SMART EYE PROTECTION SYSTEM: USING PREDICTIVE ANALYTICS FOR PREVENTING EYE STRAINS

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CHAPTER I

BACKGROUND OF THE STUDY

In an era dominated by digital devices, prolonged screen exposure has become a normal part of daily life. Although these gadgets improve communication and productivity, they also contribute to the growing problem of digital eye strain, also known as Computer Vision Syndrome (CVS). Digital eye strain (DES) refers to a group of visual and ocular problems caused by extended use of electronic devices. It is often characterized by symptoms like headaches, blurred vision, eye fatigue, dry eyes, and a feeling of discomfort or foreign body in the eye (Kaur et al., 2022). This condition affects millions of people worldwide, especially those who spend long hours on screens for work, education, or leisure. While traditional methods of managing digital eye strain include simple measures like adjusting screen brightness, using blue light filters, and taking breaks, these solutions are often reactive and address symptoms only after they appear. Preventive strategies such as eye exercises, the 20-20-20 rule, and regular breaks can help reduce the risk of digital eye strain, but most people only start changing their habits after experiencing symptoms.

In today's digital age, the global average individual spends six hours and 43 minutes daily on screens. In the Philippines, internet usage is even higher, with users spending an average of eight hours and 52 minutes online daily (Statista Research Department, 2024). Mobile phones are the most popular devices, with 79 million Filipinos using them to access the internet in 2022, and this number continues to grow (Balita, 2023). The increasing reliance on mobile devices has made digital eye strain a widespread issue, as prolonged screen time and exposure to blue light from screens can damage retinal cells and contribute to long-term vision problems like macular degeneration (UC Davis, 2022). Advancements in artificial intelligence (AI) have introduced new ways to address digital eye strain. AI techniques like machine learning and deep learning are now used to detect eye strain by analyzing factors such as blinking rates, eye movements, and other physiological patterns. However, many of these systems are either too complex or require specialized hardware, making them less accessible to the average user. Like traditional methods, these systems are often reactive rather than proactive.

This study proposes a “Smart Eye Protection System” designed specifically for smartphones. This system takes a proactive approach to predicting digital eye strain before symptoms occur. By collecting both historical and real-time data, it identifies patterns and predicts potential strain. The system uses information such as screen time, posture, and environmental factors like ambient light and screen brightness. With built-in sensors and predictive models, it suggests or automatically adjusts screen settings to help reduce eye strain. By combining AI, predictive analytics, and smartphone sensors, this system aims to offer a more practical and accessible solution to digital eye strain. It promotes healthier screen habits for smartphone users, reducing the risk of eye strain without requiring specialized hardware or advanced configurations.

STATEMENT OF THE PROBLEM

The increasing reliance on digital devices has led to a surge in cases of digital eye strain. As the world around us continue to digitize, technology has become involve in almost every areas of our life. Worldwide, people spend an average of 6 hours and 40 minutes per day on screens. Digital eye strain is a group of visual symptoms experienced concerning the use of computers. Nearly 60 million people suffer from DES globally. Prolonged usage of digital devices is associated with higher risk of myopia and main cause of computer vision syndrome. Computer Vision Syndrome not only affects eye health but also economically. Digital eye strain reduce work productivity and computer work accuracy, increase the amount of time needed to finish tasks and call for more frequent breaks. (Sheppard, Wolffsohn, 2018). Digital eye

eye strain can also cause difficulty focusing which can negatively affect students and professionals alike. Computer and digital devices also produce higher amounts of blue light. Combining exposure to blue light with prolonged use of screen devices can affect eye health and sleep habits negatively. On the other hand, despite the availability of existing tools and features to address digital eye strains, it focus on reactive measures meaning it only aims to address eye strain after it occurs. This approach doesn’t prevent the onset of symptoms. They are have limitations and static in nature meaning they are rigid and do not adapt to changes in real-time. Most tools also do not utilize real time and historical data, this approach is inconvenient and often too late to prevent strain.

To address these gaps, this study investigates how predictive analytics can be utilized to assess user behavior and environmental factors to predict and prevent digital eye strain. By leveraging predictive technologies, this research aims to provide a more proactive, personalized, and real-time approach to managing and mitigating digital eye strain. Specifically, the study seeks to answer the following questions:

a) What real-time data (e.g., screen time, blink rate, lighting conditions, screen brightness) should the system collect to accurately predict eye strain risks and offer personalized interventions?

b) What is the impact of personalized, predictive interventions on user compliance, comfort, and the overall effectiveness of the system in reducing digital eye strain?

c) How can predictive analytics be integrated into the Smart Eye Protection System to predict and proactively prevent digital eye strain before symptoms occur?

d) How can the system dynamically adjust to changing user behaviors and environmental factors (such as screen time and lighting conditions) to ensure timely and relevant interventions for preventing eye strain?

OBJECTIVES OF THE STUDY

This study aims to develop a practical and effective Smart Eye Protection System by leveraging basic predictive analytics to address digital eye strain.This research seeks to contribute to improving eye health through proactive, personalized, and real-time interventions. Specifically, the study aims to achieve the following:

a) To identify the key real-time data (e.g., screen time, blink rate, lighting conditions, screen brightness, break intervals) that should be collected from users to accurately predict eye strain risks and offer personalized interventions.

b) To evaluate the impact of personalized, predictive interventions on user compliance, comfort, and the overall effectiveness of the system in reducing digital eye strain, by measuring user adherence to recommendations and gathering feedback on system effectiveness.

c) To integrate predictive analytics into the system to predict and proactively prevent digital eye strain before symptoms occur, by analyzing historical and real-time data such as screen time, blink rate, ambient lighting, and screen brightness.

d.) To design a system that dynamically adjusts to changing user behaviors and environmental conditions (e.g., screen time, lighting conditions) to ensure timely and relevant interventions, such as adjusting screen brightness or reminding users to take breaks.

TIME AND PLACE OF THE STUDY

The study will be conducted over a six-month period, from January 2025 to June 2025. During this time, various phases of the research will be carried out, including the development of the Smart Eye Protection System, data collection, system testing, and evaluation of the results. The study will take place in Imus City, Cavite, Philippines, where participants will be recruited from the local community, including students, professionals, and individuals who regularly use digital devices for extended periods.

SCOPE AND LIMITATION OF THE STUDY

This study focuses on the development and evaluation of a Smart Eye Protection System designed specifically for smartphones, aimed at preventing digital eye strain through predictive analytics. The system will monitor screen time and ambient light conditions, providing proactive interventions such as break reminders and screen brightness adjustments. The target audience will include smartphone users who spend significant time on their devices for work, education, or leisure. However, the study is limited to smartphones and does not extend to other digital devices like laptops or tablets. Additionally, it excludes users without access to smartphones with necessary sensors, such as ambient light sensors. The study will focus on simple, practical features rather than complex interventions like eye exercises or advanced AI systems. The sample size may also be limited by participant availability, which could affect the generalizability of the findings. While external factors such as the type of content viewed or physical environment may influence results, efforts will be made to control these variables as much as possible.

DEFINITION OF TERMS

Blue Light: A type of high-energy visible (HEV) light emitted from digital screens (e.g., smartphones, computers, and tablets). Prolonged exposure to blue light is associated with potential eye strain and long-term vision problems.

Break Reminders: Notifications or alerts sent to users, reminding them to take regular breaks to reduce the risk of digital eye strain.

Computer Vision Syndrome (CVS): A term synonymous with digital eye strain, describing the symptoms that result from prolonged screen exposure, particularly in work or study settings.

Digital Eye Strain (DES): A condition characterized by visual discomfort and other symptoms, such as headaches, blurred vision, dry eyes, and eye fatigue, caused by prolonged use of digital devices.

Machine Learning: A subset of artificial intelligence (AI) that involves training algorithms to learn from data and improve their performance over time without explicit programming. It is used to identify patterns and make predictions or decisions based on historical and real-time data.

Predictive Analytics: The use of statistical algorithms, machine learning, and data mining techniques to analyze historical data and make predictions about future events or behaviors.

Random Forest: A machine learning technique that involves creating a collection of decision trees to make predictions. It works by averaging the results from multiple trees to improve prediction accuracy. In this study, Random Forest will be used to analyze patterns in user behavior and environmental data, predicting when eye strain is likely to occur and providing insights for intervention.

Screen Time: The total amount of time a person spends using a digital device, such as a smartphone, during a specific period.

Smart Eye Protection System: A system designed to monitor user behavior and environmental conditions to predict and prevent digital eye strain through proactive measures like screen brightness adjustments and break reminders.

Support Vector Machine (SVM): A supervised machine learning algorithm used for classification and regression tasks. In this study, SVM will be applied to analyze user behavior data and predict the likelihood of digital eye strain, classifying data into different risk levels to offer personalized interventions.

THEORETICAL FRAMEWORK OF THE STUDY

The Smart Eye Protection System is designed to predict and prevent digital eye strain, combining technology with user behavior insights. The theoretical foundation of this system is based on a model that integrates concepts from **Predictive Analytics**, **Behavioral Science Theory**, the **Technology Acceptance Model (TAM)**. These theories and models collectively guide the development of a proactive, user-centered system that addresses the problem of digital eye strain before symptoms arise.

1. Predictive Analytics Theory: Anticipating and Preventing Eye Strain

At the core of the Smart Eye Protection System is **Predictive Analytics**, which involves collecting and analyzing user behavior and environmental data to predict future outcomes. The system gathers real-time information about screen time, ambient light, and blink rate to assess the user’s risk of digital eye strain. By leveraging historical and real-time data, the system can forecast when the user is at risk of developing eye strain symptoms, such as headaches or blurred vision, based on their usage patterns (Aggarwal, Saxena & Sharma, 2023; Shmueli & Koppius, 2011).

Various machine learning algorithms underpin this predictive capability. Support Vector Machines (SVM) are employed to classify the risk of eye strain based on behavioral and environmental data, effectively distinguishing between at-risk and safe scenarios (Kaur & Guleria, 2021). Convolutional Neural Networks (CNNs) are utilized to analyze visual features such as eye movement patterns and pupil dilation, extracted from camera inputs, to detect early signs of fatigue (Popat et al., 2024). Additionally, Random Forests process a combination of real-time and historical data, such as ambient light readings and posture changes, to provide robust predictions (Aggarwal, Sharma, & Saxena, 2022).

Predictive models work by detecting patterns in the data and using algorithms to make recommendations or adjustments (Bhatia, 2024), such as suggesting breaks or automatically adjusting screen brightness. This anticipatory approach is central to the system's ability to prevent symptoms, as opposed to reactive measures that only address the problem after it occurs. Predictive analytics helps the system deliver personalized interventions, reducing the likelihood of strain and enhancing the user’s well-being.

2. Health Belief Model (HBM): Motivating Behavior Change

The system also draws on concepts from **Behavioral Science,** particularly the Health Belief Model (HBM), to encourage preventive behaviors. The HBM suggests that individuals are more likely to adopt health-protective actions if they perceive a health threat as serious, feel personally susceptible, and believe in the efficacy of the recommended interventions (Boskey, 2024; Glanz et al., 2015). The system leverages these principles by educating users about their specific risk factors, such as prolonged screen use or poor lighting, and by delivering tailored recommendations to highlight the benefits of proactive measures.

For the Smart Eye Protection System, the model is relevant because it helps explain why users would engage with a system that predicts and prevents eye strain. By informing users of the potential risks of prolonged screen exposure and how the system can reduce these risks, the system encourages proactive behavior. The model's constructs—perceived susceptibility to digital eye strain, perceived severity of the condition, and the perceived benefits of the system—are fundamental in designing an effective user interface that motivates users to adopt healthier habits.

3. Technology Acceptance Model (TAM): Ensuring User Adoption

The **Technology Acceptance Model (TAM)** provides insight into how users adopt new technology based on their perceptions of its usefulness and ease of use (Burgess, Worthington, 2021; Davis, 1989). This is crucial for ensuring the Smart Eye Protection System will be accepted by users. The system's success depends on users finding it helpful in preventing eye strain and easy to use on their smartphones.

TAM suggests that when users perceive the system as practical, simple to navigate, and capable of providing real-time, personalized recommendations, they are more likely to embrace it. For example, features like automatic screen brightness adjustment and timely break reminders are designed to be intuitive and non-intrusive, ensuring that the system’s value is immediately apparent to users.

CHAPTER II

REVIEW OF RELATED LITERATURE

2.1. Prevalence and Impact

Digital Eye Strain (DES) is a prevalent condition in today's digital age, significantly impacting a substantial portion of the population, including students, professionals, and even children (Sheppard & Wolffsohn, 2018). Studies by Sheppard and Wolffsohn (2018) and Kaur et al. (2022) highlight the widespread prevalence of DES, emphasizing its significant influence on various aspects of daily life. The persistent strain on the visual system can lead to decreased focus, increased errors, and a decline in overall work efficiency (Sheppard & Wolffsohn, 2018; Kaur et al., 2022).

2.2. Etiology and Risk Factors

Prolonged screen time emerges as a primary risk factor for DES across all studies (Sheppard & Wolffsohn, 2018; Kaur et al., 2022; Pucker et al., 2024). This continuous engagement with digital devices places a significant strain on the ocular muscles, leading to fatigue, dryness, and blurred vision (Sheppard & Wolffsohn, 2018). Beyond screen time, viewing habits play a crucial role. Factors such as incorrect viewing distance, poor posture, and inadequate ambient lighting significantly contribute to DES symptoms (Sheppard & Wolffsohn, 2018; Aggarwal, Sharma, & Saxena, 2022). The potential long-term effects of blue light exposure from electronic devices are a major concern, as studies suggest it can contribute to eye strain, disrupt sleep patterns, and have negative impacts on retinal health (Sheppard & Wolffsohn, 2018; Kaur et al., 2022).

2.3. Existing Solutions and Their Limitations

Current approaches to mitigating DES encompass a range of solutions:

- **Hardware Solutions:** Blue light filtering glasses and screen protectors offer a physical barrier against harmful blue light (Sheppard & Wolffsohn, 2018). While effective in reducing blue light exposure, these solutions may not fully address other contributing factors like prolonged screen time and poor viewing habits.
- **Software Solutions:** Screen time management applications provide users with tools to monitor and limit their screen time (Sheppard & Wolffsohn, 2018). However, relying solely on self-discipline and adherence to these applications can be challenging for many users.
- **Behavioral Interventions:** The 20-20-20 rule, which encourages users to take 20-second breaks every 20 minutes to look at something 20 feet away, is a simple yet effective intervention (Kaur et al., 2022). However, consistent application of this rule can be difficult to maintain in daily routines.

While existing solutions offer some relief, they often lack personalization and proactive measures. Many solutions focus on reactive measures, addressing symptoms after they occur rather than preventing them proactively.

2.4. Digital Eye Strain Detection Using Deep Learning

Sharma, Saxena, and Aggarwal (2023) introduced an Advanced Digital Eye Strain (ADES) detector system that leverages deep learning techniques to identify and mitigate DES. The system uses convolutional and recurrent neural networks to analyze sequences of webcam images, focusing on identifying eye strain through non-intrusive monitoring. By detecting patterns such as prolonged eye closure, the ADES system triggers real-time alerts to prevent the onset of fatigue.

Key insights from this study include:

- **Accuracy and Performance**: The system achieved 85% accuracy on training data and 80% accuracy on test data, demonstrating the feasibility of AI-based DES detection methods.
- **Proactive Monitoring**: The ADES system employs thresholds to evaluate blink rates and eye closure durations, providing proactive alerts to users before symptoms escalate.
- **Methodology**: The system uses OpenCV for face and eye detection and CNNs for classification. Images are analyzed in real-time, enabling dynamic interventions.

This study validates the application of deep learning in DES detection and prevention, aligning closely with the objectives of the Smart Eye Protection System proposed in this research. The ADES system's success underscores the potential for integrating predictive analytics and AI-driven models to create accessible, user-friendly solutions for mitigating DES.

2.5. **Integration of Smartphone Technology and AI for Eye Care**

The integration of smartphone technology and artificial intelligence (AI) for advanced ophthalmic care has emerged as a promising avenue for addressing eye health concerns. Jin et al. (2024) highlight the transformative potential of smartphone-based solutions in providing accessible and cost-effective eye care. Their study underscores the use of AI algorithms for analyzing ocular data, enabling early detection of eye conditions and personalized interventions.

Smartphone-based systems, as discussed by Jin et al. (2024), are equipped with AI-driven features that allow for real-time data analysis and proactive management of eye health. This aligns with the objectives of the Smart Eye Protection System, which aims to utilize predictive analytics for monitoring screen time and environmental factors to prevent digital eye strain. The study also emphasizes the importance of integrating machine learning models on mobile platforms to ensure efficient and real-time processing without reliance on external hardware or cloud computing, making it highly relevant to the development of your proposed system.

Moreover, Jin et al. (2024) identify challenges such as ensuring data accuracy in diverse environmental conditions and optimizing computational efficiency for real-time interventions. These considerations are crucial for designing an effective Smart Eye Protection System that adapts dynamically to user behavior and environmental changes.

2.6. The Emergence of AI and Machine Learning for DES Management

The field of AI offers promising avenues for more personalized and proactive approaches to DES management. Machine learning algorithms play a crucial role in analyzing user data and predicting the likelihood of DES. Here's a closer look at some specific algorithms used in research:

- **Support Vector Machines (SVM):** Kaur and Guleria (2021) demonstrate the effectiveness of SVMs in classifying eye strain based on features extracted from eye images. By analyzing features like pupil dilation, blink rate, and eye movement patterns, SVMs can predict the onset of DES with high accuracy.
- **Deep Learning Models:** Popat et al. (2024) explore the use of Deep Neural Networks (DNNs), particularly Convolutional Neural Networks (CNNs), for

- analyzing eye movement data captured through webcams. CNNs can effectively extract relevant features from eye movement patterns to predict the presence of DES.
- **Other Machine Learning Techniques:** Studies have explored the use of other algorithms, such as Random Forests (Aggarwal, Sharma, & Saxena, 2022), which utilize an ensemble of decision trees to analyze user data, including gaze patterns and blinking behavior, to predict DES onset. Kuwahara et al. (2022) utilize Eye Aspect Ratio Mapping (EARM) to detect blinks and estimate eye fatigue, providing valuable insights into user behavior.

These algorithms, along with others, can be leveraged to develop AI-powered applications that:

- **Personalize recommendations:** Based on individual user data and predicted DES risk, the system can recommend customized break schedules, posture correction reminders, and optimal screen brightness settings.
- **Enable proactive interventions:** By anticipating the onset of DES, the system can prompt users to take preventive measures before symptoms arise.

2.7. IoT and Smartphone-Based Detection Systems

Abbas and Alsheddy (2020) explored the use of multi-sensor systems, IoT-based architectures, and smartphone applications for detecting driver fatigue, offering valuable insights applicable to a Smart Eye Protection System. The study emphasized the role of real-time data collection and processing using sensors like accelerometers, gyroscopes, and physiological trackers. Similarly, these approaches can be adapted to monitor factors contributing to digital eye strain, such as screen time and ambient lighting conditions.

The integration of machine learning models, including Support Vector Machines (SVM) and Artificial Neural Networks (ANN), for analyzing driver behavior parallels the predictive analytics framework proposed in this study. Additionally, their findings on challenges like computational delays and environmental variability provide guidance for addressing potential obstacles in developing smartphone-based systems. This study highlights the importance of leveraging IoT and mobile technologies to create efficient, real-time, and user-friendly solutions, aligning closely with the objectives of this research on preventing digital eye strain.

2.9. Synthesis of Review of Related Literature

This literature review highlights the growing prevalence of Digital Eye Strain (DES), a condition that affects a wide range of individuals, from students to professionals, as they spend long hours in front of digital screens. Studies from Sheppard & Wolffsohn (2018) and Kaur et al. (2022) emphasize the widespread nature of DES and its significant impact on daily activities, including reduced focus, productivity, and overall well-being.

One of the key contributors to DES is prolonged screen time, which puts a strain on the eye muscles and leads to symptoms like fatigue, dryness, and blurred vision (Sheppard & Wolffsohn, 2018). Poor viewing habits, such as incorrect screen distance, bad posture, and inadequate lighting, also worsen the condition (Aggarwal, Sharma, & Saxena, 2022). Furthermore, the potential long-term effects of blue light exposure are concerning, as studies suggest it could disrupt sleep patterns and affect retinal health (Sheppard & Wolffsohn, 2018; Kaur et al., 2022).

Current solutions to alleviate DES include hardware interventions like blue light filtering glasses, software applications that track screen time, and behavioral techniques such as the 20-20-20 rule (Kaur et al., 2022). While these methods offer some relief, they tend to be reactive, addressing symptoms after they appear, and may lack personalization to suit individual needs or proactive measures to prevent DES from occurring in the first place.

In recent years, deep learning techniques have been explored as a way to detect and manage DES. Sharma, Saxena, and Aggarwal (2023) introduced an Advanced Digital Eye Strain (ADES) system that uses convolutional and recurrent neural networks to monitor eye strain through webcam images. This system provides real-time alerts, allowing users to take action before symptoms escalate. This innovative approach demonstrates how AI can help prevent DES by detecting early signs of strain and offering personalized, timely interventions.

Additionally, the integration of smartphone technology and AI offers a new avenue for eye care. Jin et al. (2024) discussed how smartphone apps powered by AI can monitor ocular health, track screen time, and provide personalized recommendations to prevent DES. These systems are cost-effective and accessible, offering a way for users to manage their eye health without the need for specialized equipment or medical visits.

Among the machine learning techniques being applied to DES management, Support Vector Machines (SVM) and Random Forests (RF) stand out for their potential to accurately detect and predict DES. SVMs have been shown to classify eye strain by analyzing features such as pupil dilation, blink rate, and eye movement patterns (Kaur & Guleria, 2021). This allows for high accuracy in predicting DES onset and provides a proactive way to address the issue before symptoms become severe. Similarly, Random Forests, which combine multiple decision trees, analyze various factors like gaze patterns and blinking behavior to predict DES risk. This approach ensures reliable and robust predictions, making it highly effective in personalizing interventions (Aggarwal, Sharma, & Saxena, 2022).

By incorporating these machine learning models into a system for monitoring and managing DES, users can receive personalized recommendations based on their individual behavior. For example, the system could suggest optimal screen time limits, prompt users to take breaks, or advise on better posture based on the data it collects. This proactive approach not only helps prevent DES but also enhances overall comfort and eye health by anticipating issues before they arise.

In conclusion, the use of machine learning techniques such as SVM and Random Forests in the detection and management of DES holds great promise. These models, combined with smartphone technology and AI, can create personalized, real-time solutions that help users manage screen time, improve viewing habits, and prevent eye strain. The potential for these technologies to provide proactive and tailored interventions marks a significant step forward in protecting eye health in our increasingly digital world.

APPENDICES

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Title of the Study: BAKAWAN: ASSESSING THE ENVIRONMENTAL SUITABILITY OF SONNERATIA ALBA AND CASEOLARIS FOR EROSION CONTROL ECOSYSTEM RESTORATION IN IMUS CITY RIVERS USING MACHINE LEARNING AND ENVIRONMENTAL CRITERIA

Degree or Course: BACHELOR OF SCIENCE IN COMPUTER SCIENCE

ACTIVITY	2024										2025						
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Proposal Drafting									■	■	■						
Proposal Defense											■						
System Design											■	■	■				
System Development													■	■	■		
System Testing													■	■	■		
System Evaluation													■	■	■		
System Implementation															■		
Manuscript Preparation															■	■	
Final Oral Defense																■	■
Manuscript Review																■	■

Appendices 1. Gantt chart

RESEARCH TITLE	BAKAWAN: ASSESSING THE ENVIRONMENTAL SUITABILITY OF SONNERATIA ALBA AND CASEOLARIS FOR EROSION CONTROL AND ECOSYSTEM RESTORATION IN IMUS CITY RIVERS USING MACHINE LEARNING AND ENVIRONMENTAL CRITERIA																							
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3. Coordination with the LGU's																								
4. Site Selection and Data Collection																								
5. Data Preprocessing																								
6. System Design, Model Development and Training																								
7. Model Testing and Evaluation																								
8. Implementation of System																								
9. Interpretation of Results																								
10. Writing of Manuscript																								
11. Final Defense																								
12. Reviewiing of Manuscript																								
13. Final Revisions of Paper																								

Appendices 2. Timetable of Activities

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