Depression detection system based on Gaze Tracking technology

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Abstract. Depression is a common mental health problem that affects individuals in many aspects, including emotional, cognitive, behavioral, and physiological levels. The impact of depression is profound, not only affecting the patients themselves but also affecting their families and society. Therefore, timely recognition of the symptoms of depression and seeking professional mental health services are critical to improving patients' quality of life and preventing potentially serious consequences. Based on psychology and computer vision research, this paper proposes a method to detect depression using GazeTracking technology. This method is simple to use, has small requirements for the running environment and cost, and helps detect and prevent depression in multiple scenarios.

Keywords: eye tracking, depression, artificial intelligence.

1. Introduction

1.1. Topic Selection Background

Depression (also known as depressive disorder) is a common mental disorder that involves a prolonged period of low mood or loss of pleasure or interest in activities. [1]Depression can affect all aspects of a person's life, including social life, school life, and work, and it can happen to anyone. Since the outbreak of COVID-19, the social environment and people's lifestyles have changed dramatically, with more than 70 million new people globally suffering from depression, 90 million suffering from anxiety disorders, and hundreds of millions suffering from insomnia disorders. According to a report released by the World Health Organization on March 2, 2022, the incidence of anxiety and depression increased by 25% globally in the first year of the COVID-19 pandemic. The pressure of the epidemic has brought greater challenges to the diagnosis and treatment of depression. China mental health survey shows that the lifetime prevalence of depression disorders in adults in China is 6.8%, of which 3.4% is depression; the current number of people suffering from depression in China is 95 million, about 280,000 people commit suicide every year, of which 40% suffer from depression. Depression among adolescents in school is more serious. In our country, 50% of the patients with depression are school students. Depression accounts for 30 percent of the population under the age of 18.

As a kind of mental illness, patients with depression often face pain and suffering alone because of the "stigma," and society lacks the correct understanding of this disease.

1.2. Research purpose and significance

Depression has a very negative and far-reaching impact on society and individuals, seriously threatening people's mental and physical health, life safety, quality of life, and happiness. Some studies have suggested that depression in adulthood begins in adolescence. Therefore, the purpose of this project is to identify people with early potential depression simply and humanely so that early intervention can be taken to avoid serious consequences. Such depression prevention is essential because it can help people identify possible symptoms of depression early and take early action to reduce symptoms or prevent the development of the disease. Preventive measures can help people develop healthy coping mechanisms, improve their mental health, and ultimately improve their quality of life.

[1] World Health Organization

2. Literature Review

2.1. Relevant theories

The etiology of depression is still not completely clear, and the clinical diagnosis and evaluation are mainly subjective assessments, lacking objective and quantitative indicators. In recent years, the development of eye-tracking technology has provided a possibility for objectively evaluating eye movement in depressed groups. Eye tracking technology helps explore the cognitive dysfunction and pathophysiological abnormalities in patients with depression to provide a better reference for early identification, evaluation, and clinical intervention of depression.

Humans rely mainly on the sensory system to obtain information from the outside world. The visual system transmits external data to the brain through the visual nerve to be recognized by us, which is the essential process for human beings to connect with the external environment. Although the foveal region, crucial for vision, is only 0.5 mm in diameter, it captures as much as half of the information available. There are three types of eye movements: fixation, saccade, and smooth pursuit.

Eye movement plays a vital role in visual perception, and its analysis can reveal many facts about the perceptual process. Different eye-tracking paradigms reflect the selection pattern of visual information by testing different eye movement indicators and reveal human cognitive processing and cognitive processing defects. In people with depression, the main eye-tracking paradigms used are exploratory eye movement (EEM), saccade, and free view tasks.

2.1.1 Exploratory eye movement

Exploratory eye movement is recording the eye movement tracking when the subject pays attention to a still image at will and reflecting the subject's mental state and cognitive function through eye movement. The leading indicators of exploratory eye movement were several eye fixation (NEF) and responsive search scores (RSS). The study of Mu Junlin et al. showed that the indicators of exploratory eye movement can be used as potential diagnostic indicators for patients with depression. The indicators of exploratory eye movement can be used both as diagnostic indicators and to evaluate the therapeutic effect.

2.1.2 Saccade paradigm

Saccade is one of the modes of eye movement. To ensure clear vision, the eyeball saccades, moving the point of focus rapidly so that the object of focus is in the fovea area of the retina. Over the past 30 years, research has shown that saccades are heavily influenced by various cognitive factors involving attention, working memory, learning, long-term memory, and decision-making. Moreover, many scholars have used observing saccades to study psychopathology, such as assessing the higher executive function of the prefrontal system. The saccade paradigm mainly includes the saccade toward and back tasks. The saccade toward task can be used to evaluate the essential characteristics of eye movement, such as speed, latency, and accuracy, while the saccade back task can detect the ability to inhibit the eye's automatic orientation to the target appearing in the peripheral visual field.

Some scholars believe that the eye movement index in the anti-saccade task is a state marker of depression, and can be used as a tool for clinical symptom evaluation and curative effect prediction of depression to a certain extent.

2.1.3 Free Viewing Paradigm

The free-viewing paradigm records the eye movement tracking of the subjects when they pay attention to the still images at will and reflects the mental state and cognitive function of the subjects through eye movement. In the free viewing paradigm, multiple visual stimuli are displayed to attract subjects' attention, and their presentation time is longer. Subjects can scan back and forth to different stimuli, and the attention bias is measured by measuring the total gaze time, gaze frequency, average gaze time, and first gaze point of negative images. Studies have shown that people with depression tend to selectively focus on and process negative stimuli in their environment and filter out positive stimuli directly.

Medical studies have shown that the free-viewing paradigm can be used to evaluate the severity of depressive symptoms and the efficacy of depression drugs. Almudena et al. and Lu et al. used depressed patients with different severity and healthy controls as subjects. It was found that patients with higher Baker Depression Scale (BDI-II) scores had longer first and total gaze times for sad faces and shorter gaze times for happy faces in free viewing tasks. Isaac et al., Xu Xiliang et al., Li Wenjing et al., and Li et al. took patients in remission of depression as the primary research objects. The results showed that the total number of gazes and the first viewpoint of sad faces in the remission of depression group were significantly reduced compared with those in the depression group, so it was speculated that the negative attention bias of patients in remission may recover with the improvement of depressive symptoms. More significantly, attention training for depressed patients can direct their attention toward neutral or positive stimuli and improve their depressive symptoms by improving negative attention bias. The free viewing paradigm is a crucial tool to evaluate the efficacy of attention training. The application of eye-tracking technology to the clinical evaluation of the effect of attention training can more intuitively reflect the correlation between the correction of attention bias and the degree of

2.2. Research status

In recent years, some studies have used the eye movement indicators and physiological signals (pupil diameter) collected by the eye tracking paradigm as classification features to identify depression using algorithmic classifiers. Still, the classification accuracy is slightly lower overall.

Therefore, in the future, this field needs to develop more dimensions of eye movement indicators, adopt more accurate eye movement data analysis methods and algorithm classification technology to analyze the data or combine eye movement evaluation with other more convenient and easy-to-use evaluation methods to form new evaluation technologies.

While further improving the eye movement technology, more eye movement follow-up studies should be conducted on the whole course of depression, the trajectory model of eye movement development in patients with different severity of depression should be established, the effectiveness of treatment measures should be evaluated through the changes of eye movement data during the whole course of treatment, and more effective personalized intervention and treatment programs should be explored.

3. Research Content

3.1. Research Objectives

According to the previous literature review and the current research status, the research objectives of this topic are as follows:

(1) Basic objectives

Based on the free viewing paradigm, design better methods to acquire higher accuracy of eye movement recognition;

Design software UI naturally to enhance the comfort of eye movement testing.

(2) High-level goals

A set of software and hardware for easy eye tracking and a positive mentality training system is designed through cooperation with medical institutions. The system can be run using a laptop with a camera or a large-screen TV, and the eye movement data of patients/subjects can be collected and calculated in real-time, which is convenient for medical institutions to carry out data collection, behavior training, effect analysis, and treatment plan optimization throughout the disease.

Seek healthcare provider partners for this system, which will provide practical products for early identification and intervention of depression through standard consumer-grade devices and easy-to-use software.

(3) Long-term goal

To identify potential depression and start intervention, prevention is better than treatment and avoids serious consequences.

3.2. Research steps and significant problems

Starting from the basic goal, this study focuses on the free viewing paradigm because this paradigm can not only diagnose but also conduct behavioral training to facilitate interaction and effect evaluation. At the same time, considering that the existing technologies are all measured in specific medical places with particular head-mounted eye tracker, which has high cost and interferes with user experience, this project decides to use the ordinary consumer built-in camera built into the most common laptop or desktop computer to collect various behavioral data of the eyes and conduct data analysis.

3.2.1 Technical research steps

Step 1: Training and Optimization of eye tracking model

Step 2: Design the content of depression test

Step 3: Play the depression test content and record the eye movement data accordingly in real time

Step 4: Perform data analysis to determine the potential for depression or evaluate the effectiveness of treatment.

The research's fundamental problems include accurately positioning eye position and gaze directions, designing friendly and meaningful test content, recognizing and calculating eye movement data in real-time while playing the test content, and collecting and using data with full compliance.

3.2.2 Use the built-in camera of ordinary computers to locate eyeballs in real time accurately

With the development of the AI model, an optimized face and pupil recognition model is needed to solve the problem of accurate positioning of eyeballs and eye movements by computer-built-in cameras. At the beginning of the research, the technical route I set was to train the face and pupil recognition models through the CNN neural network, and the prerequisite was first to find the data set of face and pupil recognition. I mainly studied MIT's GazeCapture project in open resources, which provides a dataset of more than 1,400 people with more than 2.4 million samples. A pre-trained model was also offered with four inputs: the left eye image, the right eye image, the face image (detected by the iPhone camera software), and the face position. The four inputs are processed separately by four branches (the branch parameters of the eye image are shared), and the fused output yields a two-dimensional coordinate position. The work was completed around 2017, using key development tools, including deep learning networks Caffee and MATLAB. However, after an in-depth study, it was found that the project completion time was seven years before, the model efficiency based on the traditional feature + statistical model was lower than that of CNN, and the system requirement was high. At the same time, because the data set involves relatively sensitive facial data, the download link cannot be obtained by email application. Similarly, other eye movement data sets are also challenging to obtain. Depression-related eye movement information belongs to medical data and cannot be directly obtained as training data for this project.

Therefore, I began to look for suitable open-source code and pre-training models. After extensive research and multiple tests, Python open-source model and code (Gazetracking) can identify and record face and pupil positioning through a relatively simplified pre-training model and Python tools such as cv2, dlib, numpy, etc. It can be run on ordinary notebooks and has been selected as the basic model for this project. After studying the code and tuning parameters for the “is_left”, “is_right”, and “is_blinking” classes in the GazeTracking class, At present, the model can be run on Lenovo Legion notebook(16-inch screen) with Python 3.10 and Lenovo Yoga notebook (14-inch screen) with Python 3.12 perfectly.

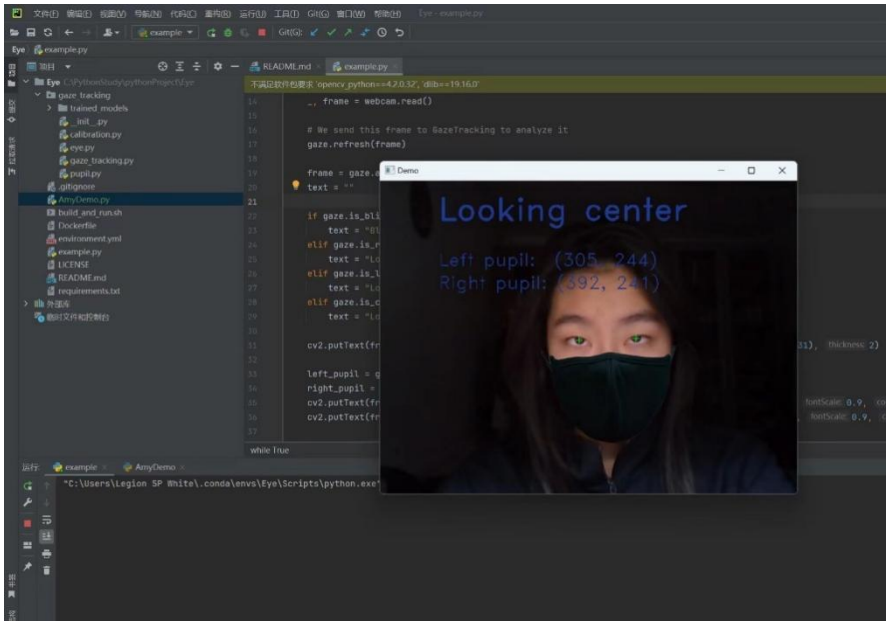

Figure 1 Pupil position recognition

3.2.3 Design test materials for eye movement data tracking

Based on the study of several medical and psychological research papers and reviews related to depression and eye movement, we believe explicit and novel materials can help the testee to take the test in a more relaxed and natural way, which is conducive to the accuracy of the test results. Therefore, in terms of presentation form and content, this project has been designed as follows:

In terms of display content, pictures with positive and negative meanings are used, and videos with positive and negative meanings are added. The eye movement characteristics of testees are collected when the test materials are displayed on the screen simultaneously (the left side of the screen is positive content, and the right side of the screen is negative content).

For the content editing tool, these contents are organized by Microsoft PowerPoint, which is convenient for ordinary psychology or medical professionals to replace the test materials to ensure that the test content is practical and flexible.

I designed and developed some new Python code to play the test materials and collect eye movement data simultaneously. It can automatically play the test PPT and flexibly set the playback time of each picture and video to facilitate recording and comparing the testee's eye movement data.



Figure 2 Picture materials

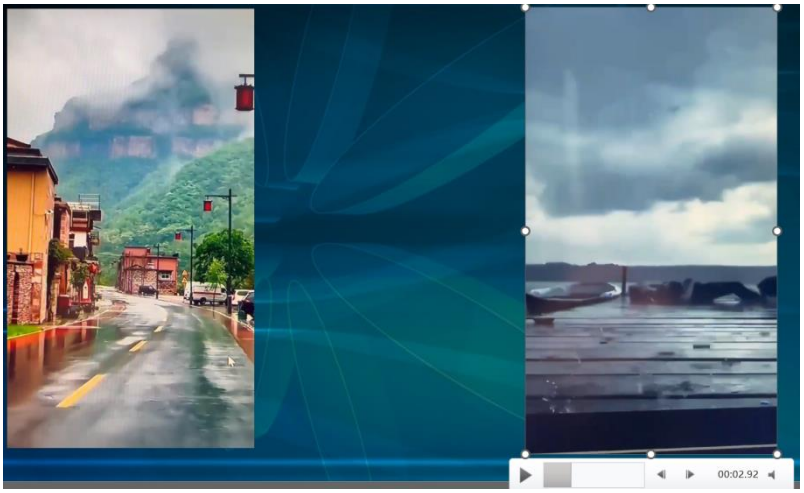

Figure 3 Video footage

3.2.4 Play test content and collect eye movement data simultaneously

Playing the test content PPT and collecting the testee's eye movement data simultaneously is a new part of the project. To synchronize the two tasks, the project introduces the thread method by leveraging the Python thread library, time library, pyautogui, and os libraries; the code can run PPT and eye tracking thread in parallel. First, the Python os library starts PPT, and the cv2 library initiates the webcam through the thread simultaneously. The code begins to record the number of eye jumps between left and right, single gaze duration, and cumulative gaze duration when the testee watches the test content PPT, and lastly, saves the data into an Excel file through the pandas library. The main work includes an eye movement acquisition function, a PPT playback function, a test data file generation function, and synchronous start and close of the main program. The code is shown in Annex 1.

3.2.5 Collect and process data with full compliance

Eye tracking involves facial information collection, which is sensitive data for citizens. I encountered more difficulties than expected in this part, and obtaining proper data sets was the first.

The “China Civil Code,” the “China Network Security Law,” and the “China Personal Information Security Code” list that facial information belongs to both personal sensitive information and biometric information, and there are strict requirements for the collection, transmission, and preservation of these data. For example, Clause 5.4 of the “China Personal Information Security Code” requires that facial information belongs to personal biometric information. Before the data collection, the collector should inform personal data subjects individually and then start a collection. Clause 6.3 regulates the requirement for transferring and storing sensitive personal information and biometric information.

After investigating laws and regulations, I used the open pre-training model in the program design. I did not record face data in the program design; I only recorded the number of eye jumps and gaze duration data.

3.2.6 Data analysis

The project's test population is relatively small, and the mean value and deviation analyses can be done through Excel. When the amount of subsequent data becomes large, the Python statistical tool library, such as Scipy and Stats, can be introduced for analysis.

Currently, by using Excel, each testee's test results have two sheets: one is detailed data, and the other one is aggregated data. Samples are as follows:

Timestamp	Direction	Time Spent
2024-05-09 15:09:34	Right	0.475971222
2024-05-09 15:09:34	Right	0.129855871
2024-05-09 15:09:34	Right	0.063869238
2024-05-09 15:09:34	Right	0.077584267
2024-05-09 15:09:35	Right	0.081359148
2024-05-09 15:09:35	Right	0.078015804
2024-05-09 15:09:35	Right	0.087497234
2024-05-09 15:09:35	Left	0.089119196
2024-05-09 15:09:35	Left	0.082115889
2024-05-09 15:09:36	Left	0.075117111
2024-05-09 15:09:36	Left	0.072550774
2024-05-09 15:09:36	Left	0.072334528

Figure 4 Detailed data

Total Left Time	Total Right Time	Total Left Count	Total Right Count	Finish Time
17.00295138	32.41477656	288	502	2024-05-09 15:10:30

Figure 5 Summary data

4. Research Results

4.1. Research output

A set of source code and documentation. cloning address: https://github.com/AmyZhangWQ/Gaze.git

A set of eye movement detection test materials. Also, in the same GitHub repository.

4.2. Environment Suggestions

(1) Hardware requirements:
CPU Intel i7 or AMD Ryzen 7, 16GB memory, 500M hard disk space;
Integrated graphics card, integrated front camera.
(2) Typical software requirements :
Windows 11, Office 2019.
(3) Python runtime environment and dependencies
Python3.10 or 3.12 environments;
The library's dependencies are shown in the figure below.

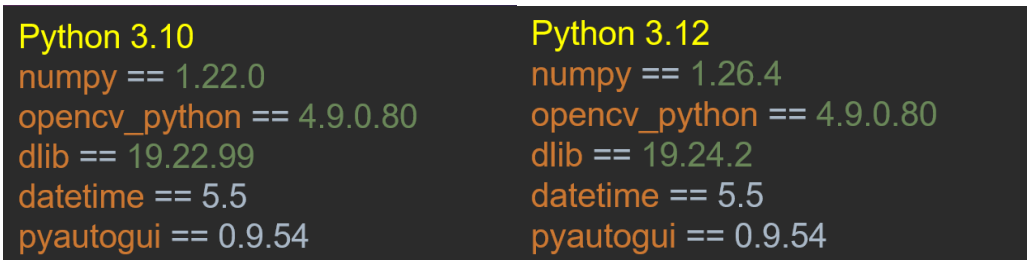

Figure 6 Dependencies

5. Conclusion and prospect

5.1. Research innovations

(1) The test only requires a laptop with a webcam, which is much cheaper than professional eye-tracking equipment. The test environment does not require complex requirements as long as the camera can photograph the face.

(2) Creating test materials using PowerPoint is simple and convenient. Regular medical personnel or non-IT professionals can freely edit test materials, making designing test content for different scenarios easy.

(3) Subjects do not need to wear head-mounted or frame-type eye-tracking devices. They can conduct tests naturally, eliminating the tension or anxiety caused by physical contact devices and increasing the reliability of test data.

(4) It can be used in various scenarios, such as general outpatient clinics, psychological clinics, schools, and community psychology centers. It can play an effective diagnostic auxiliary role when combined with other questionnaire tools.

5.2. Advantages and Potential Business Value

(1) Low deployment requirements: an ordinary computer with a built-in camera can be used without additional equipment costs.

(2) Easy operation: no professional IT skills are needed, and test material can be edited easily.

(3) Open source: This project's inherent and new code is fully open; both can be accessed on GitHub.

(4) Potential customers include general outpatient clinics, professional psychological clinics, schools, and corporate mental health departments.

5.3. Future research direction

It is hoped that a complete system from early detection to professional treatment can be developed in the future, and users can access the system via phones, pads, and other mobile platforms. For example, in the form of applets or applications, game-style tests are designed to collect user eye movement data in real-time and conduct preliminary processing, and then upload the compliant data to the analysis system for diagnosis. The analysis system has both AI experts and real professional doctors. Alternatively, users can compare their results with the depression scale to estimate their current mental health status.

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Appendix

```
import cv2
from gaze_tracking import GazeTracking
from datetime import time
import time
import threading
import os
import pyautogui
import pandas as pd

def eye_tracking_and_presentation():
    gaze = GazeTracking()
    webcam = cv2.VideoCapture(0)
    start_time = time.time()
    total_left_time = 0
    total_left_count = 0
    total_right_time = 0
    total_right_count = 0
    data = {'Timestamp': [], 'Direction': [], 'Time Spent': []}
    while True:
        # We get a new frame from the webcam
        _, frame = webcam.read()

        # We send this frame to GazeTracking to analyze it
        gaze.refresh(frame)

        frame = gaze.annotated_frame()
        text = ""
```

```
        if gaze.is_blinking():
            text = "Blinking"
        elif gaze.is_right():
            text = "Looking right"
            total_right_time += time.time() - start_time
            total_right_count += 1
            data['Direction'].append('Right')
            data['Time Spent'].append(time.time() - start_time)
            data['Timestamp'].append(time.strftime('%Y-%m-%d %H:%M:%S', time.localtime()))
        elif gaze.is_left():
            text = "Looking left"
            total_left_time += time.time() - start_time
            total_left_count += 1
            data['Direction'].append('Left')
            data['Time Spent'].append(time.time() - start_time)
            data['Timestamp'].append(time.strftime('%Y-%m-%d %H:%M:%S', time.localtime()))
        elif gaze.is_center():
            text = "Looking center"
        start_time = time.time()

        cv2.putText(frame, text, (60, 60), cv2.FONT_HERSHEY_DUPLEX, 2, (255, 0, 0), 2)
        cv2.imshow("Demo", frame)

        if cv2.waitKey(1) == 27:
            break

cv2.destroyAllWindows()    # Close the OpenCV window after the loop ends

# Create a DataFrame from the collected data
current_df = pd.DataFrame(data)

# Create a summary DataFrame
summary_data = {
    'Total Left Time': [total_left_time],
    'Total Right Time': [total_right_time],
    'Total Left Count': [total_left_count],
    'Total Right Count': [total_right_count],
    'Finish Time': [time.strftime('%Y-%m-%d %H:%M:%S', time.localtime())]
}
summary_df = pd.DataFrame(summary_data)

# Write both DataFrames to separate sheets in an Excel file
with pd.ExcelWriter('c:\Amy\eye_tracking_results.xlsx') as writer:
    current_df.to_excel(writer, sheet_name='Current Data', index=False)
    summary_df.to_excel(writer, sheet_name='Summary', index=False)

print("Data has been saved to eye_tracking_results.xlsx")

print("Total time spent looking left:", total_left_time)
```

```
    print("Total time spent looking right:", total_right_time)
    print("Total counts looking left:", total_left_count)
    print("Total counts looking right:", total_right_count)

def open_powerpoint(file_path):
    os.startfile(file_path)
    time.sleep(1)  # Wait for PowerPoint to open

    # Maximize PowerPoint window (Windows shortcut: Alt + Space, then press x)
    pyautogui.hotkey('alt', 'space')
    pyautogui.press('x')
    time.sleep(1)  # Wait for window to maximize

    # Play presentation (F5)
    pyautogui.hotkey('f5')
    time.sleep(1)  # Wait for presentation to start

    slides_count = 0
    while slides_count < 9:  # Assuming there are 9 slides, adjust this according to your presentation
        if slides_count < 5:
            time.sleep(3)  # Assuming each slide lasts for 3 seconds, adjust this as needed
        elif slides_count == 8:
            time.sleep(0.5)  # Assuming the last slide lasts for 0.5 seconds, adjust this as needed
        else:
            time.sleep(12)  # Assuming each slide lasts for 15 seconds, adjust this as needed
        pyautogui.press('right')  # Navigate to the next slide
        slides_count += 1

    # Close PowerPoint presentation (Alt + F4)
    pyautogui.hotkey('alt', 'f4')
    time.sleep(1)  # Wait for PowerPoint to close



if __name__ == "__main__":
    powerpoint_file = r"c:\Amy\TestCase.pptx"  # Change this to the path of your PowerPoint file

    # Create a thread for running eye tracking and presentation concurrently
    eye_tracking_thread = threading.Thread(target=eye_tracking_and_presentation)
    PPT_thread = threading.Thread(target=open_powerpoint, args=(powerpoint_file,))

    # Start the eye tracking and presentation thread
    eye_tracking_thread.start()
    PPT_thread.start()

    # Wait for the eye tracking thread to finish
    eye_tracking_thread.join()

    cv2.destroyAllWindows()
```