ECE496: Group Final Report

Project Title	Personality Characterization using Eye Tracking
Project Number	2015334
Supervisor Name	Prof. Jonathan Rose

Administrator Name	Nicholas Burgwin
Section Number	9

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Executive Summary (Author: Manveer Sidhu Pritam Singh)

Research suggests that eye movements can reveal an individual's personality and behaviour. The team set up an experiment to test the hypothesis that we can determine a subject's degree of Agreeableness by analysing their eye movements when presented with a set of pictures on a screen. The experiment displayed 28 pictures of faces of seven different emotions namely fearful, happy, sad, disgusted, surprised, angry and neutral, and recorded subject's eye movements as they looked at these pictures. The experiment was designed so that it would allow for iteration between theory and experiment, to account for the risk that as the research progresses, the theory or experiment may have to change to accommodate new information. We ran this experiment on more than 30 subjects, and managed to obtain 26 valid and accurate data points. We then analyzed the data and determined that there was a significant and positive correlation of 0.478 between the degree of Agreeableness of a person and the time spent fixating on the eyes of happy faces ($r = 0.478$, $p < 0.01$). Next, we went on to develop a desktop application that made use of the experimental data to predict the degree of Agreeableness of a person. The application displays the same 28 pictures used for the experiments and records the eye movements of the user. It then predicts the degree of Agreeableness of the user to within a 10% error range, with a Prediction Rate of 76.92%. The desktop application used a Multivariate Linear Regression method, which takes into account the correlations between Agreeableness of a user and the dwell time on the eyes of all 7 emotions to help generate a more accurate prediction, as compared to making a prediction solely on the correlation between Agreeableness and the dwell time on happy faces. Both the experiment and the application were tested to ensure that they met key requirements. The time taken for each experiment was set to a maximum of 20 minutes, and the processing time for data from each experiment run was set to a maximum of 5 minutes. The application had a run time of 4 minutes, and has the option to display the heat maps of a user's eye movements upon request. The estimated total cost of the project is $21,783.20. However, the total cost requiring funding is only $213.20.

Group Highlights and Individual Contributions

This section contains the group highlights from the perspective of the entire team, in addition to each team member's individual contributions.

Group Highlights (Author: Mohak Poddar)

In the initial phase of the project, our team did research to determine which pictures to use in our eye tracking experiment. We also developed two pieces of software, one to use for the experiment and the other to analyze the data generated by the Tobii Eye Tracker during the experiment.

Once this was completed and tested, we started to run experiments on subjects. We managed to obtain valid and accurate data from 26 subjects. The next step was to analyze the data. By looking at the heat maps, we determined the eyes of the faces to be the only major Area of Interest (AOI). We then calculated the dwell times on this AOI for all our subjects.

We found that the maximum correlation we obtained was between the dwell time on the eyes of happy faces, as outputted by our eye tracking test, and between the Agreeableness Big Five Personality Trait, as outputted by the online personality quiz, for 3 second duration. This correlation was found to be 0.478. Although this might seem low, any correlation between 0.4-0.6 is considered to be sufficient in this area of research [1]. Please see Table 9 for all the correlation values we obtained.

The next step was to use these correlation values to predict a subject's Agreeableness with a Prediction Rate (PR) greater than 70%. Here, if we only used happy faces for the prediction, we obtained a Mean Error (ME) of ±10.96. However, if we used all the seven different emotions, we obtained a ME of ± 9.46. So, in order to obtain the best PR, our final algorithm will use the average dwell times on all the seven emotions to predict a subject's Agreeableness personality trait. The exact equation that is used can be found in Appendix F.

The final step was to combine the two pieces of software mentioned earlier to create a desktop application. A subject will be shown a set of pictures on the screen, after which our algorithm will immediately output that subject's Big Five Personality Traits. The subject will even be able to view his/her heatmaps, if interested.

Please note that throughout this document, for simplicity, we talk primarily about the Agreeableness personality trait since we obtained the highest correlation, lowest ME and highest PR for this trait. However, our final application will be able to output the score for the remaining four personality traits as

well, only not as accurately (higher ME and lower PR) as Agreeableness.

Individual Contributions (Author: Manveer Sidhu Pritam Singh)

I've worked on four main categories of this project, which are, conducting research, developing software, setting up and conducting the experiments, and analyzing and testing the data we gathered to ensure that it is statistically significant. Initially, I worked on conducting research to select a trait to focus our experiments on and selecting the images to be used for our experiment. Through my research, I found a similar study that found strong correlations between a subject's level of Neuroticism and the time that subject spent on the eyes of fearful faces [1]. Based on this and other research, I decided to run the experiment by showing subjects images of 7 emotions (see Appendix D), and record their eye movements to see if we could find any significant correlations. Next, I worked on developing software that would display 40 images on the screen, for 5 seconds each while collecting the subject's eye tracking data by querying the Tobii EyeX engine API. All the eye tracking information was saved in text files that were to be analyzed later on by another component of the application. Next, I worked on setting up and performing the eye-tracking portion of the experiments by running the experiment software on my laptop computer at a study room in Gerstein Library. This included explaining to the subjects the what the experiment was about, calibrating the eye tracker, and running the experiment while ensuring that the subject was not distracted by external factors. Together with my teammate Mohak (who was responsible for running the personality quiz on participants), we successfully conducted over 30 experiments. After accounting for invalid data and calibration errors, we managed to get 26 valid and accurate data points which we later analyzed. Next, I worked on data analysis. First, I determined the Area of Interest (AOI) for each image. These are the x and y coordinates of the different facial features on the image. I determined the AOIs for each image so that we could analyze the percentage of time a subject fixated on the eye AOI. By analysing the data, we determined that the strongest correlation we found was a positive correlation ($r = 0.478$) between the Agreeableness of a person and the percentage of time they spent fixated on the eyes of happy faces. I analyzed this data for statistical significance, and concluded that it is indeed statistically significant with less that 1% chance the correlation is statistically irrelevant (see Appendix E).

Individual Contributions (Author: Richard Huang)

My individual contributions can be found in Table 1 below.

Table 1: Individual Contributions

Task	Description	Contribution
Research	Gather data from existing research on eye movements and the Big Five Personality Traits	● Researched on the Big Five Personality Traits ● Researched on the correlation between eye movements and personality traits [2] ● Researched on psychological research process [See 2.1 System Level Overview]
Experiment	Design and perform the experiment	● Provided a reliable online personality test [Appendix J] ● Worked on experiment application ● Acquired access to multiple psychology picture databases in order to use their pictures for our experiment [3,4]
Analysis	Analysis of the experimental results	● Coded a machine learning algorithm that takes the recorded data and generates an equation that can be used to predict personality scores based on a person's eye movements [See 2.3.2 Assessment of Application]
Software Development	Development end of project application	● Designed the architecture for the user application [See 2.1.2 Application System-Level Overview] ● Transferred usable code from experimental application ● Programmed each component and provided improvements to pre-existing experimental application code [See 2.1.2 Application System-Level Overview]

Individual Contributions (Author: Mohak Poddar)

My first major contribution was to obtain Ethics Approval since our project involved running experiments on human subjects. Next, I was responsible for conducting these experiments. This involved scheduling subjects for 20 minute time slots at a study room in Gerstein Library. I gave them a brief overview of our project and the motivation behind doing it. I also gave them instructions about the online personality quiz and told them to answer it as honestly as possible, since the results from the eye tracking experiment use the results of the personality quiz as a baseline. Together with Manveer, we managed to collect valid data from 26 subjects.

Next, I developed an image analyzer program that analyzes the data files generated by the eye tracking experiment. The first step was to use the data to create heat maps, which are a visual representation of the regions of the image that the subjects looked at. By viewing the heatmaps, I then identified the areas of interest (AOIs) in the images. Manveer then calculated the x and y coordinates of these AOIs. Using those coordinates, the next step was to extend the program so that it calculated the dwell times on those AOIs.

Last, I was responsible to determine whether there was any meaningful correlation between the dwell times, as outputted by my image analyzer program, and the results of the online personality quiz. Using Microsoft Excel, the strongest correlation I found was between a subject's agreeableness personality trait and the amount of time they spent fixating on the eyes of happy faces for the first three seconds only (not the entire five seconds). This correlation was found to be +0.478. It means that subjects who score higher on the agreeableness personality trait from the online quiz tend to spend more time fixating on the eyes of happy faces, compared to subjects who score lower. The reason to use three seconds is based on an existing research [1].

Acknowledgements (Author: Mohak Poddar)

We would like to thank our supervisor, Professor Jonathan Rose, for encouraging us to take on a project that was challenging in terms of both science and engineering. His motivation and technical expertise was invaluable, and was a major contributing factor to the project's final results that we obtained. We also appreciate the fact that he funded the Tobii EyeX Tracker which was the main component of this project.

Next, we would like to thank our administrator, Nicholas Burgwin, for giving us useful feedback during the Design and December Review Meetings, that we incorporated into our project. Given that our project involved research and was quite different from others, we appreciate the fact that he was available and willing to help us whenever we had any questions specific to our project.

Next, we would like to thank the University of Toronto Designated Ethics Review Committee for approving our Ethics Review Application in quick time.

Finally, we would like to thank all the subjects who took the time out and volunteered to sit for our experiment. The feedback we obtained from them lead us to making changes to our experiment that improved the validity and accuracy of the data we obtained.

Table of Contents (Author: Mohak Poddar)

1. Introduction

This report summarizes the motivation, requirements, design and testing of our project regarding research into the possible correlations between an individual's personality and their eye movements when looking at images of emotional faces, as part of our final year design project course ECE 496. This report walks through the initial research conducted in this area, the experiments carried out, and the analysis of the data the team obtained from these experiments. This report then describes the application the team built based on this data, that predicts a user's personality. This report concludes with potential applications of our project and future work.

1.1 Background and Motivation (Author: Mohak Poddar)

Knowing an individual's personality is important because it helps them as well as others they interact with understand why they do things or react in a certain way. The Big Five Personality Traits (BFPTs) is the most widely accepted model to measure personality dimensions. The most predominant method today to determine one's BFPTs is via online or written personality tests. However, a limitation of this method, as research suggests, is that people can easily fake their personality by deliberately answering some questions dishonestly [5].

Other possible methods to determines one's BFPTs are eye tracking, electroencephalography (EEG) and measuring skin temperature. These methods are more accurate than online tests because people cannot control or fake involuntary reactions like eye movements and skin temperature. Our team chose to pursue eye tracking because of its simplicity. Also, it will be more likely to obtain an Ethics Approval from the University of Toronto Ethics Committee, if the above methods are performed on other human subjects.

Existing research shows that eye movements can reveal an individual's personality and behaviour. For example, quick eye movements show impatience and lack of self-control [6]. However, no research exists today that can decisively categorize eye movements to determine the BFPTs of an individual [7]. The Tobii EyeX is an eye tracking device that is used to record gaze and fixation data. Our team intends to use this device to develop an experiment to find the correlation between eye movements and the BFPTs.

Currently, 13% of employers use personality tests when hiring while 40% of job applicants manipulate their answers [8] [9]. Therefore, a possible application is that hiring managers within companies can use our experiment to know the BFPTs of potential employees with more certainty, to determine if they are

a good fit for a particular kind of job. This will reduce hiring decisions that lead to a personality mismatch between employee and job, which can result in the company suffering from reduced productivity and loss of investment in training.

1.2 Project Goal (Author: Manveer Sidhu Pritam Singh)

The goal of the project is to to test the hypothesis that we can determine a subject's degree of Agreeableness, one of the traits in the Big Five Personality model, by recording and analyzing their eye movements when presented with a collection of visual data, like pictures on a screen.

1.3 Requirements (Author: Manveer Sidhu Pritam Singh)

This section contains the project requirements divided into functions, objectives and constraints. They will be used to evaluate the success of the project.

1.3.1 Functions

Functions are what the design must do. A design that meets the functional requirements could be considered as a possible solution. Functions for the project can be found in Table 2 below.

Table 2: Functions

#	Function	Explanation
F1	Statistical validity of experimental data	Any correlations determined from the experimental data will have to be tested to ensure that they are statistically significant.
F2	Minimum One Trait	The application must be able to predict at least one personality trait of a subject based on correlations found from experimental data.
F3	Prediction Rate (PR)	The PR is either greater than 70% or less than 40% to provide conclusive results

Prediction Rate (PR) is used to determine whether there is a correlation between a sample groups' eye movements and their Big Five Personality Traits (BFPTs). The stronger the correlation, the higher the PR. For example, a PR of 70% means that the degree of agreeableness was successfully determined 70% of the time in a sample group. Generally, a PR of 95% (most commonly used Margin of Error in

Engineering) would be used to establish the existence of a relationship between a personality trait and eye movements; however, a PR greater than 70% will be used for this project after taking into consideration the time and budget constraints. This is justified because a 70% PR still strongly suggests that there is a correlation and encourages further research into this area. Likewise, a PR of 40% or less would suggest that a relationship is unlikely. Table 3 below contains the PRs used for this project. Refer to Appendix C for the details of the criteria we use to determine whether a prediction is successful or not.

Table 3: Prediction Rates Used for this Project

#	**Prediction Rate**	**Explanation**
1	Greater than 70%	There is a relationship between this particular personality trait and eye movements.
2	Between 40% and 70%	The research is inconclusive and requires further investigation since there is inadequate information to decide on whether or not there is a relationship.
3	Less than 40%	There is no relationship between this particular personality trait and eye movements. Any successful predictions are likely made due to experimental errors.

1.3.2 Objectives

Objectives are what the design should do. They define the criteria that can be used to find the best solution, provided it meets the functional requirements.

The objectives for the experiment can be found in Table 4 below.

Table 4: Experimental Objectives

#	**Objective**	**Explanation**
EO1	Minimize Experiment Time	Each individual subject should take less than 30 minutes to complete the experiment
EO2	Minimize Processing Time	It should take less than 20 minutes to analyze the data collected from each individual subject
EO3	Minimize Number of Subject Visits	The subject should visit and participate in a maximum of five experiments, one for each of the personality traits, held at different times
EO4	Additional	Determine if there is a correlation between eye movements and other

	Personality Traits	personality traits using a PR identical to the one used for the primary trait. The five personality traits are Openness to Experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism.

The objectives for the application can be found in table 5 below.

Table 5: Application Objectives

#	**Objective**	**Explanation**
AO1	Minimize Application Run Time	The application run time should be less than 5 minutes in total. That is, the application should display all the images, record the eye movements of each subject, and output the predicted personality trait scores of a subject in 5 minutes.
AO2	Display heat maps of user eye movements	The application should also display the heat maps of user's eye movements, upon request.

1.3.3 Constraints

Constraints set hard limits. If a design violates any of the constraints, it is not considered feasible.

Constraints can be found in Table 6 below.

Table 6: Constraints

#	**Constraint**	**Explanation**
C1	Ethics Approval	This project shall use humans as subjects for the experiment and therefore requires Ethics Approval from the University of Toronto Ethics Committee
C2	Ontario Personal Health Information Protection Act [10]	We must protect the privacy of subjects that are taking part in the experiment.

2. Final Design (Author: Richard Huang)

Below are the details of our final design.

2.1 System Level Overview

For clarity, we have divided this section into an experiment system-level overview and an application system-level overview.

2.1.1 Experiment System-Level Overview

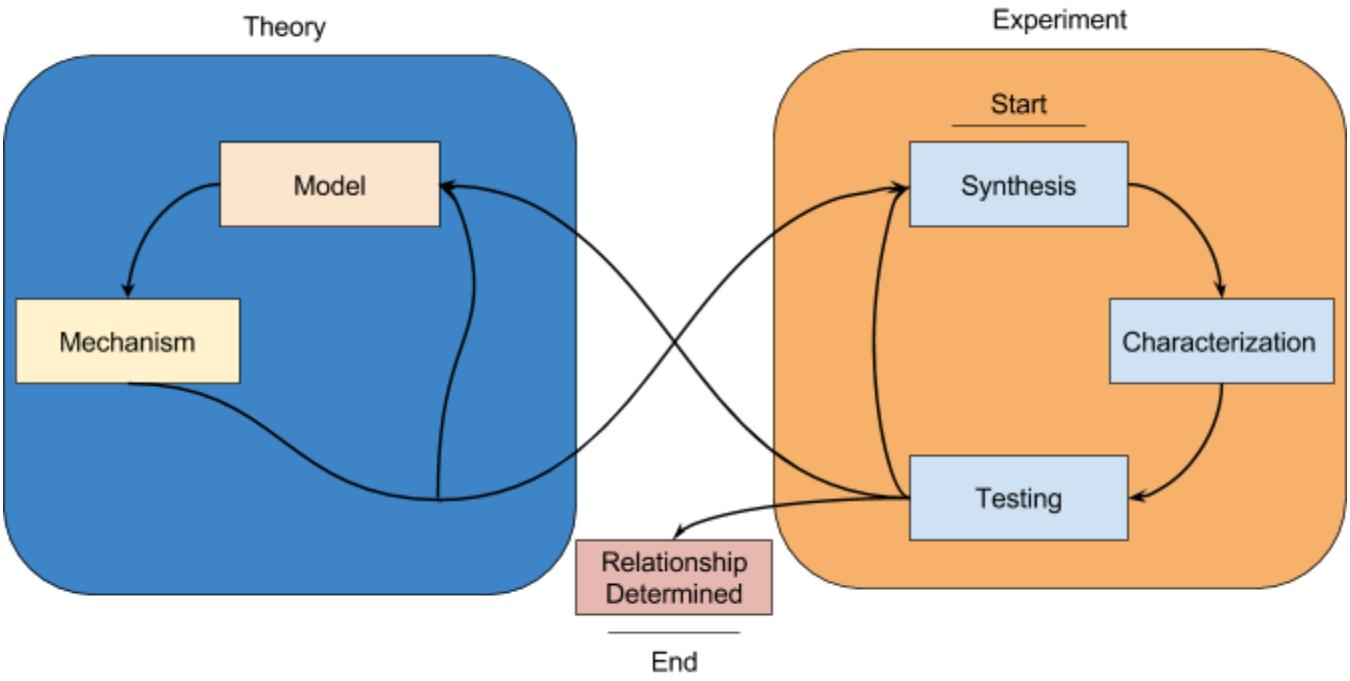

Figure 1: Experiment System Level Block Diagram [11]

The first segment of the project is a research. Figure 1 above shows the process of how the research for this segment is conducted; starting at the Synthesis block. In general, the Experiment component consists of acquiring data whereas the Theory component consist of describing the data. The significance of this separation is that it allows for the iteration between theory and experiment. This accounts for risk in that as the research progresses, the theory or experiment may have to change to accommodate new information.

The experiment module description and design can be found in Table 7 below.

Table 7: Experiment Module Descriptions and Design

Experiment Stages	Purpose
Synthesis	Formulate a testable hypothesis about the relationship between eye movements and personality traits.
Characterization	Designing and implementing an experimental procedure to test out the hypothesis.
Testing	Gathering volunteers and performing the experiment on them to gather data.
Model	Developing/refining a theory or model to describe the results from testing.
Mechanism	Developing a method of prediction for the personality traits.
Relationship Determined	The purpose of the experiment has been achieved. The relationship between eye movements and personality traits are established.

2.1.2 Application System-Level Overview

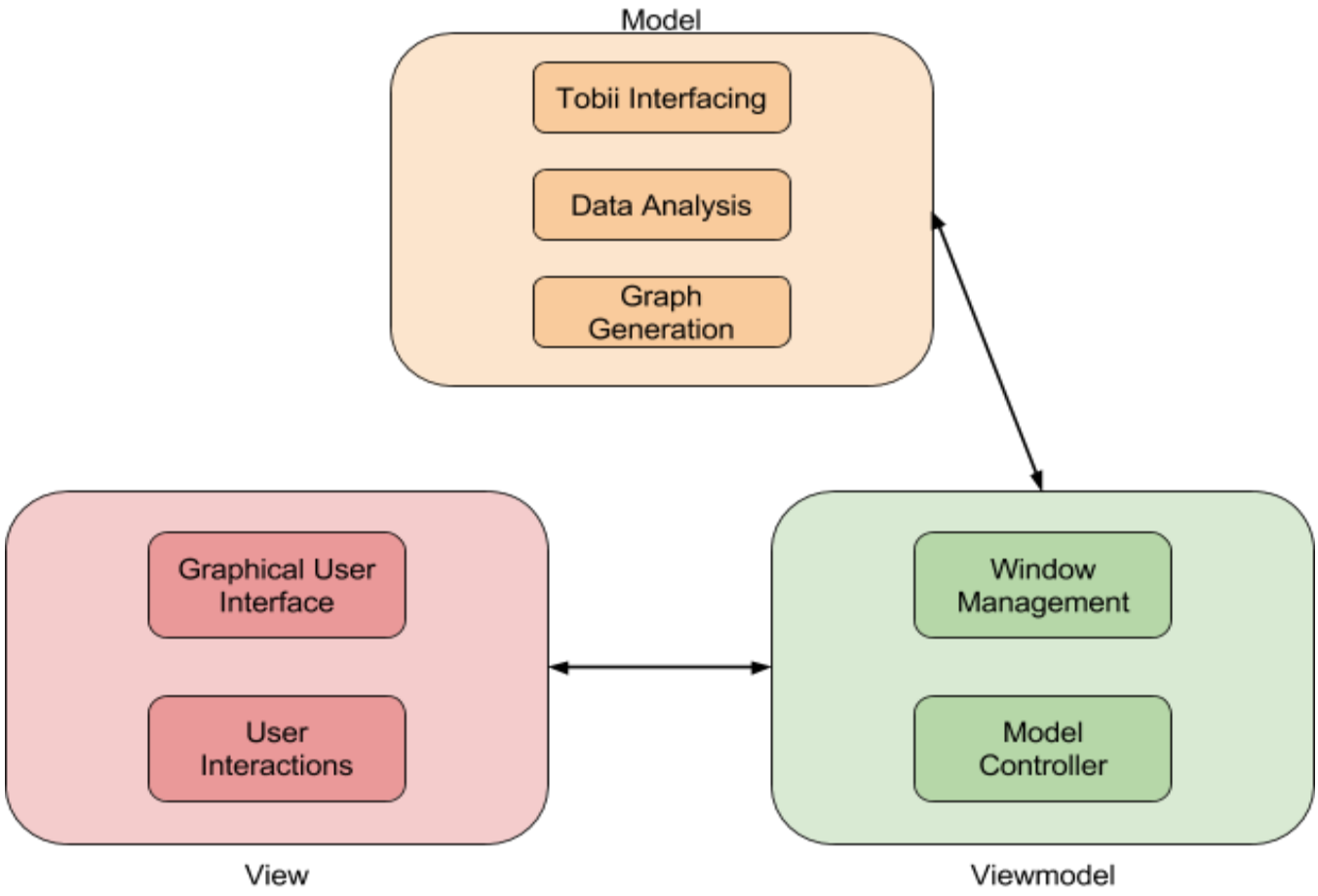

Figure 2: Application System Level Block Diagram

The second segment of the project is the design of an application which will provide a score from 0-100% for each of the Big Five Personality Traits based on their eye movements, as images of different human emotions are displayed. Specifically, this application will measure the dwell time of the user's eyes on the Areas of Interest (human eyes), averages the time based on the emotions of the person in each image, then calculate the score based on a formula generated by a Linear Multivariate Regression algorithm (see Appendix F for the formula). There are three main components to this application, as can be seen in Figure 2 above: Model, Viewmodel , View. The View is responsible for everything the user sees and interacts with. The Model is responsible for measuring dwell time, computing the user's trait scores, and generating heatmaps to be displayed. The Viewmodel manages what windows are being displayed, provides instructions to control what the Model does and provides communication between windows. The View is the visible portion of the code to the user and it handles all user interactions; relaying that message to the Viewmodel. Each Window is an instance of a View.

2.2 Application Module Descriptions and Design

The Application Module Descriptions and Design can be found in Table 8 below.

Table 8: Application Module Descriptions and Design

Components	Subcomponents	Description
Model	Tobii Interfacing	**Input:** ● Enable or Disable **Output:** ● The screen coordinates of the eyes ● A timestamp as to when the coordinates were taken **Function:** This subcomponent interacts with the Tobii Eye Engine. The Tobii Eye Engine records the fixations and sends the data to this subcomponent. This data is then stored into memory. The data is separated based on which image was displayed while recording data.
	Data Analysis	**Input:** ● The screen coordinates of the eyes ● A timestamp as to when the coordinates were taken **Output:** ● Big Five Personality Trait Scores **Function:** This subcomponent takes the data that was generated by the Tobii Interfacing Component, and calculates the average dwell

		time for each emotion. In total there are 7 different emotions, each emotion having 4 pictures. This subcomponent takes those 4 pictures and generates the average dwell time for each emotion. Afterwards, this dwell time is used to generate the scores for each Big Five Personality Trait based on the formula generated by the Multivariate Linear Regression algorithm (See Appendix F for the formula).
	Heatmap Generation	**Input:** ● The screen coordinates of the eyes **Output**: ● Heatmap based on the screen coordinates **Function:** This subcomponent takes the screen coordinates for each picture and draws a transparent layer over the picture based on where the fixation points are. This new picture is the heatmap (See Appendix H for generated heatmaps)
Viewmodel	Window Management	**Input:** ● Window to be displayed ● The Mode of the Window **Output:** ● Displays the Window **Function:** This component controls what windows are displayed at a single moment. It will prevent multiple instances of the same window from being displayed.
	Model Controller	**Input:** ● Messages from the View **Output:** ● Messages to the Model **Function**: This subcomponent manages the communication between the View and the Model. This comes from design where you can have multiple Views but only one Viewmodel . The Viewmodel serves as the center point and manages communications from both sides.
View	Graphical User Interface	**Input:** ● Messages from the Viewmodel ● User Interactions **Output:** ● Desired objects are displayed to the user **Function:** This subcomponent is the visual display which the user will see.
	User Interactions	**Input:** ● Keyboard hotkeys

		● Mouse Clicks **Output:** ● Desired Actions ● Messages to the Viewmodel **Function:** This subcomponent is responsible for handling of all user interactions such as button clicks or keyboard shortcuts. It translates those interactions into a message to the Viewmodel or informs the current View (window) to perform an action.

2.3 Assessment of Final Design

For clarity, we have divided this section into Assessment of Experiment and Assessment of Application.

2.3.1 Assessment of Experiment

Table 9: Correlation Between Trait and Human Expressions

Trait	Fearful	Happy	Sad	Disgusted	Surprised	Angry	Neutral
Agreeableness	0.284	0.478	0.265	0.375	0.219	-0.008	0.307
Openness to Experience	0.279	0.135	0.233	0.088	0.228	0.099	0.005
Neuroticism	0.117	-0.061	0.194	0.061	0.257	0.007	0.079
Conscientiousness	0.122	0.042	0.005	0.007	-0.076	-0.041	-0.193
Extraversion	-0.019	0.106	-0.074	0.039	-0.128	-0.209	0.031

The results of the experiments are displayed in Table 9 above. The entries range in value from -1 to 1 where -1 represents full anti-correlation, 0 represents no correlation, and 1 represents full correlation. A small correlation would have a magnitude around 0.3 and a large correlation would have a magnitude of 0.6. As shown, Agreeableness and Happy Human Expressions show the highest correlation. This means that people who score higher in Agreeableness spend more time looking at the eyes of happy faces.

To show that the results of this experiment was meaningful, a test was performed to determine the significance of this data. This test is called the Significance Testing of Pearson Correlations using the Student's T-Test [12]. The explanation as to how the T-Test was performed can be found in Appendix

E. The result of this test is that there is a 99% chance that the experimental data is statistically significant when considering Agreeableness and happy faces (see Appendix E for the results when considering Agreeableness and other human emotions). This means that there is a 1% chance that a random process will generate data that will show the same results as the data above. As such, we can conclude that this data is meaningful, specifically the correlation between agreeableness and happy human expressions.

2.3.2 Assessment of Application

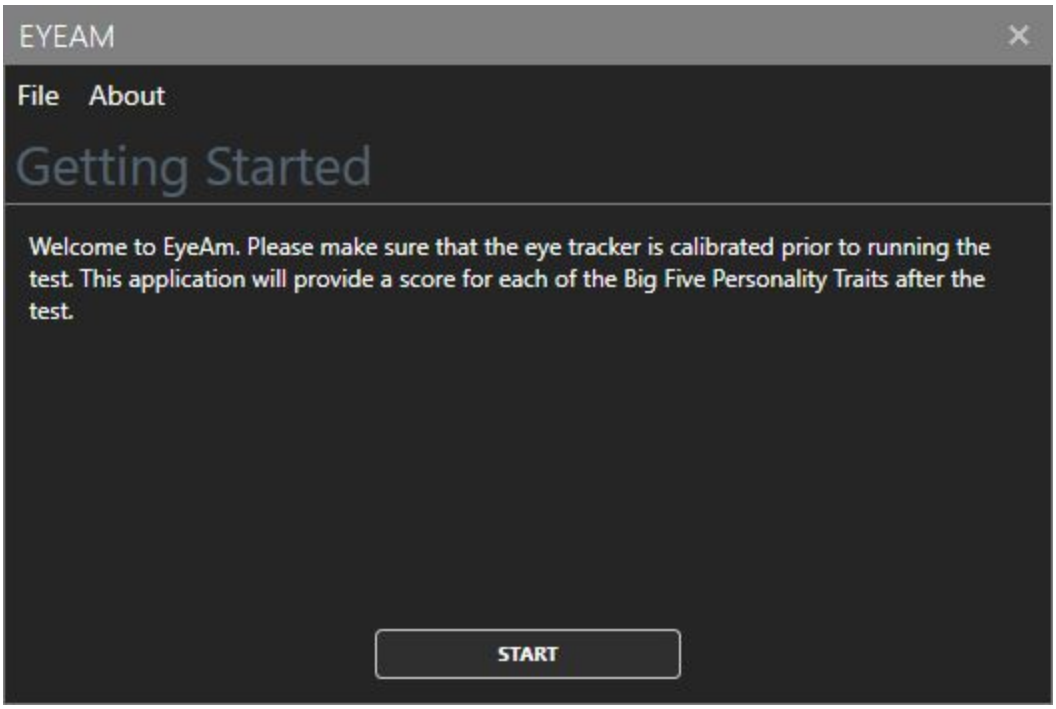

Figure 3: Main Window Screenshot

To demonstrate that the application is functioning, this section will provide a walkthrough of the process of using the application. Above is a screenshot of the window that appears once the application is launched. This is one of the windows which is a member of the View. Once you hit start, it will take you to a new window.

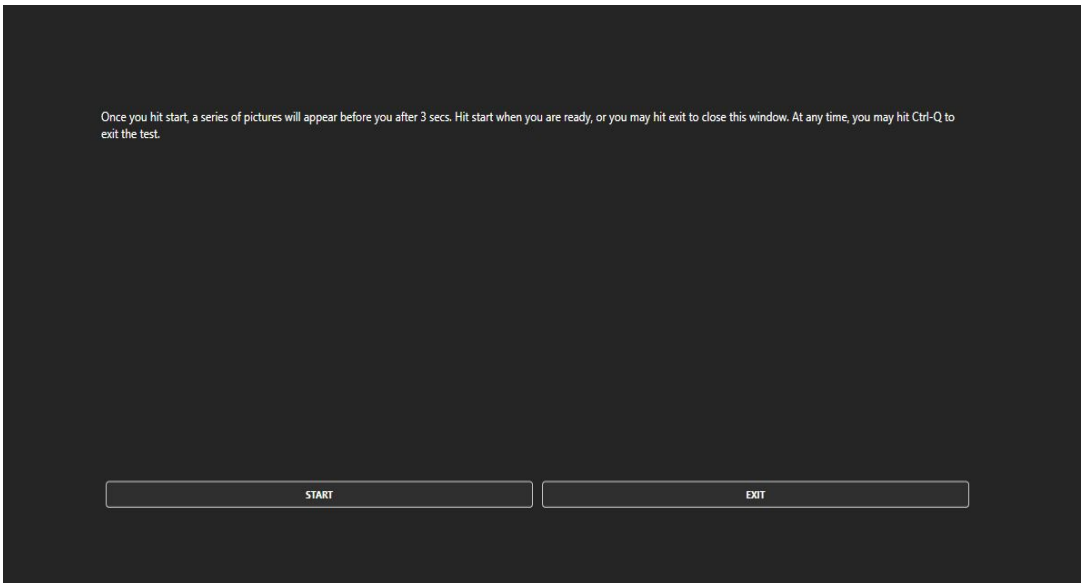

Figure 4: Test Start Window

Once you hit start, it will display a series of pictures such as the one in Figure 5. Meanwhile, the eye tracker will record the x and y coordinates of the user's eye movements for each picture.

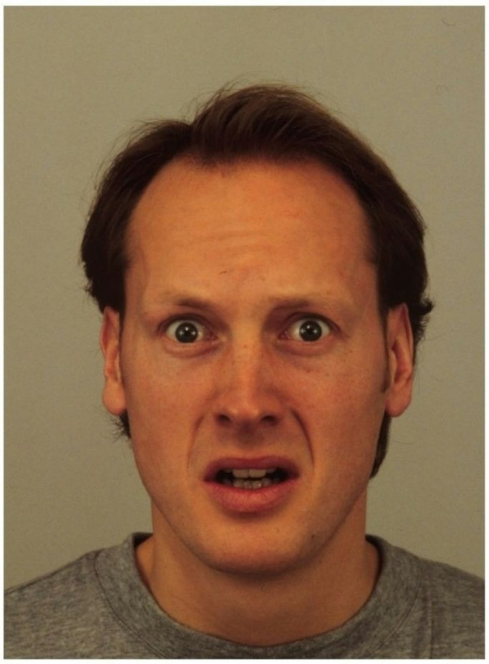

Figure 5: Sample Test Picture

After the Test, the eye movements recorded will be processed to provide a score for each personality.

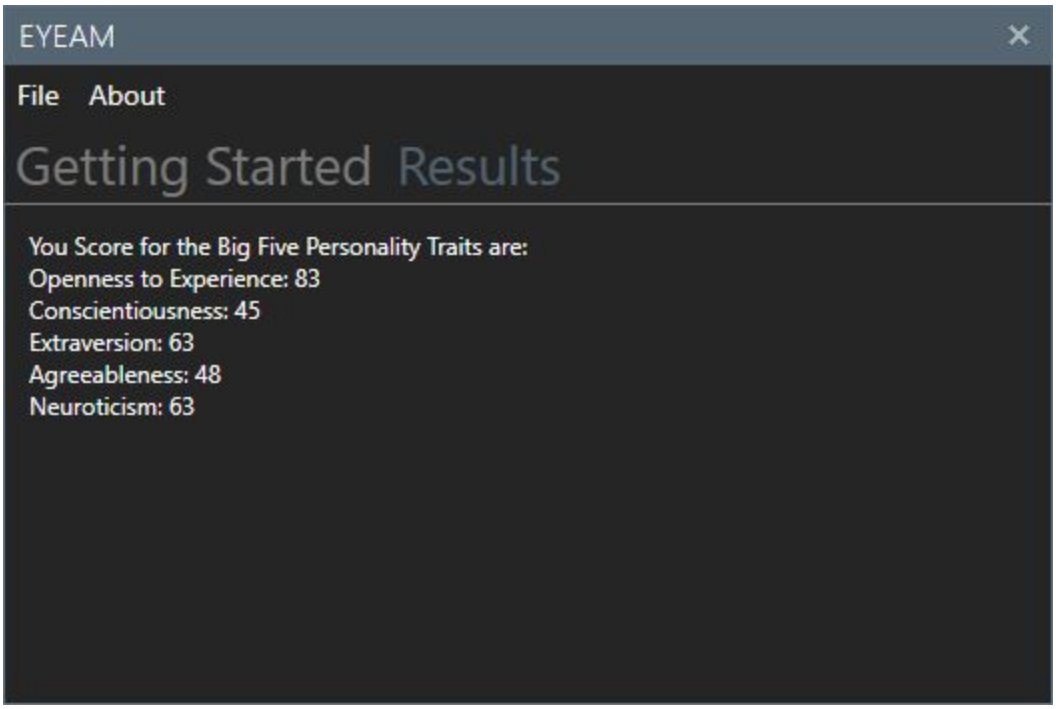

Figure 6: Sample Results

As shown above the application is working. To demonstrate that the results are correct, it is important to understand how the scores are predicted. The datasets from the research segment are used as a training set for a Multivariate Linear Regression algorithm. This algorithm generates an equation that predicts a person's personality traits based on their dwell time on the eyes of each person in the pictures displayed (see Appendix F for equation). The personality scores produced by this equation was compared to the actual personality scores of the volunteers from the online personality quiz.

Table 10: Mean Squared Error

	Univariate Linear Regression	Multivariate Linear Regression
Agreeableness	120.2226	89.4539

The Univariate Linear Regression in Table 10 refers to the line of best fit between agreeableness and the dwell time on happy faces only (see Figure 7 below), as generated by Microsoft Excel. On the other hand, the Multivariate Linear Regression refers to the results when considering Agreeableness and the other six emotions. In summary, the Table 10 values show that the multivariate model, which is also used in the application, has the lower error of the two models. Additionally, on average, it will generate an error that is ± 9.458 compared to the actual score, which meets the requirements of this project, as will be shown in Section 3 below.

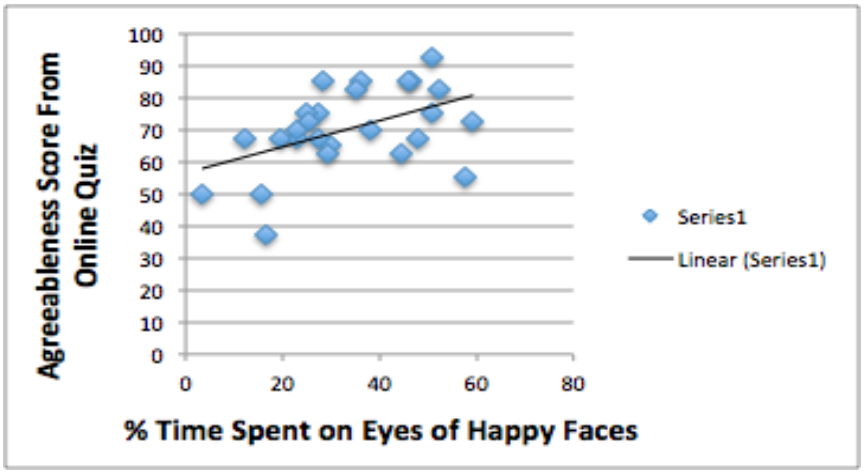

Figure 7: Line of Best Fit

3. Testing and Verification (Author: Everyone)

The results of testing our design against our target requirements can be found in Table 11 below.

Table 11: Testing and Verification

Requirement (# and title)	Target Specification	Final Result	Compliance	Comments and Documentation
F1 - Statistical validity of experimental data	Any correlations determined from the experimental data will have to be tested to ensure that they are statistically significant. We decided that in order for our correlations to be deemed statistically significant, they should have a 95% significance level or more, as is common with non-highly critical data [12].	The strongest individual correlation the team found was r = 0.478 between Agreeableness and % of time spent on the eyes of Happy Faces for 3 seconds. (See Table 9 above for results). The statistical significance of this correlation was calculated to be 99%. (See Appendix E for detailed calculations).	PASS	The statistical significance of the strongest correlation detected from the experimental data was 4% higher than the required significance level.
F2 - Minimum One Trait	At least one trait can be determined within a reasonable tolerance (± 10) (see Appendix C for details of the Validation and Acceptance Test).	As indicated in the Assessment of the Application (2.3.2), the Mean Squared Error for agreeableness is 89.4539. This means that the application's results will vary by ± 9.458 ,which is within the desired tolerance.	PASS	The other traits do not meet the required tolerance specified.
F3 - Prediction Rate (PR)	The algorithm used to predict the personality scores will meet the required Prediction Rates indicated in the Functional Requirements (1.3.1) (see Appendix C for details of the Validation and Acceptance Test).	Of the 26 volunteers, 20 of the scores were predicted within the ± 10 tolerance. This means that the prediction rate is 76.92%, which is greater than the required Prediction Rate. See Appendix G for details.	PASS	This Prediction rate is based on Agreeableness, which is the primary trait targeted in this project.
EO1 -	Each individual subject	We measured the	PASS	Maximum time

Minimize Experiment Time	should take less than 30 minutes to complete the experiment	approximate time taken for each subject to complete the experiment. The maximum recorded time taken was 20 minutes.		per experiment turned out to be 10 minutes less than required.
EO2 - Minimize Processing Time	It should take less than 20 minutes to analyze the data collected from each individual subject	We measured the approximate processing time taken for each data set. The maximum recorded time taken was 5 minutes	PASS	Maximum processing time for each data set turned out to be 15 minutes less than required.
EO3 - Minimize Number of Subject Visits	The subject should visit and participate in a maximum of five experiments, one for each of the personality traits, held at different times	Each subject only participated in one experiment, which tested for all five of the Big Five Personality Traits.	PASS	The number of subject visits was 4 less than the stated maximum.
EO4 - Additional Personality Traits	Determine if there is a correlation between eye movements and other personality traits using a PR identical to the one used for the primary trait. The five personality traits are openness to experience, conscientiousness, extraversion, agreeableness and neuroticism.	We are able to determine a correlation between eye movements and the primary trait (Agreeableness) with a PR of 76.92% (see Appendix G). However, for the other four personality traits, the correlations we found had a PR of less than 70%, which is considered unacceptable.	FAIL	Four of the five personality traits did not have correlations with eye movements with a sufficiently high PR.
AO1 - Minimize Application Run Time	The application run time should be less than 5 minutes in total. That is, the application should display all the images, record the eye movements of each subject, and output the predicted personality trait scores of a subject in 5 minutes.	We measured the total run time of the application. The time taken for each run of the application was 3 minutes and 20 seconds.	PASS	The application run time was 100 seconds less than the required run time.
AO2 - Display	Our application should	As shown in Appendix	PASS	The red pixels in

heat maps of user eye movements	be able to accurately display the heatmaps of the subject's eye movements	H, our application meets the target specification. To test the accuracy, we ran a test experiment where one of us intentionally looked at the top-right area of the images.		the heatmaps are the regions where the subject has spent the most time looking at, while the blue pixels are where the subject has spent the least time looking at
C1 - Ethics Approval	This project shall use humans as subjects for the experiment and therefore requires Ethics Approval from the University of Toronto Ethics Committee	We obtained Ethics Approval from the University of Toronto Ethics Committee towards the end of November 2015.	PASS	See Appendix I for the screenshot of the approval.
C2 - Ontario Personal Health Information Protection Act	We must protect the privacy of subjects that are taking part in the experiment.	We stored all information and experimental data from our subjects on a password protected computer. Also, each subject was given a unique user number, and any reference to data from a subject was made using that number, instead of the subject name.	PASS	

4. Summary and Conclusions (Authors: Mohak Poddar & Manveer Sidhu)

From Section 3, it is clear that we have met all our project goals and requirements except the Additional Personality Traits experimental objective. The Mean Errors (MEs) for the other traits, excluding Agreeableness, were beyond the tolerable threshold (± 10) and the PRs were below the required 70%. Our testing and verification accurately depicts our final design, with the exception of the heatmap generation. The current heat maps being generated, as shown in Appendix H, may be replaced by a heat map design that is more professional and presentable, time permitting. Also, we may make the user interface (UI) of our final design prettier, again, time permitting.

Our team designed the experiment that we would have subjects sit for at the very beginning of the project. At that point in time, since we could not be certain that we would find meaningful and strong correlations between personality traits and eye movements, we focused on planning and implementing the software of the experiment. Later on, once we neared the end of our experimental phase, we decided to start designing and implementing the final application that would predict a user's personality based on their eye movements. This was because the analysis of our experimental data did indeed show numerous correlations between the Big Five Personality trait and a user's eye movements when looking at various emotional faces. Therefore, it's fair to say that our planning and design was adequate as it allowed us to focus on the the important aspects of the project throughout its lifecycle.

The key conclusion to be drawn from our project is that research and experimental data suggests that there is indeed a link between eye movements, or to be more specific a person's fixation on the eyes of an emotional face and the personality of that person, as can be clearly seen in Table 9. Broadly speaking, it seems to be that human personalities are related to how we perceive and interact with the our social world [1].

Using eye tracking techniques provides us with an innovative way to determine one's Big Five Personality Traits (BFPTs). It truly lends belief to the long held ideas that the eyes are the window to the soul. This method is an improvement to using online tests because it is harder to fake. Therefore, a potential application is that hiring managers of companies can use this to determine the BFPTs of potential employees with more certainty and accuracy, to prevent a mismatch between employee and job.

In the future, as eye tracking technology becomes more powerful and affordable, we hope that the results of this project can be used as an encouragement to drive more research in this as well as other areas, with the hope that it benefits society and improves the quality of life.

5. References (Author: Everyone)

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6. Appendices (Authors: Mohak Poddar & Manveer Sidhu Pritam Singh)

Appendices contain relevant information that is used to support the arguments presented in the body of the document.

Appendix A - Gantt Chart History (Author: Manveer Sidhu Pritam Singh)

Below is the initial Gantt Chart that the team designed for the Project Proposal.

The Gantt Chart in Figure 8 below showed the plan for scheduling of tasks. Steps 10, 11, and 12 (Running the experiment) and steps 13, 14, and 15 (Analyzing data and making appropriate changes) were performed twice, due to the fact that we had to account for possible experimental error. C1 and C2 indicate Cycle 1 and Cycle 2 respectively.

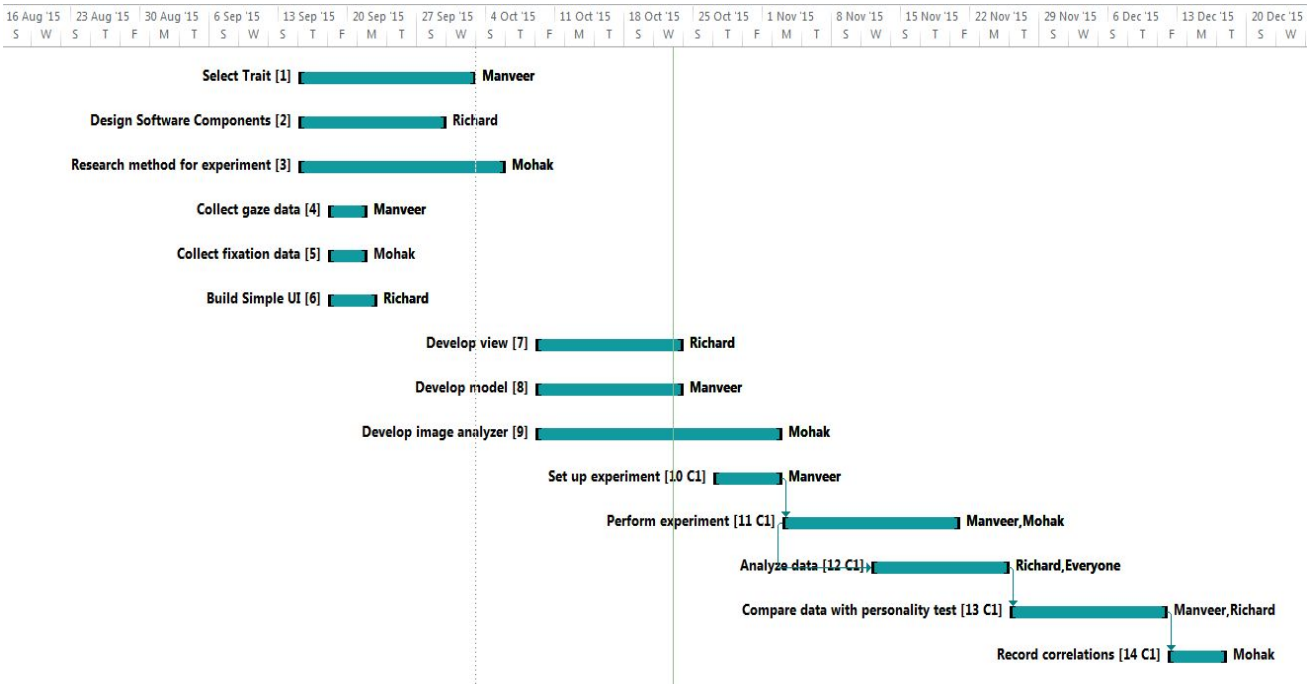
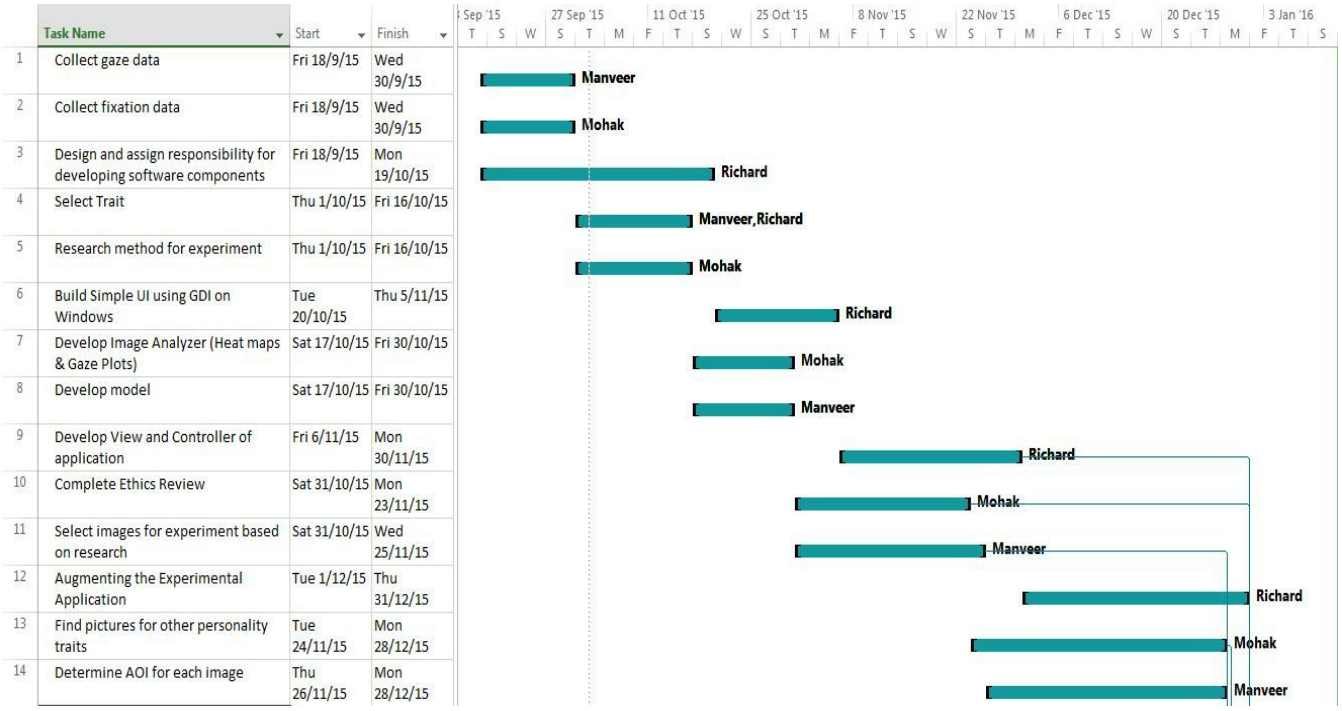


Figure 8: Gantt Chart from the Project Proposal

Below is the updated Gantt Chart from the Progress Report.



	Task Name	Start	Finish
1	Collect gaze data	Fri 18/9/15	Wed 30/9/15
2	Collect fixation data	Fri 18/9/15	Wed 30/9/15
3	Design and assign responsibility for developing software components	Fri 18/9/15	Mon 19/10/15
4	Select Trait	Thu 1/10/15	Fri 16/10/15
5	Research method for experiment	Thu 1/10/15	Fri 16/10/15
6	Build Simple UI using GDI on Windows	Tue 20/10/15	Thu 5/11/15
7	Develop Image Analyzer (Heat maps & Gaze Plots)	Sat 17/10/15	Fri 30/10/15
8	Develop model	Sat 17/10/15	Fri 30/10/15
9	Develop View and Controller of application	Fri 6/11/15	Mon 30/11/15
10	Complete Ethics Review	Sat 31/10/15	Mon 23/11/15
11	Select images for experiment based on research	Sat 31/10/15	Wed 25/11/15
12	Augmenting the Experimental Application	Tue 1/12/15	Thu 31/12/15
13	Find pictures for other personality traits	Tue 24/11/15	Mon 28/12/15
14	Determine AOI for each image	Thu 26/11/15	Mon 28/12/15

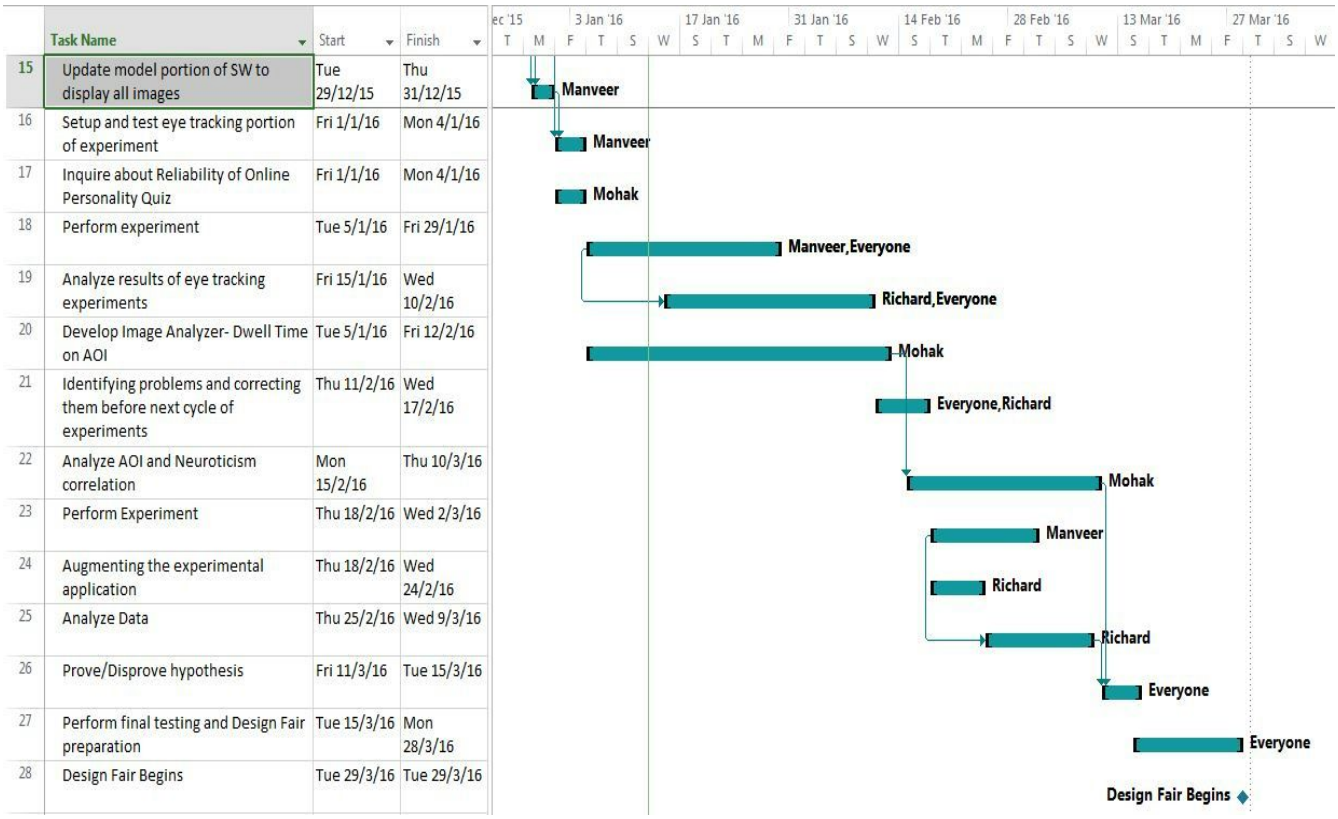


Figure 9: Gantt Chart from the Progress Report

One of the major changes to the updated Gantt Chart as can be seen above is that the for the month of September and early October, there is no longer an overlap of tasks assigned to each team member. Initially, the plan included team members working on two tasks at once, with one task centered around research, and another centered around building the initial software components such as the User Interface, and collecting gaze and fixation data by interacting with the Tobii EyeX. However, the updated Gantt Chart has clarified the manner of which the team worked on these tasks in a more accurate representation, where each team member is only assigned one primary task at a time.

Another area where the updated Gantt Chart differs is the date at which the team begins experimentation. In the project proposal, we estimated that we would begin running experiments by early November. However, we only actually managed to start running experiments on January 5th, 2016. This is because the Ethics Review process took longer than expected and was only approved at the end of November. Running experiments in December was not ideal since it was during the final exams period and subjects would be reluctant to spend time sitting for experiments. Therefore, we began running experiments on January 5th, 2016.

The second, updated Gantt Chart was a more accurate representation of the workflow of the team throughout the course of the academic year.

Appendix B - Financial Summary (Author: Mohak Poddar)

The actual financial expenses of the project can be found in Table 12 below. No new items were added since the Project Proposal document.

Table 12: Budget Table

Consumables/Services

Item	Priority	Cost/unit	Quantity (hours)	Total Cost	Requires Funding
Internet Data Plans	2	$150/mo*10% = $15/mo	8 mo	$120	n
Total Consumables/Services				**$120**	
Total Requiring Funding				**$0**	

Capital Equipment

Item	Priority	Cost/unit	Quantity (# or hours)	Total Cost	Requires Funding	Kept/Paid for by Students
Tobii EyeX Controller	1	$213.20*	1	$213.20*	y	n
Laptops	1	$4500	10%	$450	n	y
Microsoft Visual Studio Enterprise	2	$0	100%	$0	n	y
Total Capital Equipment				**$663.20**		
Total Requiring Funding				**$213.20***		

***$164 USD @ 1.3 CAD = $213.20 CAD**

Student Labour

Item	Cost/unit	Quantity (# or hours)	Total Cost
Student 1	$25	280	$7,000
Student 2	$25	280	$7,000
Student 3	$25	280	$7,000
Total Student Labour (unfunded)			**$21,000**

Funding

Source	Contribution
Students	$0
Supervisor	$213.20
Request from Design Centre	$0
Total Funding	**$213.20**

Total Cost of Project: $21,783.20
Total Cost Requiring Funding: $213.20

The reasoning behind some of the Budget Table components can be found below:-

→ The cost of the internet data plans is $150/mo. This is assuming a cost of $50/mo for each team member

→ The cost of laptops is $4500. This is assuming a cost of $1500 for each member's laptop

→ Microsoft Visual Studio Enterprise is budgeted at $0 because, as students, we obtained it for free from Microsoft Dreamspark. In industry, this would cost $5,999 [13]

→ The cost of student labour is $25/hour per team member because it was the average of our Professional Experience Year (PEY) salaries

→ The number of student labour hours is estimated at 280. Over 7 months (September - March), this is equal to 40 hours/month which is, on average, 10 hours/week

Appendix C - Validation and Acceptance Test (Copied from Project Proposal) (Author: Mohak)

Our team will analyze the data and use the results from the experiment to create a test that uses eye tracking to determine one's personality trait(s). The team will write an algorithm that takes as input the subject's gaze and fixation data and outputs their personality trait on a scale ranging from 0 to 100%. For example, assume that the results from the experiment show that people who are highly neurotic will spend half their time fixating on the eyes of people or objects in images throughout the test. The algorithm takes that data as input and outputs a high neurotic rating (such as 80%) if such an individual takes the test. Subjects will undertake this new personality test alongside a known and validated personality quiz (see Appendix J).

The experiment will be conducted with a sample size of 20 subjects, consisting of University of Toronto students and staff. If the new test can provide a score within a 5% error when compared to the the validated personality quiz scores, then the prediction is considered to be accurate. The prediction rate (PR) is acquired by the ratio of successful predictions to total predictions from the new personality test. If the calculated PR is greater than 70%, then the new test is considered to be accurate and we have proved the hypothesis. If it is less than 40%, then the new test is inaccurate and we have disproved the hypothesis.

Additionally, each test will be timed to determine if the time objective is met. The number of personality traits that can be determined by the new personality test will indicate if the project was successful in researching additional traits.

Validation and Acceptance Test - Updated Version

The only difference is that we used a 10% error instead of the 5% error mentioned above. This is because, after discussions with our supervisor, we concluded that a 5% error was very ambitious and difficult to achieve.

Appendix D - Images used for Eye Tracking Experiment (Author: Manveer Sidhu Pritam Singh)

Below are the thumbnails for the 28 images of facial emotions used for the experiment. These images are of 4 (2 males, 2 females) individuals displaying 7 different emotions (happy, sad, fearful, angry, disgusted, neutral, surprised).

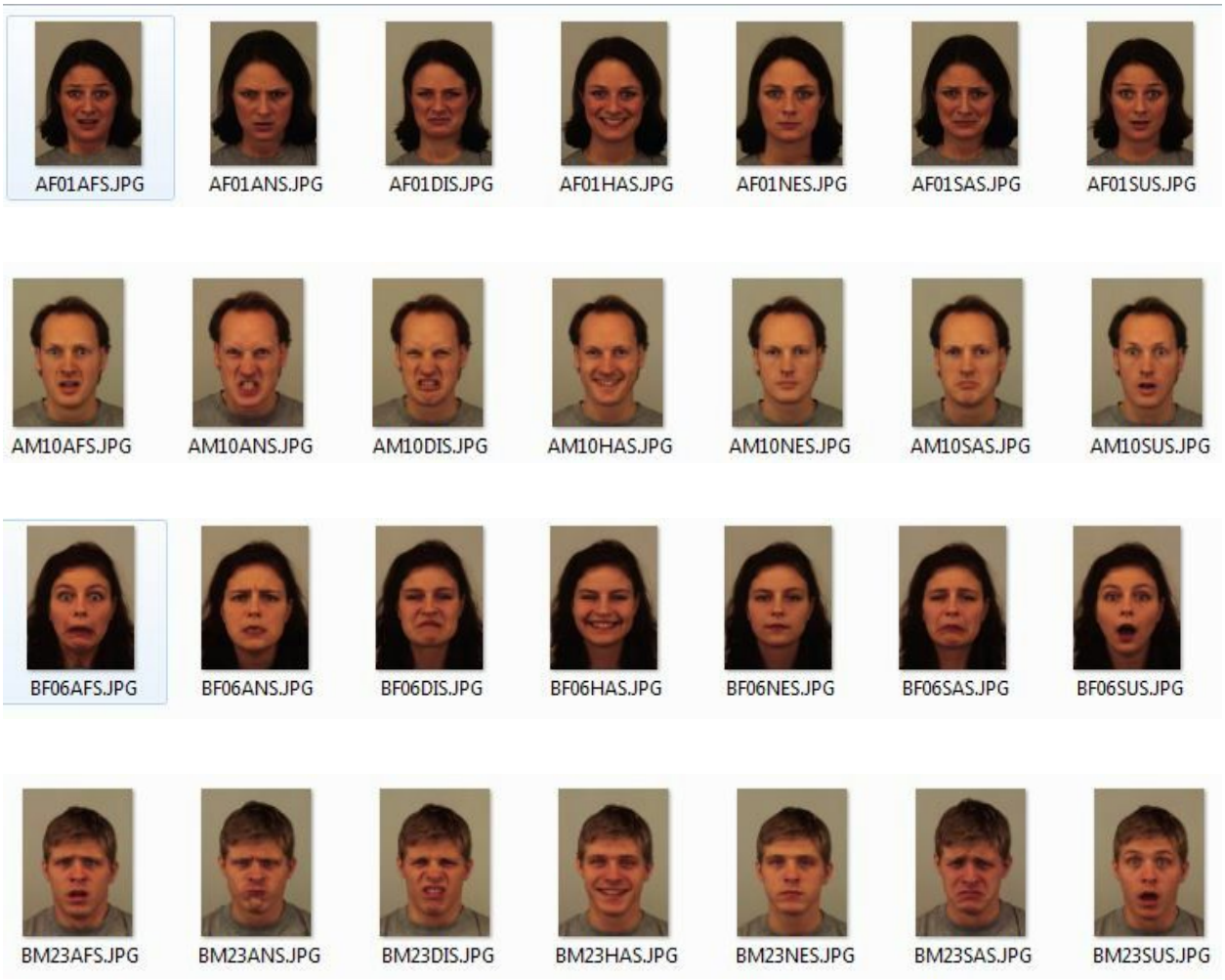


Figure 10: Images used for our Experiment

Appendix E - Statistical Validity of Experimental Data (Author: Manveer Sidhu Pritam Singh)

In Table 12 below, we can see the correlations between the Agreeable trait and the percentage of time spent on the eyes of 7 emotional faces. These correlations were calculated across 26 data points.

Table 12: Correlations and their statistical significance

Trait	Fearful	Happy	Sad	Disgusted	Surprised	Angry	Neutral
Agreeableness	0.284	0.478	0.265	0.375	0.219	-0.008	0.307
Statistical Significance	92%	99%	90%	97%	86%	52%	94%

For each correlation, we calculated the statistical significance of the correlation, that is, the percentage of probability that the correlation is statistically significant, and not due to a Null Hypothesis.

We calculated the statistical significance using the Student's t-test, as described below.

Calculating the statistical significance for the correlation between Agreeableness and the time spent looking at the eyes of happy faces:-

First, we calculate the t value using $t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$,where r is the correlation value, and n is the number of data points across which it holds.

In this case, substituting r = 0.478 and n = 26 gets us t = 2.666

Next, we check if the calculated value of t is significant.

We compare this value of t to a t-table [14], with a degree of freedom of n - 2 = 24.

Based on the t-table, we can see that there is a 99% chance that that this correlation is statistically significant, or $r(24) = 0.478, p < 0.01$

We calculate the statistical significance of all the other correlations (for the other 6 emotions) in a similar way.

Appendix F - Formula Generated by Multivariate Linear Regression Algorithm (Author: Mohak)

The formula generated to calculate the Agreeableness personality trait is below.

Formula to Calculate Agreeableness:-

Agreeableness (%) = (0.578*DTH) + (-0.3651*DTF) + (0.1445*DTSa) + (0.3826*DTD) + (0.09*DTSu) + (-0.8506*DTA) + (-0.0316*DTN) + 67.3089

Where DTH = Average Dwell Time on Eyes of Happy Faces

DTF = Average Dwell Time on Eyes of Fearful Faces

DTSa = Average Dwell Time on Eyes of Sad Faces

DTD = Average Dwell Time on Eyes of Disgusted Faces

DTSu = Average Dwell Time on Eyes of Surprised Faces

DTA = Average Dwell Time on Eyes of Angry Faces

DTN = Average Dwell Time on Eyes of Neutral Faces

The coefficients and constant in the equation above were generated by the Linear Multivariate Regression algorithm. We have shown the formula for Agreeableness above. The formulas for the other traits were generated similarly.

Appendix G - Prediction Rate Calculation (Author: Mohak Poddar)

The error in determining each subject's Agreeableness can be found in Table 13 below.

Table 13: Error in determining Agreeableness

Subject	Predicted Output from Team's Algorithm	Actual Output from Online Quiz	Error
3	72.5921	62.5000	10.0921
4	79.0667	85.0000	5.9333
5	83.5945	55.0000	28.5945
8	76.4059	75.0000	1.4059
9	67.3980	67.5000	0.1020
11	74.9069	72.5000	2.4069

12	65.5582	70.0000	4.4418
13	56.6200	50.0000	6.6200
14	83.1230	82.5000	0.6230
15	77.5952	92.5000	14.9048
16	68.0617	65.0000	3.0617
17	67.3570	62.5000	4.8570
19	75.7244	85.0000	9.2756
20	72.7542	67.5000	5.2542
21	77.3208	82.5000	5.1792
23	71.7086	85.0000	13.2914
24	54.1458	50.0000	4.1458
25	50.7039	37.5000	13.2039
26	74.7969	67.5000	7.2969
27	68.2655	75.0000	6.7345
28	67.9653	72.5000	4.5347
29	73.8423	75.0000	1.1577
30	69.5218	85.0000	15.4782
31	75.6475	67.5000	8.1475
33	61.0138	67.5000	6.4862
35	61.8102	67.5000	8.1898

Subjects 3, 5, 15, 23, 25 and 30 above are not within the ±10 error tolerance. Total number of subjects are 26. Of these, the agreeableness of 20 subjects were predicted within the required error tolerance. So, the prediction rate can be calculated as 20/26 or 76.92%.

Appendix H - Heatmaps (Author: Mohak Poddar)

Figures 11 and 12 below are example heat maps that are generated by our application.

Figure 11: A sample heat map generated by the application

Figure 12: Another sample heat map generated by the application

Figures 13 and 14 below show the heat maps generated with eye movements focused on the top-right areas of the images.

Figure 13: A sample heat map from the test experiment

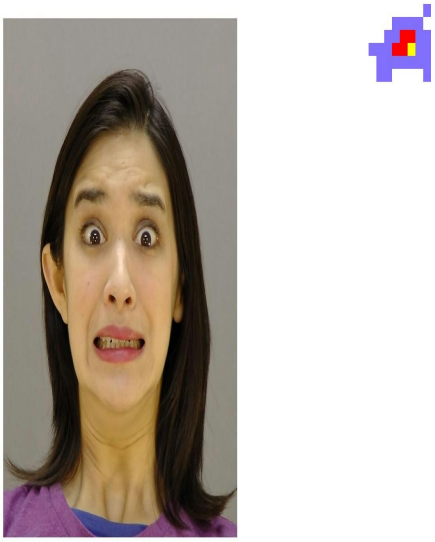
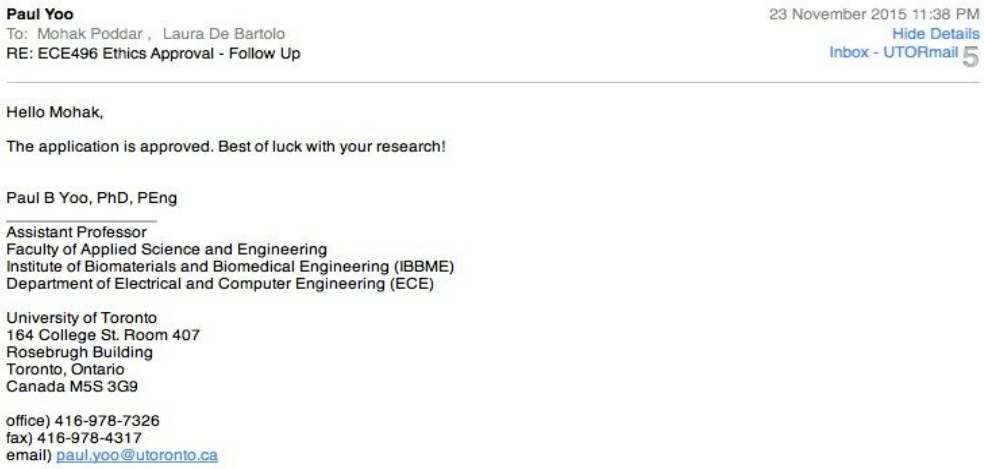


Figure 14: Another sample heat map from the experiment

Appendix I: Completed Ethics Review (Author: Mohak Poddar)

The screenshot showing approval of the Ethics Review Application is below.



Paul Yoo
To: Mohak Poddar , Laura De Bartolo
RE: ECE496 Ethics Approval - Follow Up

23 November 2015 11:38 PM
Hide Details
Inbox - UTORmail 5

Hello Mohak,

The application is approved. Best of luck with your research!

Paul B Yoo, PhD, PEng
Assistant Professor
Faculty of Applied Science and Engineering
Institute of Biomaterials and Biomedical Engineering (IBBME)
Department of Electrical and Computer Engineering (ECE)

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fax) 416-978-4317
email) paul.yoo@utoronto.ca

Figure 15: Screenshot of the Email From Professor Yoo showing that the Ethics Review Application has been Approved

Appendix J - Validated Personality Quiz (Author: Mohak Poddar)

The quiz that the subjects will be required to take can be found here:

http://www.truity.com/test/big-five-personality-test. The output of the quiz is a percentage number for each of the Big Five Personality Traits. For example, a possible output could be as follows:-

Example Output from the Quiz
Openness was at 10%
Conscientiousness was 20%
Extraversion was at 30%
Agreeableness was at 40%.
Neuroticism was at 50%