VitalGaze_Proposal

Format:

Proposal

1. Significance
   a. Background (sight issue, screen fatigue) - how many persons, financial impacts
   b. Existing approach (20-20-20) to eye fatigue manage/relex
   c. Our idea (highly accessible, cost effective, self-manage, etc)
   d. dEscription about the implementation
2. Innovation
   a. Technical
   b. Health/clinical use
3. Method
   a. VR
      i. Task 1
      ii. Task 2
   b. Wearable

Abstract(to do later):

Significance(Background):

- Background (more detail and reference):
  The human eye is one of the most heavily used organs in daily life and is prone to strain and fatigue, especially in today's digital world where prolonged screen time has become the norm (Agarwal et. al., 2022). Eye exercises are known to alleviate these symptoms (Kim, 2016), but current methods lack personalized feedback and real-time monitoring. Extended screen time, especially exposure to flashing images and blue light, can lead to digital eye strain and even long-term eye damage. It's estimated that about 33% of people experience this, with the number rising to 50% for those who spend significant time in front of digital screens (Mylona et. al., 2023). Additionally, strobing from devices is another hidden threat to our eyes, particularly in OLED screens, which produce high strobe rates, causing eyes to feel dry and fatigued due to constant on-and-off light cycles.

  In the US, the economic burden of vision loss and eye strain has become a major concern, with total costs estimated at $134.2 billion annually (Centers for Disease Control and Prevention, n.d.). This includes direct medical and supportive service expenses as well as productivity losses due to absenteeism and reduced labor force participation. As screen time increases, the need for more accessible and effective solutions to manage eye strain and its long-term impact grows more urgent.

- Existing Approach:
  The 20-20-20 rule is a popular method to manage eye fatigue, advising users to take a 20-second break every 20 minutes and look at something 20 feet away (Coles‑Brennan et. al, 2018). While effective to a certain extent, this approach is passive and often difficult to remember in the middle of work. There's a clear need for a more engaging, automated solution that individuals can integrate into their daily routines without manual effort. There has been some research in the area of wearable devices, not explicitly related to digital eye strain, which encountered issues relating to visual field obstruction and could potentially induce scotomas (Ianchulev et. al., 2014). In addition, Eye massagers can also help relieve eye strain, but they are often bulky and expensive, leading to a high sunk cost if they prove effective. Eye drops can help relieve eye strain, but they require you to close your eyes and wait for the medication to take effect, which is a boring time you need waiting. There has been some research into the gamification of eye exercises, but was primarily focused on the measurement and analysis of the subjects' performance rather than its efficacy in treating digital eye strain (Vasiljevas et. al, 2019).

- Our idea:
  Our solution, VitalGaze, integrates a VR eye trainer game and a wearable glass device to provide a more immersive and effective way to combat screen fatigue. The VR Eyetrainer helps users perform gaze exercises in an engaging game environment, while the wearable glass tracks real-time eye movements using a wireless camera and provides feedback via LED arrays. Together, these tools create a highly accessible, affordable, and self-managed system that users can employ without external assistance. The solution is adaptable for various environments, from home to work, ensuring maximum usability.

- Advantages of VitalGaze Technology:
  VitalGaze offers several key advantages that make it an ideal solution for combating screen fatigue. First, its high accessibility ensures that users can easily integrate the system into their daily lives, whether at home or work. The low-cost design makes it affordable for a wide range of users, eliminating the need for expensive professional treatments or interventions. The combination of a VR eye trainer game and a wearable glass device enhances the effectiveness of the solution, offering users an engaging and interactive way to perform eye exercises. By incorporating real-time eye movement tracking and LED-based feedback, VitalGaze creates a user-in-the-loop system where users receive immediate, personalized feedback on their performance, helping them stay engaged and motivated. This self-managed, feedback-aware approach empowers users to take control of their eye health without the need for external assistance. Together, these features provide a comprehensive, effective, and easily manageable solution to screen fatigue.

- Description of the Implementation

  For tracking functions, we use a microprocessor to deploy a compact AI model that continuously optimizes accuracy while reducing power consumption.

  a. Technical:

     AI - tracking eyeball
     Arduino - microprocessor (CPU, Wifi, Bluetooth)
     cloud connectivity (connect with a cloud-based platform if needed - sever)
     Android - design app to connect glass by wifi , Bluetooth
     Welding - reinforcement of the port and wire connection
     3D print - create shell

  b. Health/Clinical use

     Treatment for digital eye strain
     Eye health monitoring
     Vision therapy
     Possible rehabilitation after Eye surgery

  Phase 1:

  VR Eyetrainer Game: Developed using C and 3D Unity programming, the game tracks the user's gaze movements during tasks designed to relax and train the eye muscles. The game calculates the user's performance and provides feedback, such as adjusting the level of difficulty or suggesting specific exercises.

  Phase 2(Leader: N/A Member: Yingyi, Diyun):

  Wearable Glasses: The glass is a 3D-printed frame fitted with a wireless camera (BLE/WiFi) that tracks eye movements in real-time. The embedded processor controls LED arrays and receives feedback from the camera to guide the user through relaxation exercises. The glass connects to a smartphone or laptop via an app, where users can monitor their progress and adjust settings.

Innovation:

- Technical Innovation: The Vitalgaze system combines cutting-edge VR and wearable technology to actively engage users in eye relaxation exercises. Unlike passive solutions, our system collects real-time data and **provides instant feedback**, making it both proactive and adaptive. The combination of hardware (wearable device) and software (VR game) is a novel approach to tackling screen fatigue, offering a more effective solution than standalone methods like the 20-20-20 rule or blue-light filters.

- Health/Clinical Use: Vitalgaze could be useful in clinical environments to help patients suffering from eye strain. By providing a structured and measurable way to track eye movements, this solution could be recommended by eye care professionals as part of a treatment plan for individuals experiencing chronic screen fatigue or related issues. It can also be used to monitor patients after an eye surgery to confirm the process worked.

Method:

- Task 1: VR-Based Gaming System(Leader: | Member:):
  - Develop a VR game similar to "Eye Trainer" with gaze-tracking capabilities to analyze user interaction.
  - Programming languages: C/C#/C++.
  - Development Platform: Unity
  - Resources for learning will be shared if needed.
- Task 2: Wearable Gaze Tracker(Leader: N/A | Member: Yingyi, Diyun):
  - Create 3D-printed glasses with embedded camera sensors to track eye movement and wirelessly transmit data(possibly transmission communication methods: I2C, SPI, etc.) to a smartphone or PC.
  - Implement a gaze-tracking algorithm for data analysis.

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For the phase 2:
Possibly microcontroller: ESP32/ESP-EYE
We will use these MCUs as the core hardware platform for the smart glasses, responsible for LED control, data collection, and wireless(wifi, bluetooth)/wired communication with external devices.(Have not determined where the MCU should be placed, inside the glasses? Or outside the glasses?)
The camera module will capture the user’s eye movements, with the data transmitted via Bluetooth to an external processing unit.
A machine learning model will analyze the eye movement data and generate personalized training feedback in real time.
A user interface will be developed for a mobile app or desktop application, allowing users to view their training history and progress.

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Questions to discuss and brainstorm:

How can we effectively embed the microcontroller into the glasses for the gaze tracker?

Depends on the framework/structure of the glasses. Current solution: see [1]

What are the potential technical challenges related to tracking eye movement for different eye colors?

The brown eye is closer in shade to lighter skin tones compared to a black eye, which might lead the AI model to misinterpret it.

How do we really show the importance of our project in tackling eye fatigue?

(to do)

(This question could be answered with the "implementation of this project" above)Unlike passive methods, VitalGaze offers real-time data collection and personalized feedback, which is proven to increase user engagement and effectiveness in health-related interventions.

Are there any safety concerns that need to be addressed in our design? Side effects to avoid? (see Ianchulev et. al. 2014)

Yes (Ianchulev et al 2014). We will likely need to consult with someone from the Department of Ophthalmology.

Citations

Make sure to replace links with proper citations and remove notes, eventually

Also need in text citations

Agarwal, R., Tripathi, A., Khan, I., & Agarwal, M. (2022). Effect of increased screen time on eyes during COVID-19 pandemic. Journal of Family Medicine and Primary Care, 11(7), 3642. https://doi.org/10.4103/jfmpc.jfmpc_2219_21

- same topic as above citation from researchgate, high screen time correlates with symptoms of eye fatigue, but this is more reliable source than researchgate

    majority of participants had increased screen time due to pandemic

    use of multiple devices/screens at once increases symptoms of eye strain

    recommends overall reduction in screen time (<4 hours screen time per day), and 20-20-20 rule

Mylona, I., Glynatsis, M. N., Floros, G. D., & Kandarakis, S. (2023). Spotlight on Digital Eye Strain. Clinical Optometry, Volume 15, 29–36. https://doi.org/10.2147/opto.s389114

-Spotlight on Digital Eye Strain ; relates asthenopia symptoms -> prolonged fixation to near-field viewing , dry eye -> reduced blink rate when fixing gaze to screen and increased exposure of eye due to horizontal gaze

Singh, S., Downie, L. E., & Anderson, A. J. (2021). Do blue-blocking lenses reduce eye strain from extended screen time? A double-masked, randomized controlled trial. American Journal of Ophthalmology, 226. https://doi.org/10.1016/j.ajo.2021.02.010

- alternative solution, do lenses that filter blue light reduce eye strain? Definitively no

Kim, S.-D. (2016). Effects of yogic eye exercises on eye fatigue in undergraduate nursing students. Journal of Physical Therapy Science, 28(6), 1813–1815. https://doi.org/10.1589/jpts.28.1813

- study on yogic eye exercises, results indicate such exercises are effective in relieving eye fatigue

Coles‐Brennan, C., Sulley, A., & Young, G. (2018). Management of digital eye strain. Clinical and Experimental Optometry, 102(1), 18–29. https://doi.org/10.1111/cxo.12798

- comprehensive review of existing literature on the matter, tables 4&5 indicate contact lenses worsens symptom scores, and existing literature seems to be more focused on ergonomic practices (lighting, positioning of the device, and frequent breaks) particularly the 20/20/20 strategy (after 20 minutes, look at objects that are over 20 feet away for 20s), overall prevention seems to be the main strategy (**may be worth incorporating into wearable device in addition to eye movement exercises, i.e. ensure the wearer is maintaining a healthy blink rate, built-in reminders to take breaks**)

Vasiljevas, M., Damaševičius, R., Połap, D., & Woźniak, M. (2019). Gamification of Eye Exercises for Evaluating Eye Fatigue. Artificial Intelligence and Soft Computing, 104–114. https://doi.org/10.1007/978-3-030-20915-5_10

- research on gamification of eye exercises, only 14 subjects, mostly aimed creating method of measuring and analyzing performance in the game relative to subjects learning the game and becoming fatigued

Ianchulev, T., Minckler, D. S., Hoskins, H. D., Packer, M., Stamper, R., Pamnani, R. D., & Koo, E. Y. (2014). Wearable Technology With Head-Mounted Displays and Visual Function. JAMA, 312(17), 1799. https://doi.org/10.1001/jama.2014.13754

- study on Google Glass, "device created clinically meaningful visual field obstruction", "many people wear the device near or overlapping their pupillary axis, which may induce scotomas and interfere with daily function" ; we must be mindful of hardware to avoid unintended negative side effects

Sun, G., Meng, Y., & Wang, L. (2022). The Effect of Exercise on Visual Fatigue Based on Eye Movement. Communications in Computer and Information Science, 234–240. https://doi.org/10.1007/978-3-031-06388-6_31

- active eye movement (playing table tennis) made subjects have better subjective feeling and appears to encourage greater blink frequency, but overlooking still has positive impact on recovery from visual fatigue, and pupil diameter in active eye movement group was smaller due to fixation (as overlooking distant objects does not require fixation)

Centers for Disease Control and Prevention. (n.d.). Economic studies. Centers for Disease Control and Prevention. https://www.cdc.gov/vision-health/php/data-research/index.html

-2017 cost estimates for the U.S. economic burden of vision loss and blindness are as follows:

Total: $134.2 billion

Medical, nursing home, and supportive services (direct): $98.7 billion

Absenteeism, lost production, and informal care (indirect): $35.5 billion

Some useful project's Github link:

—----------------------------------Mechanical, Hardware—----------------------------------

[1] https://github.com/EyeTrackVR/EyeTrackVR

- A VR project provides some useful tips about how to effectively put sensors and microcontrollers into glasses; how to arrange LEDs inside the glasses. (Since the goal for this project is totally different from us, we can just learn hardware part from this project)

—-----------------------------------Software, API, etc—---------------------------------------

[2] https://github.com/antoinelame/GazeTracking

- A library that provides a webcam-based eye tracking system, it gives you the exact position of the pupils and the gaze direction, in real-time.

[3] https://github.com/opengazer/OpenGazer

- OpenGazer is an open-source software that uses standard webcams to estimate the direction of the user's gaze, allowing this information to be passed to other applications. Current features and workflow:

1. Feature Point Selection: During the initial setup, the user manually selects key facial points (such as the corners of the eyes) with a mouse. (These points are then used to track eye movements and extract eye images for further analysis.)
2. System Calibration: To train the system, the user looks at red dots displayed on the screen, which allows the software to capture corresponding eye images. (These images are then used to create a model (Gaussian Process) that maps the user's gaze to a position on the screen. Head movements may require recalibration.)
3. Gaze Tracking: After calibration, the trained model can predict the user's point of gaze in real-time based on new eye images. (The system uses the Viola-Jones face detector to find the user's face and track feature points, which are then used to refine the eye image extraction and gaze estimation.)

[4] https://github.com/hiro-wpi/VIVE-Motion-Capture-With-Wearable-Cameras

- This wearable camera system consists of HTC VIVE VR headset, trackers and various cameras. It can be used for human motion capture, to track human gaze input (if you have VIVE Pro Eye), to provide camera stream from various cameras, or any combination of these modules.

[5] https://github.com/iitmcvg/eye-gaze?tab=readme-ov-file(This project recently cannot use from github)

- Some useful feature:

1. Pupil detection: The system accurately identifies the location of the pupil, which is critical for determining the user's line of sight

2. Facial normal detection: By analyzing facial landmarks and head orientation, the system computes the normal direction of the face, which helps adjust for head movements.

3. Gaze direction estimation: Using the pupil location and head pose, the system calculates the user's gaze direction, making it possible to track where the user is looking on a screen.

[6] Ninja-Fruit-Like-Game-with-hand-gesture-and-opencv (This is for hand gesture, we can learn from this algorithm then analyzing the eye area)

Hardware and Component Choices:

[1] Microcontroller (ESP-32 S3, ESP 32 S3 with Cam) - contain powerful dual-core processor and enhanced features like AI acceleration with help for eye detectors.

[2] Camera(OV2640 Cam long version, OV3660 160 Degree YUV RGB version) - the macro sensor and high sensitivity enable a smaller glass size and reduced weight.

[3] Screen(E ink) - different from OLED and LCD monitors without strobe to deepen the digital eye, but slow fresh rate affects the game development.(We may need to customize the glasses screen according to the glasses made from 3D printing)

[4] Power supply(Power Bank Battery Charging Module, AC to DC Power Supply Single Output 5V 3Amp) -

[5] Glasses frame(Using 3D printing, we need to decide which material to use) -

[6] LED Light Array(for phase 2)
Additional function?(to do)