Preventive Driver Analysis System for Highway Hypnosis

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Abstract

The core research question of this study was to develop and evaluate an in-car driving safety system aimed at detecting and preventing highway hypnosis, a trance-like state that can endanger drivers. The methodology involved a combination of expert consultation, surveys, and engineering design. Initially, experts in advanced driving techniques were consulted to identify the key indicators of highway hypnosis, such as blink rate, eye openness, and head and body movements. This input, combined with survey results, led to the development of an algorithm designed to monitor these indicators via cameras integrated into the vehicle, using a Raspberry Pi platform.

During the engineering phase, the optimal placement of cameras within the vehicle was determined using 3D design software, ensuring the system's effectiveness. Testing the prototype revealed that the system successfully detected early signs of highway hypnosis and triggered appropriate warnings, thereby potentially preventing accidents.

The study concluded that the developed system could play a significant role in reducing traffic accidents and enhancing road safety by addressing a previously underexplored aspect of driver behavior. The findings suggest that implementing such systems in vehicles could be a vital step toward safer driving conditions, particularly on monotonous highways where the risk of highway hypnosis is higher. Further implications include the potential adaptation of the system for use in autonomous vehicles, where driver attention remains crucial.

Keywords: Highway Hypnosis, Driving Safety, Smart Vehicles, Traffic Accidents

Purpose

This study aims to develop an intelligent in-car driving safety system designed to preemptively detect and prevent the issue of highway hypnosis, also known as highway trance, through auditory warnings. Research indicates that there is currently no active system in the existing literature that addresses this problem. Although various studies and experiments have been conducted to elaborate on the issue of highway hypnosis, there is a lack of research focused on its early detection. Therefore, this study aims to develop and integrate four different image processing software applications on Python to detect early signs of hypnosis in drivers and intervene accordingly.

The developed system is intended to be affordable, portable, and retrofittable to any type of vehicle. The project also aims to have commercial and export potential. Additionally, the study focuses on the indirect goals of preventing potential loss of life and property that may result from accidents. During the research process, it was observed that awareness of highway hypnosis is low, and to address this, it is planned to raise awareness through social responsibility initiatives and promotional activities. This will help spread the understanding of the problem and encourage interest in ongoing and future research in this area.

Introduction

The increase in the number of active vehicles on the road today has been directly proportional to the rise in traffic accidents, highlighting the importance of intelligent driving safety systems. With 99% of accidents being driver-related, it is crucial to address the challenges drivers face and the factors that distract them (Çavdar, Uçar, 2013). In this context, understanding the impact of highway hypnosis, a situation affecting drivers during long journeys, on traffic safety and developing solutions to counteract it is of paramount importance (National Highway Safety Administration, 2021). Despite numerous hypotheses proposed regarding highway hypnosis, there has been no progressive international step towards solving road hypnosis. The aim of this study is to assess and increase awareness of highway hypnosis, develop findings related to the issue, and create technological solutions to address the problem.

Highway hypnosis is a state of hypnotic trance experienced by drivers while driving on long, straight roads that are visually undisturbed; it is a significant factor contributing to a high rate of road traffic accidents and life-threatening injuries (Manikandan, Vijayan, 2023). This condition, which appears similar to sleeping with eyes open and is explained within the framework of cognitive psychology, causes the brain to develop automated behavior in drivers due to the focus of consciousness and subconscious on different stimuli (Williams, 1963).

According to researcher Jim Horne from the Sleep Research Centre at Loughborough University, while a driver may appear to be focused on driving, simple reactions dependent on road conditions (e.g., tracking straight lines, steering) continue partially due to muscle memory. However, the driver's perception of speed, distance, and stimuli (e.g., tunnels, intersections, bridge entrances, pedestrians, following distances, and vehicle exits) diminishes. Although we frequently experience hypnosis in daily life (e.g., while watching a film, reading a book, attending a lecture), its occurrence during driving poses a risk (BBC, 2013).

The influence of modern highways and vehicles on the occurrence of highway hypnosis is significant. Modern highways are praised for their utility and comfort but criticized for their monotony. There are no steep gradients, curves are wide, pedestrian access, stopping, and walking are prohibited, and slow-moving traffic is redirected to alternative routes. Under these conditions, driving requires minimal engagement with stimuli and reality; there are few distracting factors (Karlin, 1997).

Similar praise and criticism are directed at modern automobiles. Seats are designed for maximum comfort, necessitating maintaining the same posture for long periods. The steering mechanism is designed for "finger-tip control," with minimal steering control needed, especially on straight and wide roads. Vibrations and shocks are minimized; the engine's continuous dull sound synchronizes with the slight vibrations of the tires (Adeyemi, Paul, Delmelle, DiMaggio, Arif, 2022). It is also known that when in a state of comfort, responses to our environment are limited (Shor, 1959). Increasing use of automatic transmission vehicles also reinforces this situation. It is hypothesized that the monotony of modern highways combined with the comfort and ease of modern vehicles introduces a new danger to contemporary driving.

An examination by the National Highways Authority of India revealed that 60% of accidents occur on newly constructed highways, with highway hypnosis being a primary cause. Recent accidents on the first section of the Samruddhi Expressway in Maharashtra have been attributed to highway hypnosis. According to authorities, approximately 140 accidents occurred within 3 months of the highway's opening, with 39 fatalities and 143 injuries. Highway officials aim to prevent highway hypnosis by installing billboards, signs, posters, and message boards along the Samruddhi Expressway to engage drivers with constructive distractions (Manikandan, Vijayan, 2023).

Figure 1 - Sample Image from the Samruddhi Expressway

As a result of this trance state, even if the driver continues to operate the vehicle, road awareness significantly decreases, leading to insensitivity to the road. The driver is unable to respond quickly to sudden stimuli (e.g., pedestrians, animals, traffic lights). Accidents often occur at speeds above 140 km/h because the driver in a state of hypnosis is unaware of their speed. Individuals in a hypnotic state may experience partial or complete amnesia (loss of awareness or memory). Many experienced drivers have encountered this issue. Additionally, backup drivers and assistants often report that the driver appears dazed and unresponsive. In some cases, this response is observed from passengers; however, it is noted that it is more difficult for others to detect this response compared to the driver (Wertheim, 1978).

According to Wertheim, it has been reported that experiences occur under the following two conditions: (a) when drivers are required to follow trucks or other large vehicles over significant distances or (b) during nighttime driving where the visual range is limited by the beam of light. Under condition “a,” numerous accidents resulting in rear-end collisions have occurred and continue to occur. A truck moves to the shoulder, and a car that has been following it mechanically follows and eventually collides with it. There is no skid mark, no evidence of braking, and even no evidence that the driver was moving toward the truck.

Figure 2 - Example Accidents Resulting from Highway Hypnosis

Due to highway hypnosis, drivers often report that they do not remember the accident because they experienced amnesia during the first and last 15 minutes of the accident. Many accident victims claim, “It suddenly appeared in front of me, I didn’t see it,” which is another result of the hypnotic state. Such rear-end collisions create conditions that challenge police and traffic engineers. Additionally, the legal responsibility becomes questionable since the driver experiencing highway hypnosis does not consciously perform their actions and does not remember the event. The scenario that emerges in such cases shows that the driver has started following the vehicle in front irreversibly (Manikandan, Vijayan, 2023).

Since the 1950s, many different explanations have been proposed to explain highway hypnosis. These suggestions do not include rigorous and quantitative research explanations, mainly due to the limitations of the available technology and the lack of recognition of highway hypnosis as a significant problem. Some of these suggestions are outlined below.

McFairland and Moseley (1954) argued that the primary cause of this phenomenon is fatigue. However, this theory is limited by the difficulty of objectively measuring fatigue and the observation of highway hypnosis even in the absence of fatigue (see discussion: Crawford, 1971).

Williams (1963) was the first to introduce the term "Highway Hypnosis," suggesting that the monotony of the environment and the necessity to focus on a narrow field may lead to a hypnotic trance state. In new highways, the unchanging glare from the road is continuously within the driver's field of view. Additionally, glares from the hood and instrument panel also induce trance (Doreus & Schaefer, 1945). The bright fixation points and monotony mentioned have played an active role in hypnotic induction methods since ancient times, as seen in records from the Hebrews and Hindus. Since hypnosis is a self-induced state, there is no significant difference between self-induced hypnosis and hypnosis occurring spontaneously. The only thing the individual conducting the experiment can influence is creating an environment suitable for the individual being observed, which is inherently provided by the nature of the road. Williams' (1963) hypothesis is one of the most widely accepted theories. However, the difficulty in quantifying monotony and automaticity and defining these terms behaviorally and physiologically limits this explanation.

Roberts (1971) proposed that the primary cause of the symptoms is "functional hyperinsulinism," characterized by extreme sensitivity to blood sugar concentration. Although sudden loss of consciousness observed in individuals with this disorder supports the hypothesis, the primary difficulty is that the definition assumes everyone experiencing highway hypnosis is narcoleptic or has functional hyperinsulinism.

Another hypothesis with a higher level of verifiability compared to previous hypotheses and currently widely accepted is Wertheim's (1978) theory. This theory also shows that Williams' (1963) inference is partially effective. Wertheim argues that mental abilities are related to the oculomotor system, specifically suggesting that eye movements during driving have a significant impact on the oculomotor system and a non-negligible effect on other psychological functions.

The oculomotor system can be considered part of a feedback control system that provides eye movements. The retinal information about the position of an image relative to the fovea (retinal error signal) is generally considered the main feedback signal in this system.

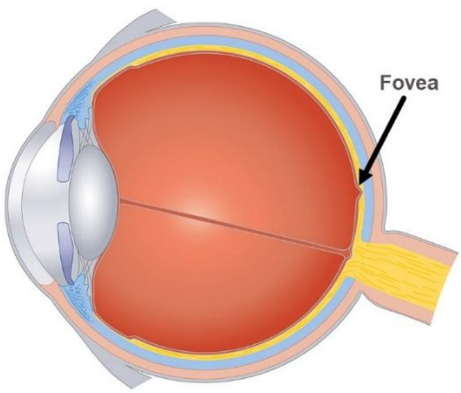

Figure 3 - The Region of the Fovea in Eye Anatomy

Studies on the effects of proprioceptive signals on eye muscles suggest that these signals do not play a significant role in oculomotor control (Brindley and Merton, 1960; Fender and Nye, 1961; Merton, 1964; Festinger and Canon, 1965; Robinson, 1968; Weisfeld, 1972). However, this does not conclusively prove that conscious eye behaviors have no effect on oculomotor control, as this might be a phenomenon where conscious eye movements are disregarded. Instead of the inference that eye movements only exhibit reflexive behaviors, the hypothesis of the necessity of extra-retinal information is currently in use.

According to this hypothesis, oculomotor neurons in the brain can use both retinal and extra-retinal information when sending neural signals to eye muscles. However, retinal error information is not always required for feedback to the eye muscles (Steinbach, 1969; Young, 1971; Wertheim, 1974; Festinger, 1976). Especially in cases where the eyes follow a predictable visual signal, automatism may develop in eye muscle activity, forming an internal motor program. This motor program can reduce the need for retinal error information for oculomotor neurons, but vision continues unaffected. In this situation, two components are identified in oculomotor control: retinal feedback and intention.

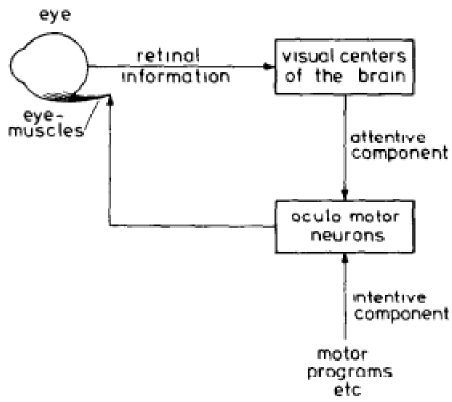

Fig. 1. Schematic representation of the attentive and intentive components in oculomotor functioning.

Figure 4 - Diagram Showing the Structure of the Oculomotor System (Wertheim, 1978)

The distinction between attentive and deliberate oculomotor control is not necessarily implied to relate to perception as it only refers to different inputs to oculomotor neurons. It is unlikely that there is a clear binary between attentive or deliberate control. The degree to which retinal information serves as a monitoring principle determines how much eye movements are controlled with attention or intention (Wertheim, 1974).

Wertheim has demonstrated this hypothesis through various experiments. The implication is that since eye movements represent both conscious and unconscious actions to some extent, they play a significant role in highway hypnosis. Eye muscles continue to move highly with signals coming to the retina. However, there is a variable ratio between cognitive movement and this.

In this context, the complexity and interrelationships of various theoretical approaches to explaining highway hypnosis reflect the depth of the issue. In this project, a system has been developed to detect and prevent highway hypnosis at an early stage based on these studies.

Methods

Materials

- Raspberry Pi 4B (8GB RAM) – 1 unit
- Raspberry Pi Camera Module 3 – 1 unit
- USB Camera – 1 unit
- Buzzer – 3 units
- Powerbank – 1 unit

Software and Libraries Used

- SolidWorks
- PyCharm
    - Python
    - OpenCV
    - Mediapipe
    - Time
    - Numpy
    - PyGame
    - CvZone

Raspberry Pi 4B- The Raspberry Pi 4B is a single-board computer (SBC) developed by the Raspberry Pi Foundation in the United Kingdom. For this study, the 8GB RAM version was used due to availability, but systems with higher RAM sizes will perform more stably. Its ease of use, widespread adoption, relatively low cost, and stable performance were influential in its choice.

Figure 5 - Raspberry Pi Used

Raspberry Pi Camera Module 3 - The Raspberry Pi Camera Module 3 is the official Raspberry Pi camera module featuring a 12-megapixel Sony IMX708 image sensor, automatic focus, low-light sensitivity, and HDR (High Dynamic Range) support. It was chosen for its performance in low light conditions and the advantages offered by automatic focus in terms of accuracy and stability in software.

Figure 6 - Raspberry Pi Camera Module 3

Buzzer- A buzzer is a circuit component commonly used to produce sound with a voltage range of 2 to 4 volts. It creates weak vibrations by inducing sudden changes in current in a coil. It was chosen for its low cost and low energy consumption.

Figure 7 - Buzzer

Powerbank- A power bank is used as a temporary power supply, while in the normal system, current will be drawn by stepping down the power from the battery.

Figure 1- Powerbank

USB Camera- It was chosen due to the single flexi connector available on the Raspberry Pi board for the camera and the unavailability of multiplexer products in Turkey. In cases where a multiplexer is available, it is also possible to use the Raspberry Pi cameras.

Highway hypnosis is one of the significant issues that, despite being a hidden cause of many severe injuries and fatalities worldwide, has not received much attention in the literature. Our project aims to raise awareness about highway hypnosis and develop a system with national export potential that can prevent deaths and injuries before they occur.

The project follows a systematic and detailed approach based on four main engineering design process steps (literature review, software, design, testing). This includes literature review, surveys, collecting experiences from knowledgeable individuals, evaluation, algorithm development, software arrangement, software enhancement, design, assembly, testing, and further refinement.

a- Literature Review/Survey and Solution Development

The issue falls within the scope of cognitive psychology. It was found that while many sources often support each other, some also show discrepancies (see “Introduction” for discussion). Given the difficulty of proving the psychological phenomenon of "highway hypnosis" through quantitative experiments, the study proceeded through qualitative experimental methods. Initially, document/data analysis was completed. Consultations were held with advanced driving techniques experts. An online public survey was conducted to measure awareness levels. In addition to measuring awareness levels, individuals who experienced the phenomenon shared their experiences. Cameras were installed in vehicles to examine driver images during long-duration drives.

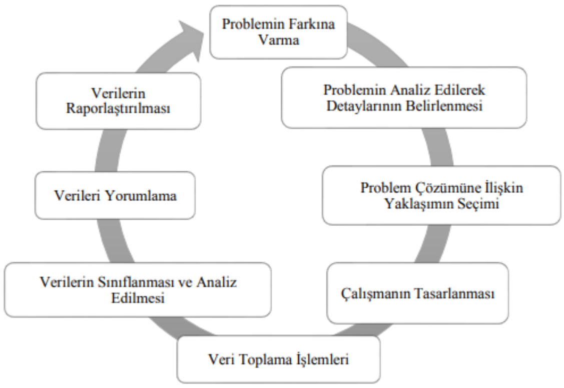

Figure 2- Qualitative Research Processes (Baltacı, 2019)

Figure 10 - Driver Images Observed During Long Drives

Figure 11 - Cameras in the Observation System

After meticulously completing each stage of the qualitative research process and identifying all the primary and auxiliary methods that could be used to detect highway hypnosis, the possible solution systems were evaluated. Three main methods were found, and the most suitable one was selected based on different criteria (suitability, usability, cost, portability).

The first method: Involves detecting and measuring the frequency of touches on the radio, steering wheel, and other frequently touched areas by the driver. Advantages include its ability to work fully integrated with fatigue detection systems and potentially using data from existing fatigue detection systems. Touch detections on radios and manual gear shifts can be done with inexpensive touch sensors. However, problems may arise with sensors on increasingly popular digital screens and digital-automatic gears. It has been observed that existing fatigue detection systems cannot detect highway hypnosis and are inadequate for this situation. There is uncertainty about the stability of the data from these systems. Additionally, a system that cannot be retrofitted means it would need to be installed during vehicle manufacturing, potentially excluding vehicles already in use within our target audience. For these reasons, this method was not chosen.

The second method: Is a solution system developed using wearable technologies. Advantages include increasing and guiding the use of increasingly popular wearable technologies today. It can also integrate with any driver and has high accuracy due to direct skin contact. When integrated with the vehicle's audio system, it can be used without requiring any additional setup in the vehicle. However, this method is quite expensive. While heart rate and blood oxygen levels can provide information about highway hypnosis, individual baseline levels vary, making specific value examination inaccurate. Additionally, it can be easily affected by factors such as ambient temperature and may cause discomfort to the driver. Driver comfort and system continuity are critical in the project. For these reasons, this method was not chosen.

The third method: Involves an intelligent system with four different image processing software modules. The system analyzes and interprets the driver's eye, head, and body movements. The driver's movement rates (blinking frequency, eye openness, head rotation, vehicle-road control movements at intersections, back-arm angles, and general movement status) are collected individually for the first 15 minutes and termed as "normal." Each driver has unique normal values, and the system resets its initial data with each power cycle. This personalized system, containing two cameras, a microcontroller, and buzzers, is very cost-effective. The system continues to operate by discarding only the average of the software that fails to detect a situation, ensuring high accuracy. The system can be easily integrated into in-car cameras of both developed and developing vehicles and is powered by the vehicle's battery with very low energy consumption. For these reasons, it was chosen.

b- Software Preparation (Findings Assessment, Algorithm...)

Following the determination of the most suitable method, efforts have commenced to develop four different image processing software programs. In this context, a system algorithm has been established, and to facilitate easier modifications to the developed algorithms, a single algorithm was created.

The Softwares

The software was developed using Python in the PyCharm environment, tailored to the algorithms. It primarily employs the OpenCV and MediaPipe libraries. A description of the software development process is provided below:

1. Software: This software represents a basic example of image processing used for motion detection. The OpenCV library has been utilized. It fundamentally captures video streams from a webcam, processes these video streams to detect motion, and visually highlights the detected motion. The software logically initiates real-time image transfer using a "0" parameter. By creating an object in the background, it detects pixels moving on the object. A mask is created to identify pixels changing relative to the background, and contours are detected and looped over, with boundaries drawn. The drawn boundaries result in masked and framed outputs.

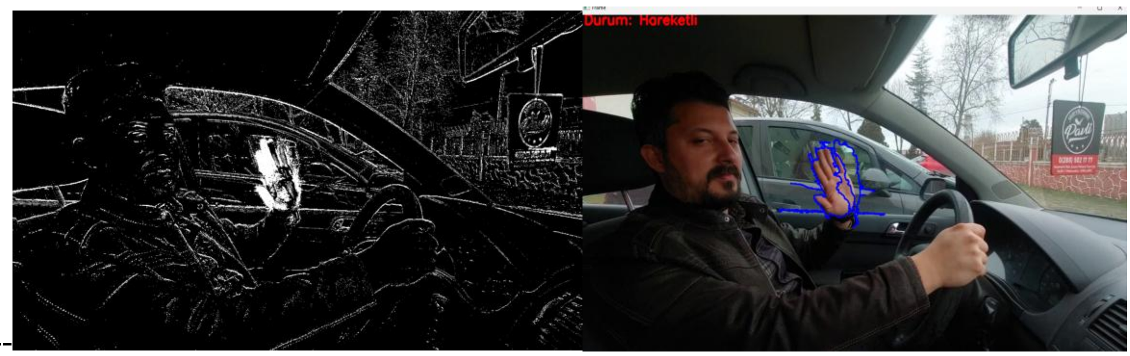

Figure 3- 1. Software Testing

2.Software: This image processing software is designed to measure driver movements such as reaching, gripping, and touching by identifying body landmarks. The MediaPipe and OpenCV libraries are predominantly utilized. The MediaPipe Pose model is employed to define body postures. The offset distance between symmetric body landmarks, such as the hips, eyes, and shoulders, is defined as follows:

$$ofset = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

The system defines offset distances and body landmarks, and measures the change in distance based on x and y coordinates during the software's operation.

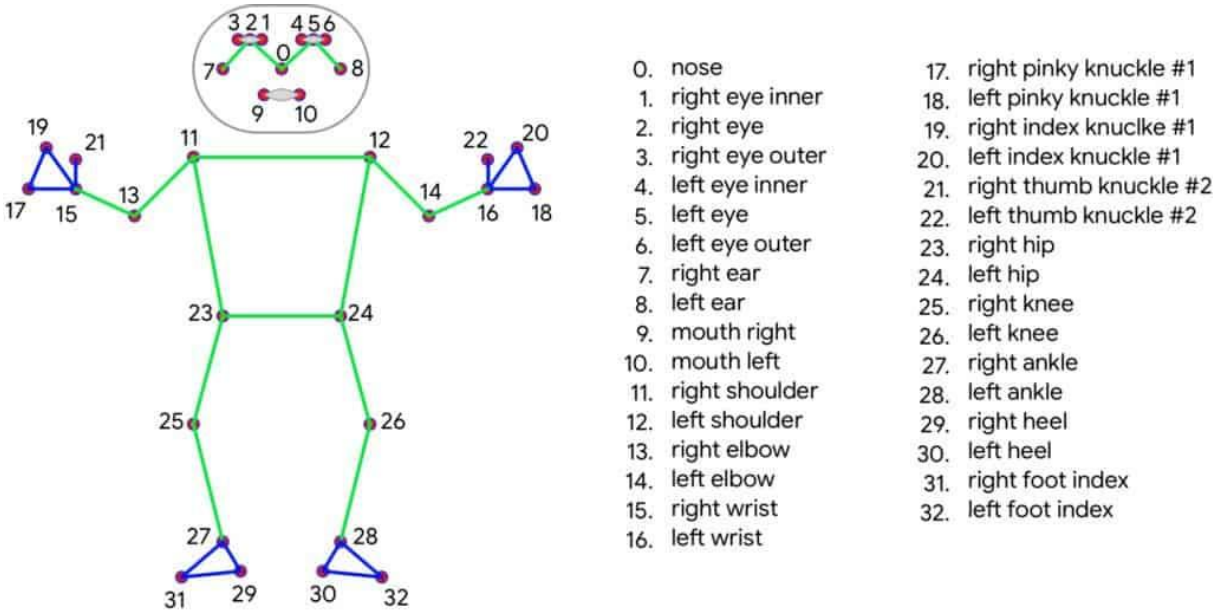

Figure 4- MediaPipe Pose

Figure 5- Driver Body Landmark Identification Test

1. *and 4. Software:* As the third software, an image processing program was developed to monitor head movements and the driver's attention to the road. As the fourth software, an image processing program was created to detect and graphically represent the number of blinks and the instantaneous eye openness. Both software programs utilize Convolutional Neural Network (CNN) models. In the third software, facial index points were detected, and the software was developed based on changes in these values. The PERCLOS algorithm, which is commonly used in fatigue detection systems for its precision and rapid positioning capabilities, was also employed in this software.

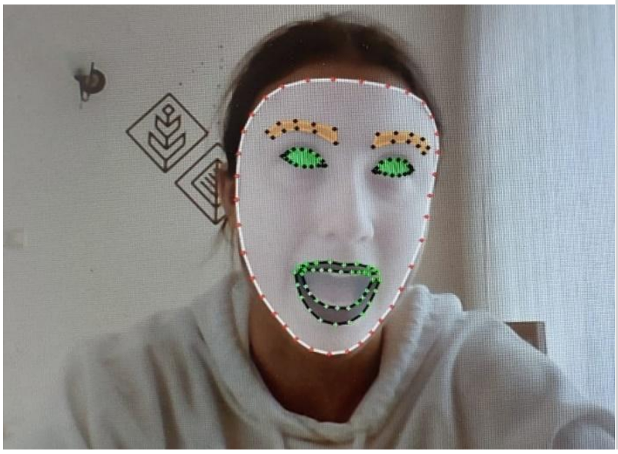

Figure 6- 3. Initial Testing Phase of Software Development

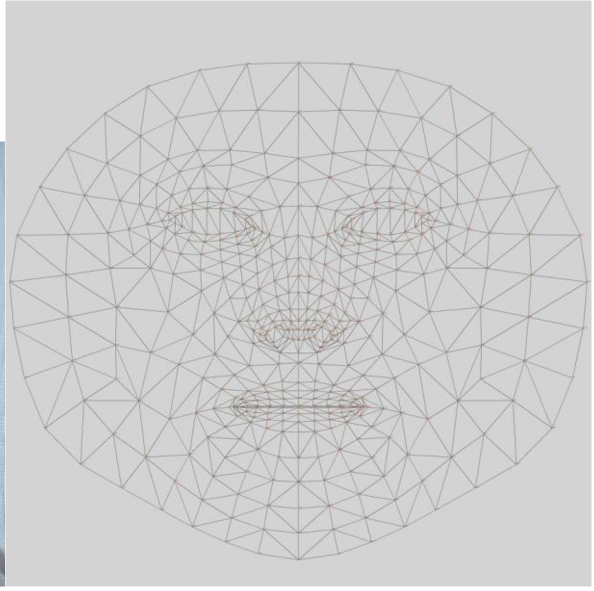

Figure 7- General Facial Contours

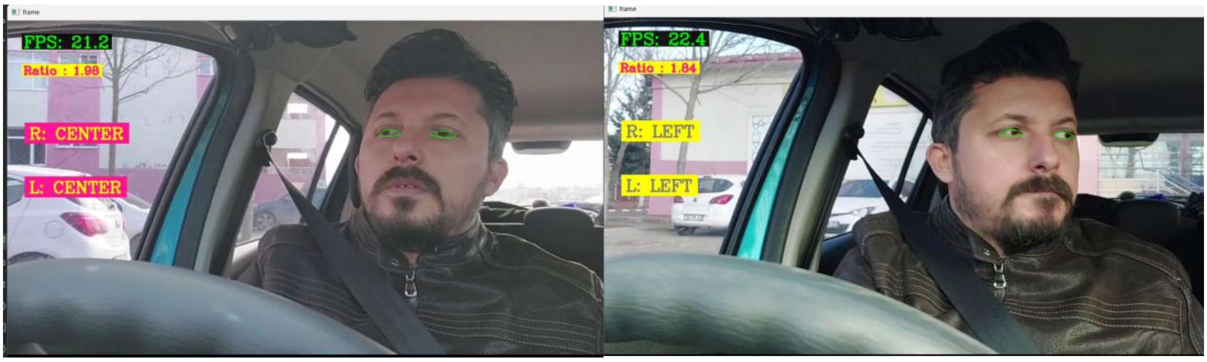

Figure 8- Software Testing Phase

Similarly, in the software used for tracking eye movements, contour points on the eyes have been identified. In this system, evaluation has been performed based on rotation and photometric changes according to the Viola-Jones detection system. The equation used to detect these changes has been specified.

$$\frac{|P2 - P6| + |P3 - P5|}{2|P1 - P4|}$$

Figure 9- MediaPipe Eye Landmark Detection

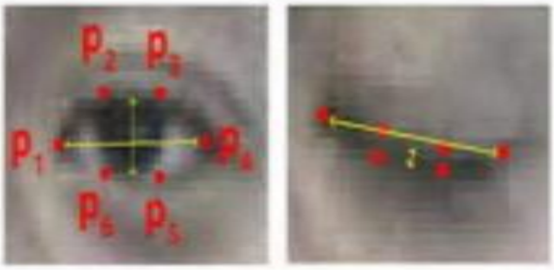

Figure 10- Identification of Points Used in the Software

Figure 11- Software Testing Phase

It has been determined that the most critical aspect of the software is its ability to perform fast and accurate detections. Accordingly, the software has been adjusted and developed to meet this requirement. The choice of Python for the project is based on its advantages over other programming languages, including ease of use, speed, widespread adoption, and facilitation of project development. Additionally, the aim is to reduce awareness gaps related to highway hypnosis and to promote the issue by sharing the code as open source. This approach allows individuals interested in further development to easily review the system. Python was selected due to its widespread use and simplicity.

- ***Design***

During the design phase, areas for camera installation were determined to ensure the stability and accuracy of the image processing software. Since the driver's seat is the reference point for this determination, a 3D model of the driver's seat was created using SolidWorks.

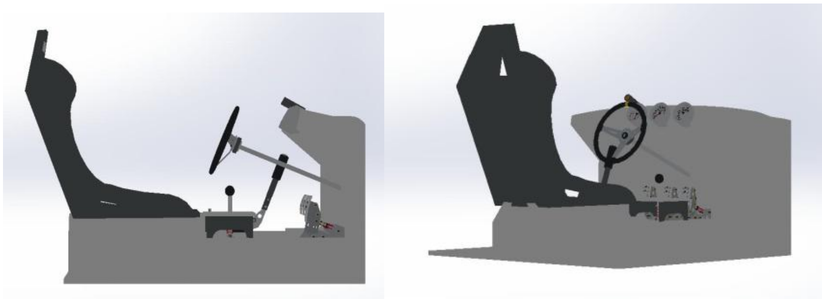

Figure 12- Design Created Using SolidWorks

A meeting was held among the project team members, during which potential locations for camera placement were identified based on the created 3D model. Some of the identified potential locations were eliminated through internal discussion, reducing the possible placements to seven. These seven different potential camera locations were evaluated based on five criteria: usability, effectiveness, suitability, accuracy, and installation. A matrix was created from the evaluation results. In the matrix, each location was scored on a scale of 10 points for each criterion. The location with the highest total score was selected as the camera placement. This process was applied separately for both cameras.

KAMERA YERLEŞİM KRİTER DEĞERLENDİRME MATRİSİ

GÖZ TESPİT KAMERALARI	KULLANIŞLILIK	ETKİLİLİK	UYGUNLUK	DOĞRULUK	KURULUM		
1. Yerleşim (Torpido)	5	3	6	1	7	Toplam: 22	
2. Yerleşim (Torpido Sağ Çapraz)	2	1	2	0	7	Toplam: 12	
3. Yerleşim (Sürücü Yan Koltuğu Kapı)	0	0	0	0	5	Toplam: 5	
4. Yerleşim (Sürücü Tarafı Kapı)	2	1	1	1	5	Toplam: 10	En Uygun Yerleşim Alanı : 7. Yerleşim
5. Yerleşim (Ön Sağ Çapraz Tavan)	5	4	5	4	6	Toplam: 24	
6. Yerleşim (Ön Sol Çapraz Tavan)	1	4	4	5	6	Toplam: 20	
7. Yerleşim (Üst Çapraz Tavan)	8	7	7	9	6	Toplam: 37	
PUANLAMA HER MADDE İÇİN 10 PUAN ÜZERİNDEN YAPILMIŞTIR							

KAMERA YERLEŞİM KRİTER DEĞERLENDİRME MATRİSİ

HAREKET TESPİT KAMERALARI	KULLANIŞLILIK	ETKİLİLİK	UYGUNLUK	DOĞRULUK	KURULUM		
1. Yerleşim (Torpido)	3	2	7	2	7	Toplam: 21	
2. Yerleşim (Torpido Sağ Çapraz)	5	5	8	5	8	Toplam: 31	
3. Yerleşim (Sürücü Yan Koltuğu Kapı)	2	1	2	1	4	Toplam: 10	
4. Yerleşim (Sürücü Tarafı Kapı)	1	2	3	3	4	Toplam: 13	En Uygun Yerleşim Alanı : 5. Yerleşim
5. Yerleşim (Ön Sağ Çapraz Tavan)	8	9	8	9	5	Toplam: 39	
6. Yerleşim (Ön Sol Çapraz Tavan)	7	4	7	2	5	Toplam: 25	
7. Yerleşim (Tam Üst Tavan)	7	7	4	6	5	Toplam: 29	
PUANLAMA HER MADDE İÇİN 10 PUAN ÜZERİNDEN YAPILMIŞTIR							

Figure 13- Matrices Used for Determining Placements

Technical drawings have been completed for the selected optimal locations. It should be noted that this design is based on a specific vehicle design, and the cameras may need to be repositioned depending on the type of vehicle or driver preferences.

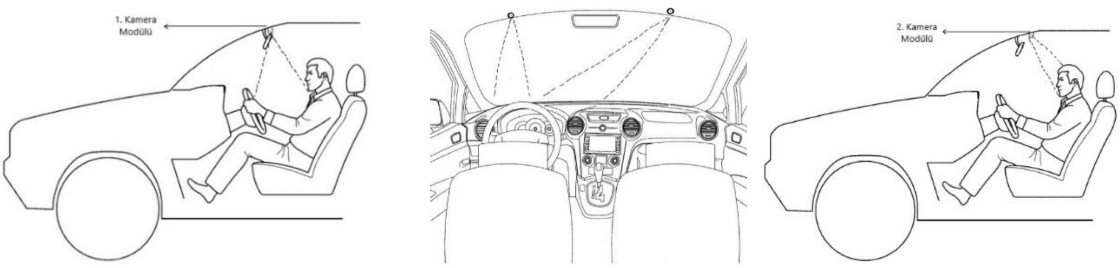

Figure 14- Technical Drawings

In this project, the critical aspect of the design is camera placement. Different locations need to be planned for buzzers, Raspberry Pi, and battery installations depending on the type and design of the vehicle. Given the vast diversity of vehicle designs, it is not feasible to specify a definitive location. Additionally, since the space occupied by the materials is minimal and wired connections are used, there is no issue with placing these components in any desired location within the vehicle.

- ***Assembly, Testing, and Development***

Initially, the Raspberry Pi 4 and power bank battery were mounted in a suitable location. Subsequently, the cameras were placed at the designated positions (diagonally forward and diagonally to the right on the driver's seat). After the camera installation was completed, the buzzers were installed. Although the placement of buzzers varies depending on vehicle designs, it is recommended to install them close to the driver. Suggested locations include the door side and the glove compartment side. After the placements were completed, connections were established.

The software and libraries loaded onto the Raspberry Pi 4 allowed for image transmission from the cameras to the software. The prototype was tested both while the vehicle was in motion and at rest. Additionally, the prototype was tested on several individuals with varying physical characteristics. For the final version of the system, further consultations were held with advanced driving techniques instructors, and their suggestions were incorporated. After the software testing phase was completed, further improvements were made. The system was tested in four different vehicles with individuals of varying physical characteristics and was observed to perform successfully.

- ***Simulator-Based Testing Platform (Pre-Vehicle Validation)***

To reduce the need for continuous on-road testing and to enable long-duration observations under controlled conditions, an additional test platform was developed. Emphasizing the importance of recycling and sustainable prototyping, this platform was constructed using decommissioned and unused student desks collected from schools. The system was designed as a driving simulator to support early-stage testing of the initial software versions. A joystick mechanism positioned at the rear of the simulator was mechanically linked via a tensioned nylon line, enabling the driver to reproduce throttle/brake and steering movements in a consistent direction and manner. Using this simulator setup, the driving scenario was implemented through the Euro Truck Simulator environment, allowing the project team to observe driver behavior over extended periods and to validate the first iterations of the image-processing algorithms before transitioning to real-vehicle trials. Following simulator-based verification, testing proceeded to in-vehicle evaluations: the system was integrated into eight different vehicles and tested with ten individuals during approximately two-hour driving sessions. Across these trials, the alarm-trigger accuracy of the system was determined to be 100%.

Accordingly, additional consultations and interviews were conducted to better understand user/customer expectations, to increase public awareness regarding the phenomenon, and to finalize the remaining stages of product development and iterative improvements.

Figure 25,26,27- Simulator-Based Pre-Vehicle Validation Setup/Dissemination Activities

Figure 28,29- Real-World In-Vehicle Trials

Figure 30, 31- Real-World In-Vehicle Trials

Findings

Driver eye movements are influenced by the specified oculomotor neurons and, consequently, by proprioceptive signals (which significantly diminish in the case of hypnosis, see Wertheim (1978), Weisfeld (1972)) and retinal information, making their detection crucial. Based on this hypothesis, two different software applications were developed to monitor the driver's head and eye movements.

A common observation in most articles written about highway hypnosis is the decrease in movement rates. Consequently, the decision was made to develop two different software applications. The first software detects and evaluates the driver's arm and back movements, while the second software assesses the general movement status of the driver and the vehicle. In alignment with the hypotheses confirmed by the literature, the aim was to develop a software focusing on the driver's mirror and road monitoring. A total of four different software applications are utilized based on the data collected from individuals during the first 15 minutes. Driver behavior was analyzed over a long distance (240 km) using installed cameras. At specific points along the road (100-150 km), the driver was exposed to metronome ticks at a rate of one tick per second, with the aim of helping them enter a semi-trans-like state by focusing on the sound. A significant reduction in driver movements (eye, head, back-arm) was observed, especially in the monotonous sections of the highway.

Survey questions are detailed in the appendix (Appendices 2 and 3). The responses are represented in a circular graph as shown below. The survey was completed by 91 participants, all of whom were over 18 years old and possessed a driving license. The age distribution shows that individuals aged 25-34 (29 people) constitute the largest group. This is followed by the age groups 18-24, 35-44, 45-54, and 55-64 in descending order of frequency. Of the participants, 53 identified as male, 37 as female, and 1 chose not to specify. All participants reported driving a car, with motorcycles being the second most common response. Prior to being informed, participants assessed their knowledge of highway hypnosis; the most frequent response was "Moderate Knowledge" (33 people), followed by "Little Knowledge" and "No Knowledge" (19 people each). A total of 20 participants indicated that they had "Good" or "Very Good" knowledge of highway hypnosis. The 71 participants marking "Moderate" or less highlight a low level of awareness about this significant issue.

After being informed about highway hypnosis, participants continued with the survey. Among them, 38 reported experiencing highway hypnosis, while 18 had witnessed it. The survey results indicate a low level of awareness about highway hypnosis and its frequent confusion with terms like "fatigue/sleepiness/sleep." Additionally, it was observed that many of those who gained awareness had either experienced or witnessed such situations. Some participants were asked to describe their experiences, with a few examples provided below:

- "During a trip from İzmir to Konya, after Afyon, the road was flat, and as I continuously followed the road, my brain started to stop perceiving objects on the road. I resolved the issue with a 15-minute break."
- "While traveling from Ankara to Antalya, I experienced it, which resulted in a collision with another vehicle. Fortunately, I noticed it just in time and reduced my speed, avoiding casualties, though the cars sustained minor damage."
- "After traveling for about an hour on a road without city or tree-like markers, I had a moment of awakening, realizing I was driving and feeling my hands on the steering wheel."
- "On long, flat, and uninterrupted roads (like highways), I experience desensitization to the road, slowed reflexes, and a state akin to being asleep while awake."
- "After a sleepless night, I had to make an intercity journey. After three hours, we reached Trabzon. While continuing on the coastal road to Maçka, I remember trying to maintain a safe distance from the car in front. Unintentionally, I started drifting from my lane to the right, and I was jolted awake by my friend's shouting, realizing I was scraping the car against the median. I managed to regain control and stop the vehicle. Thankfully, we were not injured, but the car was damaged. My friend commented that I had fallen asleep with my eyes open and almost caused an accident."
- "I observed that a driver with their eyes open lost control of the vehicle."
- "I encountered situations where I did not remember parts of the journey. This typically occurs on days when I am tired or during intercity travel. I have also experienced this while riding a motorcycle."

As indicated by these situations, highway hypnosis is a common, unrecognized condition that can result in accidents. It is not limited to enclosed vehicles but can also occur in situations with constant airflow, such as motorcycles. When asked to rate the importance of the problem, 58 participants considered it to be a very important issue, while 24 deemed it moderately important.

Participants were shown long test videos of the system and asked about their likelihood of using such systems. Thirty-four participants indicated that they would definitely use it, while thirty-five said they would probably use it. Participants preferred to use the system during long journeys and night driving. When asked about their concerns regarding the system, the highest concern was the possibility of incorrect alerts, followed by concerns about cost and data privacy. Based on these concerns, the system was restructured, and the number of alternative solutions was reduced.

Factors affecting their willingness to use the system included three main categories: system cost, ease of use, and discomfort during driving. The most important features desired in the system were high precision and accuracy, and ease of integration. Discussions with advanced driving technique experts led to additional improvements based on their suggestions. The system was developed with the feedback from surveys and interviews, aiming to meet the supply, demand, and expectations. It was tested in various vehicles with different physical characteristics while in operation. The accuracy, stability, and individual customization of the system were crucial for further development and enhancement.

Conclusion and Discussion

This study aimed to assess the likelihood of drivers experiencing highway hypnosis during long journeys and its impact on traffic safety. The findings include drivers' experiences with highway hypnosis, their awareness levels, and their thoughts on the developed system.

The first hypothesis posited that software evaluating head and eye movements might be effective in detecting highway hypnosis. The results reveal a significant decrease in driver eye, head, and back-arm movements during long journeys. This reduction becomes more pronounced in monotonous sections of the highway, indicating that highway hypnosis is a genuine issue and that drivers' attention wanes under monotonous road conditions.

The second hypothesis focused on the potential contribution of software evaluating arm and back movements to detecting highway hypnosis. The findings suggest that these software applications are also effective in assessing the driver's physical state. The observed decrease in back and arm movements during long journeys supports the presence of highway hypnosis symptoms.

Survey results indicate that participants generally have low awareness of highway hypnosis. This suggests that highway hypnosis is often experienced unconsciously, with most drivers lacking information about this issue. Furthermore, it was observed that cases of highway hypnosis are frequently confused with fatigue, sleepiness, or drowsiness.

The developed system could be a significant tool in detecting highway hypnosis symptoms. According to survey results, the main concerns of drivers are the possibility of incorrect alerts, cost and pricing issues, and data privacy. These concerns may significantly impact the system's reliability and usability. To address these concerns, the system has been designed to be cost-effective, retrofittable to existing vehicles, compatible with current vehicle systems, and highly accurate, leaving no room for doubt. Additionally, images are processed and deleted after use, and data evaluations restart afresh each time the vehicle is restarted.

There is currently no active system in the literature specifically targeting highway hypnosis. While this project has no direct competitors, indirect competitors should also be considered. According to advanced driving technique experts, taking a 15-minute break every hour, frequently changing music genres, and opening and closing windows can temporarily address the issue. Additionally, long-distance drivers have reported their own methods, such as driving barefoot on the gas pedal and continuously moving their foot or extending their arm out of the window to temporarily counteract the problem.

The system was developed with user satisfaction in mind, deeply analyzing the issue and evaluating usability, suitability, cost, and ease of installation. The system's accuracy in detecting highway hypnosis was verified. Since the system will continue based on numerical averages and comparisons with those averages, it ensures high accuracy.

In addition, under the banner of social responsibility, numerous promotional activities have been carried out, and brochures have been distributed to many individuals. Although the goal of raising awareness about the issue has been partially achieved, the promotions are ongoing. Some visuals from the promotional activities are shown below.

Figure 32- Visuals from Social Responsibility Campaigns

Recommendations

The developed system has the potential to be a significant tool in detecting symptoms of highway hypnosis; however, user concerns regarding false alarms and cost factors must be addressed. Survey results indicate that drivers generally have low awareness of highway hypnosis, which is often confused with fatigue or sleep deprivation. To address this issue, awareness-raising campaigns, educational programs, and exploration of alternative solutions are recommended. Since highway hypnosis is a relatively new topic, there is an opportunity to write articles and develop diverse solutions.

Additionally, with the growing popularity of autonomous vehicles, the necessity for drivers to actively monitor the vehicle could be leveraged as an advantage for the system's application. This presents an important hypothesis for the continuity of the project.

In case of issues related to material supply for system development, microcontrollers such as Arduino UNO could be considered. The system currently utilizes Raspberry Pi for its cost-effectiveness and development ease, but using devices with higher RAM, such as the Jetson Nano, could yield more stable results. Similarly, the system's software is implemented using Python due to its simplicity and widespread use. For further development, accessibility and ease of modifications were prioritized. It is recommended that for higher performance, the system be recompiled using C++. Further investigations into the conditions under which highway hypnosis occurs and alternative detection methods are suggested.

For individuals with disabilities, alternative stimulatory systems, such as vibration-based alerts, could be developed. Considering the potential for higher casualties and property damage in public transportation and commercial vehicles due to hypnosis-related accidents, the feasibility of making such systems mandatory should be explored.

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