver's eye movements throughout the experiment once the calibration process is finished. The eye tracker captures the driver's eye movements throughout the trial, providing useful information about where the driver is looking. In order to ascertain whether the driver is distracted during the trial, the eye tracker data is crucial. A high level of accuracy is provided by the eye tracker, which records the driver's eye movements at a rate of 120 Hz.
The experiment is carried out in a controlled space to guarantee the correctness and dependability of the data gathered from it. The closed environment is intended to offer a controlled atmosphere that reduces any irrelevant variables that might affect the study's findings. The area is soundproofed to keep outside noise out, and it is carefully lit to avoid glare or other visual distractions that can affect the driver's performance. This makes it possible to get reliable and precise data and guarantees that no outside influences will have an impact on the outcomes.

By conducting the experiment in a closed space, we are able to ensure that the users are not interrupted or distracted by any external people. This enables users to give the experiment their complete attention and their best effort while driving. Additionally, it guarantees that any data gathered throughout the trial is unaffected by outside influences. Only the users taking part in the experiment and the researchers conducting the study generally have entry to the experiment room. Throughout the experiment, the door to the space is normally kept shut to prevent any illegal access. This offers a safe and controlled setting for carrying out the experiments.

Results of an experiment may be significantly impacted by the lighting during that experiment. Hence, we carried out the trials in two different lighting environments—a brightly lit room and with the lights off—to guarantee that the results were not biased. The studies were carried out in the brightly illuminated room during the day, when there was a lot of natural light accessible. This made sure that the users could easily see both the buttons on the steering wheel and the videos playing on the screen. Also, the illumination stayed constant throughout the trial, ensuring that the user's perception was not affected by variations in the lighting.
In contrast, we did the studies in the second scenario with the lights out. This was done to mimic night driving conditions where the user must rely on their own vehicle's headlights and other lighting to navigate. It was crucial to assess the user's capacity to respond to distractions and maintain attention on the road in low-light situations. We were able to collect more data on the user's performance across different settings by running the studies in both lighting conditions. Our understanding of how distractions affect a driver's performance in both bright and low-light situations improved as a result of this method, which also ensured that the results were not biased towards a certain lighting condition.
VI. **EXPERIMENT**

Six users took part in this pilot experiment in order to collect a wide range of data and guarantee that the findings were not biased in favor of any one user. To make sure that the Tobii Fusion Pro eye tracker was precisely capturing each participant’s eye movements, each user had to go through a calibration procedure. The user was given a short amount of time before each trial to become used to the driving simulator and the steering wheel. Additionally, the user was given instructions on how to handle distractions during the trial.

During the trial, the users participated in 3 blocks. Each block had four different videos showing four different landscapes. In the first video, a typical road was shown. In the second, a farmland with lush vegetation was shown. In the third, a road was shown between rocky, dry mountains. In the fourth, a road was shown with snow covering both sides. The videos shown in the experiment were chosen to simulate different driving scenarios and environments to make the driving experience as realistic as possible. By showing different terrains, we aimed to replicate the diversity of driving conditions that drivers encounter in the real world. This diversity helped to create a more realistic and engaging driving experience for the participants.

Since the road conditions, weather, and other environmental factors were accurately depicted in each video, it was planned to be as realistic as possible. As a result, the distractions had a greater effect on the participants’ driving experiences and we were able to quantify their effects on driving performance more precisely. The experiment’s findings were kept from being skewed toward one driving scenario or setting thanks to the utilization of a variety of videos. We were able to collect a larger dataset that reflected a variety of driving circumstances and
scenarios by displaying several sorts of videos. This diversity also contributed to the experiment’s findings being relevant to a broader spectrum of drivers and circumstances.

The main goal of the experiment is represented on the screen by a red dot that represents the driver’s focus. The dot indicates how well the driver can maintain simultaneous attention on the road and distractions. The dot stands out clearly from the background as it is small (1cm in diameter) and solid red in color. The dot is set up to move dynamically in reaction to the movements of the steering wheel, simulating actual driving. The dot moves in accordance with how the operator twists the steering wheel. This requires the user to maintain attention on the dot and make sure it stays in the middle of the road and in the appropriate lane as well. The user must adjust the steering wheel appropriately to keep the dot in the appropriate lane because the roads in the films are not straight and feature curves.

![Figure 6 Distraction 1 – Mathematical problem](image-url)
There are two different kinds of visual distractions in every video. One challenged the user to solve a challenging math problem, and the other needed them to memorize an ordinary number. The user had to react to each visual distraction, which was presented during the video at predetermined intervals. The user had to choose from two possibilities after the distraction had been displayed in order to proceed with the response. The user had to push the X and O buttons on the steering wheel to choose from the options that were shown on the screen. To gauge how distractions affect driving performance, the responses for each distraction were tracked.

A math problem served as the experiment's initial distraction. Although the arithmetic problems were intended to be easy to understand, some of them were more difficult than others. The only operations used in each problem were addition, subtraction, multiplication, and division, which ensured that none of the problems were unduly challenging or complex. The math problem appeared in the screen’s left-top corner and stayed there for 10 seconds. A question requesting the solution to the arithmetic problem appeared in the same location after 10 seconds. The user was presented with two options, and to select their response, they had to press the X or O button on the steering wheel. Additionally, these choices were visible on the screen for ten seconds. The user was given a 10-second break after the first 10 seconds to allow them to return their attention to the road.

It was decided to utilize mathematics as a distraction since it takes cognitive processing and concentration, both of which might conflict with the focus needed to drive. The user had to shift their focus back and forth between the road and the math issue, simulating the distractions that drivers can experience in real-world circumstances. Two choices were presented to the user, which made it more likely that they would interact with the distraction rather than just ignore it.
Previous studies have shown that these kinds of exercises can significantly affect driving performance, which is an additional case supporting the use of math problems as a distraction. For instance, a research that appeared in the journal Transportation Research indicated that when asked to perform math problems while driving, drivers had slower reaction times and were more likely to miss important incidents on the road than those who were not distracted [31].

![Figure 7 Distraction 2 – Memorization task](image)

A straightforward memorizing task served as the experiment’s second distraction. This distraction was used to test how well participants could remember information while driving. Ten seconds after the video began, a five-digit number appeared in the bottom right corner of the screen. The number was displayed for a duration of 10 seconds, after which it disappeared, and a question was displayed at the same place asking which number was displayed. Similar to the previous distraction, the users were given a choice between two possibilities for their reaction, and they had to do so by using the X and O buttons on the steering wheel. The selections would vanish after 10 seconds, giving them another ten seconds to return their attention to the road. This approach was used in the experiment to gauge users’ concentration and focus on the
driving job as well as the effect of distractions on their memory and recall skills. The task at hand was straightforward, ensuring that users could do it without difficulty and with ease, leading to more accurate results.

The variety of distractions included in the experiment allowed for a thorough evaluation of the impacts of various cognitive demands on driving ability. The memorization exercises were displayed in the right bottom corner of the screen, and the complex math problems were displayed in the left top corner. These distractions were placed such that they wouldn’t obstruct the driver’s view of the road or the surroundings.

In order to guarantee that the information gathered was uniform across all participants, these two distractions were included in each of the four videos for each of the three trials. A gray screen was shown for 5 seconds after every video was completed to give the user’s pupils time to return to their normal size. This was crucial to ensure that the user was starting each video with no previous experience and to prevent the impacts of one video from affecting the next. When the user hits the button to choose an answer, a beep sound is made, and this is an essential component of the experiment’s setup. There is no need for the user to press anything after that because it makes sure they are aware that their input has been received. The beep sound is played over the computer’s speakers. It is intended to be distinct and clear so that the user can hear it with ease. In order to let the user know that their input has been received, the beep is timed to sound just as the button is pressed. This feature is essential to this experiment because it guarantees the accuracy and dependability of the data that is gathered. Additionally, it contributes in preventing user annoyance or confusion caused by the experiment’s design, which might have an adverse effect on their performance. To determine the effect of distractions on
driving performance, statistical methods were applied to the data gathered from the experiments. Both the number of accurate responses and the pupil dilation for each distraction were examined to determine their effects on accuracy and concentration.
VII. DATA ANALYSIS

The analysis of this experiment involves several steps. Initially, the data collected from the experiment is analyzed to obtain a statistical representation of the user's performance. This is the data that an eye tracker obtained during the experiment. This data is used to analyze how individuals interact with their surroundings.

A huge amount of data that was gathered throughout each experiment is contained in a.mat file that is used to load the eye tracking data into a MATLAB program. The code produces variables for various eye tracking data points, such as gaze point location, pupil diameter, gaze origin coordinates, etc. after the data has been loaded.

Additionally, a column of cell data titled "messages" is collected from the data. These messages were sent during the experiment to indicate specific incidents during the experiment. We can better understand how the eye movements relate to various experimental circumstances or events by adding these messages in the study. After parsing all of the data, a table is formed with all of the above-mentioned variables as columns and rows corresponding to each millisecond of data. This table is saved in a new CSV file that we can use in the next phase to get the necessary information for our analysis.

The next step in the analysis involves using a new program that uses the previously created file as input to generate a new CSV file that has been filtered to only contain the specific data that we are interested in. After the data has been loaded from the input file, it is processed to only contain the pupil dilation data and the responses for each user and trial before and after each distraction. The first step in doing this is locating the indexes in the table where the message column includes the message connected to the first distraction, signifying the beginning of a
distraction period. The program then scans through the messages to look for a certain message that signifies the end of the distraction. In this way, the total duration of the data is split into 4 segments: “Before distraction 1”, “during distraction 1”, “before distraction 2”, and “during distraction 2”. For each of these runs, the pupil dilation values and the responses for the distractions are gathered for each of these 4 sections. This procedure is repeated for every block for every user. The end result is a subset of the original data table that only contains the pupil dilation values for the designated time periods. Once all the necessary information has been gathered, it is saved in a new CSV file as shown in Table 1, that will subsequently be utilized to create the necessary graphs.

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<th>Response1</th>
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Table 1 Pupil dilation data for distractions

In the final phase of analysis, the data gathered in the previous phase is compared and analyzed through the generation of relevant graphs and statistics. This phase's major goal is to better understand how the pupil dilation changes before and during the distractions in each of the 4 movies. For each movie, we create bar graphs to compare the pupil dilation before and during distractions. This makes it easier to compare the degree of pupil dilation caused by each movie and determine which ones had the most impact. Additionally, we create a bar graph that
compares the pupil dilation before and after the distractions and displays the mean of all 4 movies. This aids in comprehending the overall effect of distractions on pupil dilation across all movies.

To ensure the statistical significance of the data, we calculate and plot the standard error in each of these graphs. This helps in understanding the degree of variability in the data and provides an estimate of how confident we can be in the observed effects. Finally, we compare the total number of accurate responses for both distractions to determine the accuracy of the answers given during the experiment. This aids in understanding the level of distraction caused during each movie and how it impacts the execution of cognitive tasks. The overall objective of this analysis is to provide a thorough understanding of how pupil dilation changes before and during distractions in each of the movies and how it impacts the execution of cognitive tasks. We can derive important conclusions and insights from the experiments by analyzing the data gathered from the earlier steps and plotting relevant graphs.

When comparing the means of two groups, a statistical test called a T-Test is employed to evaluate whether the difference is significant. In this instance, we are comparing the mean pupil dilation before and during the distractions using T-Tests. The T-Test analyzes the difference between the means of two groups in relation to the variance within each group by computing the T-value. Greater significance exists between the two groups when the T-value is higher. The P-value, which measures the likelihood that the observed difference resulted from chance, is calculated as part of the T-test. There is a significant difference between the two groups when the P-value is observed to be less than 0.05.
We performed T-tests on the pupil dilation data before and during distractions for each of the four movies as part of our analysis. We discovered that the difference in pupil dilation before and during distractions was significant for all four movies, with the T-value being significant and the P-value being less than 0.05 in each case. This indicates that our study is sound and that the distractions had a significant effect on pupil dilation.
In this pilot study, we measured cognitive processing and focus using pupil dilation. The autonomic nervous system is known to regulate pupil dilation, and it has been demonstrated that during tasks requiring higher cognitive processing and focus, such as problem-solving or decision-making tasks, pupil dilation increases [27].

We plotted the graphs to compare the difference in pupil dilation before and during the distractions and obtained similar results to each video as shown:

![Video 1: Pupil Size Before and During Distractions](image)

*Figure 8 Pupil size comparison before and during distractions for video 1*

Video 1 as shown in Figure 8, had an average pupil dilation of 3.6mm before distraction 1 and an average pupil dilation of 2.56mm during distraction 1. The T-Test resulted in a P value < 0.0001.
and the T-Test = 8.0364 indicating the difference before and during the distraction 1 to be extremely statistically significant. The graph also had an average pupil dilation of 3.46mm before distraction 2 and an average pupil dilation of 2.68mm during distraction 2. The T-Test for this distraction resulted in a P < 0.0001 and the T-Test = 14.8180 indicating the difference before and during the distraction 2 also to be extremely statistically significant.

Figure 9 Pupil size comparison before and during distractions for video 2

Video 2 had an average pupil dilation of 3.63mm before distraction 1 and an average pupil dilation of 2.74mm during distraction 1 as shown in Figure 9. The T-Test = 20.7156 and P < 0.0001 indicates a significant difference before and during the distraction 1. The graph also had an average pupil dilation of 3.53mm before distraction 2 and an average pupil dilation of 2.68mm
during distraction 2. The values $T\text{-Test} = 12.0675$ and $p < 0.0001$ indicates a significant difference before and during distraction 2.

![Figure 10 Pupil size comparison before and during distractions for video 3](image)

Video 3 had an average pupil dilation of 3.61mm before distraction 1 and an average pupil dilation of 2.76mm during distraction 1 as shown in Figure 10. There was a significant difference before and during the distraction 1 with $T\text{-Test} = 24.6262$ and $P<0.0001$. The graph also had an average pupil dilation of 3.35mm before distraction 2 and an average pupil dilation of 2.75mm during distraction 2. There was a significant difference before and during the distraction 2 with $T\text{-Test} = 30.2089$ and $P<0.0001$. 
Video 4 had an average pupil dilation of 3.57mm before distraction 1 and an average pupil dilation of 2.76mm during distraction 1 as shown in Figure 11. The difference before and during the distraction 1 was statistically significant with T-Test = 25.9143 and p < 0.0001. It also had an average pupil dilation of 3.35mm before distraction 2 and an average pupil dilation of 2.75mm during distraction 2. The difference before and during the distraction 2 was extremely statistically significant with T-Test = 31.1560 and p < 0.0001.

We also plotted the graph taking the mean of all four videos and obtained the graph as shown in Figure 12.
This graph as shown in Figure 12 had an average pupil dilation of 3.60mm before distraction 1 and an average pupil dilation of 2.71mm during distraction 1. The difference before and during the distraction 1 was extremely statistically significant with T-Test = 10.4189 and P < 0.0001. This graph also had an average pupil dilation of 3.42mm before distraction 2 and an average pupil dilation of 2.71mm during distraction 2. The difference before and during the distraction 2 also was extremely statistically significant with T-Test = 13.5936 and p < 0.0001.
Another interesting observation from Figure 12 is that there was no significant difference in pupil dilation between the two types of distractions - a complex math problem and a simple memorizing task. It implies that being distracted itself may have more of an impact on cognitive functioning than the kind of distraction. Whatever their nature, distractions have the potential to divert our attention from the primary task at hand. This may result in a decrease in the demands placed on cognitive processing and attention, which will then have a negative impact on pupil dilation. The reduction in pupil dilation during distraction compared to before distraction in this study was indicative of the participants' attention being successfully diverted by both types of distractions.

Finally, we also plotted the graph to check the accuracy of responses the users selected for the distraction.

![Figure 13 Percentage of correct responses for both distractions](image)
The fact that the percentage of correct answers dropped in Figure 13 when participants were distracted suggests that they were unable to completely concentrate on both the driving tasks and the distraction tasks at the same time. This phenomenon is known as dual-task interference, which occurs when two tasks require cognitive resources that exceed the limits of the cognitive system. In other words, the task of driving and distraction tasks competed for the participants' cognitive resources, which reduced accuracy for both tasks. This finding is particularly relevant in the context of distracted driving, as it highlights the potential danger of engaging in distracting activities while driving, even if the distractions are seemingly simple or easy.
IX. CONCLUSION

The distractions in this study were complex math problems and simple memorization tasks, which needed different cognitive processing than driving. The participants' pupils were more dilated while driving because their attention was largely on the visual inputs of the video, which required more cognitive processing and attention. But, during the distraction, they were forced to focus on responding to the questions on one small part of the screen, which required a different form of cognitive processing. As a result, there was less demand for cognitive processing and attention, which reduced pupil dilation. Hence, the findings imply that the distractions had a significant impact on the participants' levels of attention and that during the distraction, their focus was redirected to completing the math problems and the memorization tasks. This result is in line with earlier research, which showed that cognitive load can affect pupil dilation and that when cognitive load is decreased, pupil size is less [27][28].

The fact that there was no statistically significant difference in pupil dilations between the two types of distractions also shows that the degree of cognitive load may not be that significant in decreasing the focus. Instead, it's possible that any distraction—no matter how simple or complicated—can interfere with driving and reduce the driver's focus. This emphasizes how important it is to avoid all types of distractions while driving, including those that may appear easy or harmless.

Additionally, the results of the accuracy analysis suggest that distractions may interfere with task performance. The decreased accuracy shown during distractions indicates that people
struggle to divide their attention between multiple tasks, which can result in mistakes on both the primary task and the distraction task.

This study emphasizes the significance of avoiding distractions when engaging in activities that demand a lot of concentration, like driving. Any distraction has the potential to be harmful, reduce performance, and even result in errors or accidents. To ensure safety and optimal task performance, it is crucial to eliminate distractions and keep your focus on the task at hand.
X. Future Applications

Based on the results obtained in this research, future applications as follows can be developed:

a. Developing better distraction detection systems: An alert can be issued to warn the driver if their eyes are taken off the road for an extended period or if their pupil dilation suggests a lack of focus.

b. In-vehicle distractions: This study can be extended to suggest that distractions within the vehicle, such as GPS or infotainment systems, may also have a negative effect on the driver's focus. Therefore, more user-friendly interfaces that are less likely to distract the driver can be implemented into the design of future automobiles.

c. Autonomous vehicles: As these vehicles grow in number, it will be crucial to make sure that the drivers can remain focused on the road ahead without becoming distracted. It is possible to utilize eye-tracking technology and other sensors to make sure that passengers are alert and capable of controlling the vehicle if necessary.

d. Enhancing driver training programs: The study can be utilized to create more efficient driver training programs that educate drivers on how to stay focused and avoid distractions while driving.

e. Healthcare: Medical professionals must maintain a high degree of focus and cognitive processing throughout critical operations. The findings of this study can be used to create training materials and equipment that will aid healthcare workers to minimize distractions and focus during procedures.
REFERENCES


