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A RESEARCH SURVEY APPLICATION USING EYE TRACKING TECHNOLOGY

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I. Introduction

Historically, eye tracking equipment has been expensive and not accessible to the general public (researchers). Up until the present, eye tracking systems would commonly range anywhere from approximately \$1,500 (Gazepoint, 2015) to as much as \$19,000 (Arrington Research, 2015). These older systems include both the hardware and software, and come in a variety of types (e.g. mobile compatible, desktop systems, headsets) With the availability of new eye tracking equipment on the market (e.g. EyeTribe), researchers now have the opportunity to implement eye tracking within their studies. Newer equipment can be dramatically less expensive, yet have many of the same capabilities as more expensive systems. For example, the \$99 EyeTribe tracker has the same sampling frequency, accuracy, and mobile capabilities as the \$1,500 Gazepoint tracker. However, the challenge presented to researchers is that most inexpensive eye tracking are not meant for research purposes. An SDK is often provided with these trackers but the limited software provided does not have the capacity to design an application to meet researcher needs. This project is to examine the usefulness of these eye tracking systems in a research environment and understand if these newly available technologies can meet the needs of researchers. The purpose of the capstone is to construct an application for conducting academic research using an eye tracker.

In the following sections, an overview of the technology is provided to understand the evolution of eye tracking. Next, an overview of the benefits eye tracking research can provide over traditional research tools (i.e. surveys) is discussed including how eye tracking technologies work and the output they provide. Finally, an overview of the application being developed is discussed including the features in the application, guidelines for setting up eye tracking studies and an explanation of the progress toward completion of the tool. A timeline of tasks to be completed is included at the end of this proposal.

II. Evolution of Eye Tracking Technologies

Originally, eye tracking experiments were conducted using only visual observations. An experimenter would place mirrors so they could observe a participant's eye movements without distracting the participant. (Javal, 2011 (Original 1905)) However, this method only enabled scientists to record large eye movements. To assist with studying small movements, microscopes and magnifying lenses were employed. Later, scientists would use systems to physically track eye movement. In the late 19th century, scientists employed bite bars to steady a participant's head and place a plaster of Paris contact lens on the anaesthetized eyeball. The contact lens had a pin-hole through which participants could see and was attached to a writing mechanism which recorded movement. (Huey, 1908)(Delabarre, 1898) At the turn of the century, Dodge and Cline introduced the technique of photographing external light reflecting off of a participant's fovea. (Dodge & Cline, March, 1901) In the 1920s, Guy Thomas Buswell recorded light reflected from a participant's eye on film. The recording of light reflections onto film eluded to modern-day eye tracking technology, which uses a camera to measure infrared light reflections off of a participant's fovea.

As with most technologies in their infancy, the availability of said technology is limited and costly. Often, scientists wishing to conduct experiments had to first construct their instruments. Their technology was designed and fabricated by individuals who specialize in areas requiring the utility, but not well trained in designing and manufacturing hardware. Eye tracking technology is no exception to this guideline. Infrared recording devices have only become widely available and less costly in the past 15 years. Today, an eye tracking system can be no more difficult to acquire than a webcam. As evidence of this availability, this project uses The EyeTribe tracker which retails at \$99. (Eye Tribe Products, 2015) An API is included with the EyeTribe and allows users to build systems to their own specifications. While this eliminates the design and construction of hardware used for eye tracking, the software design and development remains.

III. Research in Eye Tracking

The use of eye tracking technology presents researchers with a tool to measure variables in a more precise and unbiased way. Researchers have leveraged eye tracking technology to conduct studies in a wide variety of areas, from e-commerce to medicine. Web design and human computer interaction (HCI) are the most commonly thought of uses for eye tracking. However, eye tracking has also been used to help understand how people on the autism spectrum react to social stimuli. (Boraston & Blakemore, 2007) Eye tracking has also been used to study how to determine driver fatigue. (Zhang & Zhang, 2006) As the availability of cost-effective eye tracking increases, researchers continue to expand the use of this technology in their studies. Two additional applications of eye tracking are related to gathering objective survey data and observing a participant's memory and attention abilities.

Survey Research

Researchers commonly use surveys as an avenue through which they receive experimental data from participants. Surveys provide information directly from the participant, but this information is subject to the biases, limited memory and contentiousness of those participants. In a study performed in 2008 (Galesic, Tourangeau, Couper, & Conrad, 2008), researchers used an eye tracker to monitor how survey participants responded to questions and observed multiple cognitive shortcuts during the experiment. When asked to identify desirable traits in children, only 75 percent of all participants fixated on each of the 12 listed traits. This experiment also noted participants frequently answered without reading the entire question, particularly in questions with complex syntax. Because of these types of issues, inherent with human respondents, data gathered from surveys is very subjective. However, "eye tracking gives us a relatively direct window into what respondents attend as they process questions", as stated in that 2008 study (Galesic, Tourangeau, Couper, & Conrad, 2008). Eye tracking filters out some of the bias by providing objective, hard evidence in the form of gaze locations, fixations and saccades. Quantifying an experiment participant's response allows the derivation of additional information that had not been possible or reliable in previous surveys.

Memory and Attention

Eye tracking has also aided in the measurement of memory and attention. A study conducted in 2009 tested participants' short term memory of spatial locations and their ordering (Guérard, Tremblay, & Saint-Aubin, 2009). Using eye tracking, researchers were able to measure how well participants could recall the patterns of dots displayed on a screen, and how visual distraction between the display and recall affects memory. Researchers were also able to study relational memory in infants using eye trackers. This study's findings suggest that infants as young as 9 months can learn and remember faces and associations, and retain those memories with a short delay in between learning and recall (Richmond & Nelson, 2009).

IV. How Eye Tracking Works

Eye tracking studies the motion of the human eye during the assimilation of visual information by a human subject. To better understand how eye tracking works, one must understand how a person "sees". Human sight begins with the focusing of light through a person's pupil onto the retina, a light-sensitive membrane in the back of the eye. The light waves are processed by the retina into neural impulses and transmitted to the brain for interpretation. (Holmqvist, et al., 2011)

Within the retina are rods and cones. Rods and cones are light receptors that process visual images in low and high light intensities, respectively. An extremely high density of cones exists within the retina at a point called the fovea. The fovea, which makes up less than 2% of the visual field, is the only area of the retina that provides full visual acuity. As such, humans can only see about the area of their thumb nail at arm's length with full visual acuity. (Holmqvist, et al., 2011)

Two main biological components of the eye are most important with current eye tracking methodology: the pupil and the cornea. As discussed above, the pupil is the opening of the eye which allows light in. The cornea is the outermost layer of the eye, covering the pupil, and reflects light. Using an infrared light

and a camera, modern eye tracking equipment measures the location and motion of a subject's pupils and corneal reflections. The corneal reflection is the "glint" in a person's eyes and is the brightest reflection of light. The pupils also provide another reflection. A subject's pupils will appear bright under infrared light because of a reflection of light from the retina. Both the corneal reflection and pupils are recorded by cameras used in modern eye tracking technology.

Eye tracking involves the measurement of multiple variables to accurately understand the processing of visual information. The most obvious variable is the location of a subject's gaze, or where a subject is looking. An eye tracker will provide basic Cartesian (X,Y) coordinates for a subject's gaze on-screen. Also recorded is a fixation. The fixation is the state where an eye remains motionless for a given period of time. Typically eye trackers record the duration of a fixation, in addition to its (X,Y) coordinates. A fixation most commonly last between 200 and 300 milliseconds. The eye tracker is also designed to track a saccade, or rapid motion from one fixation to another. A common occurrence of saccades exists while reading. Humans read by jumping quickly from one word to the next, as opposed to a fluid motion across letters. Most saccades last for between 30 and 80 milliseconds. That fluid motion across letters, or any other path, is known as a smooth pursuit.

V. Application Development Overview

The goal of this capstone was to develop a research tool that integrates an EyeTribe tracker with a custom survey and output measurement application. The application was developed in Java and incorporates the EyeTribe SDK and API provided with the equipment. The EyeTribe API exchanges JSON messages between the eye tracker and application via TCP sockets. Request messages are sent from an application to the tracker with a request category, message, and values to be provided. The response message provided by the tracker includes each of the above datum, but adds a "statuscode" variable which is an HTTP code denoting the status of the overall request. The SDK provides all the underlying tools for creating an EyeTribe application in Java, C# or C++. Tools are mostly broken down by functional

component of a potential application, such as listeners for request/reply messages, conversions from pixel coordinates to scaled coordinates (-1 to 1), and calibration requirements.

The application allows users to load an image to be tracked during the experiment. It also allows the researcher to customize the tool by including survey questions as part of the experiment. Using a recommended setup and the completed application, a researcher can administer the survey to a participant and collect the objective eye tracking data, such as Cartesian coordinates, timestamp and type of gaze (fixation or saccade). This objective data can then be compared to the more subjective responses provided in the survey and conclusions can be drawn about what elements in the image a participant considered when completing the survey.

The application consists of four major features:

User Interface

The application is able to load an image for participants to view. Initially, loading a properly scaled image file (.jpg, .png, .tif) directly into the application would achieve this goal. However, if the researcher wanted to incorporate a webpage or image with dimensions requiring scrolling, the application accommodates scrolling. The challenge with implementing a scrolling feature was to ensure gaze points are recorded at the appropriate coordinates relative to the image and not the screen.

Survey Development

A researcher is able to develop a survey using an external survey tool, such as Qualtrics, to access within the survey tool. The researcher creates the survey and input a hyperlink within the tool to access the external survey. Restrictions may also be implemented around the duration for displaying an image to a participant and the corresponding eye tracking duration.

Eye Tracking Application

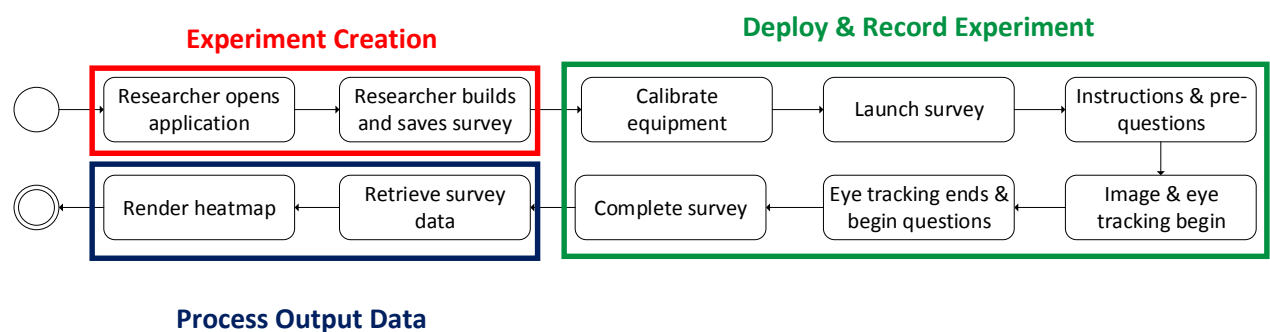
The next major feature is the ability to record eye movement details from a participant. Cartesian coordinates relative to the screen, adjusted coordinates due to scrolling and the angular distance between two recorded points are recorded by the application. The (X,Y) coordinates present a challenge in translation. The eye tracker will return an (X,Y) coordinate for gazes relative to the position on-screen. If the application were to plot this (X,Y) coordinate onto an image and the image is not the exact on-screen dimensions, the coordinate will not be placed properly relative to the image. To solve this issue, the (X,Y) coordinates relative to the screen must be translated into a coordinate relative to the image.

Output Processing

The final major feature of this application is the ability to export recorded data from survey sessions in a useable format. One useful format is a heat-map for the survey session. The application can reload a previously recorded survey session and render a heat-map of the participant's eye movement. In addition to displaying a visual format of the data, the application exports raw, numerical data in a comma separated value (CSV) format.

VI. Tool Overview and Walkthrough

Below is a simplified process flow of the eye tracking survey application, broken down into the primary functions.



Researchers and participants will both begin on a welcome page for the application (See Figure 1 below). From this page, the user will select their role in an experiment: Researcher or Participant. Based upon your role, the user then be presented with a home page with available role-based functions. From this homepage, one of three main functions may be performed depending on the role selected:

- 1) Experiment Creation
- 2) Test (Launch) Experiment
- 3) Output Data Processing

The Researcher role has access to all three functions (See Figure 2 below), while the Participant will only be able to launch an existing survey. The launching and testing of a survey are the same process.

However, during the testing of an experiment, no participant ID is generated and the eye tracking data is labeled “TEST”. The application also creates a default directory for all eyeSurvey experiments, images and output data at: “C:\Users\username\eyeSurvey”, where *username* is based upon the Windows login name. Within this default directory, each experiment created is housed in an individual folder. Each experiment folder has subfolders for images used in the experiment, eye tracking data captured in the experiments and heat maps generated with experimental data. Also, an experiment file is created that contains parameters for the experiment. This default directory is displayed on the Create an Experiment screen (See Figure 3 below).

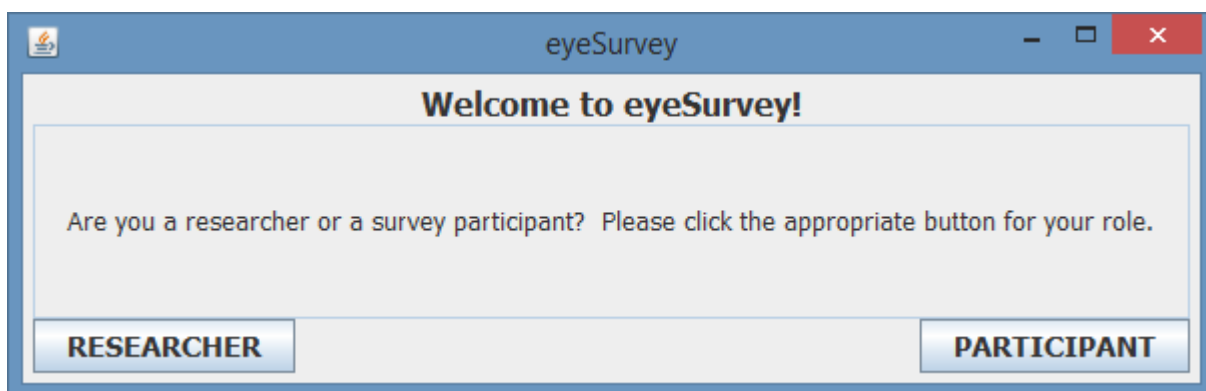


Figure 1: eyeSurvey Welcome Page

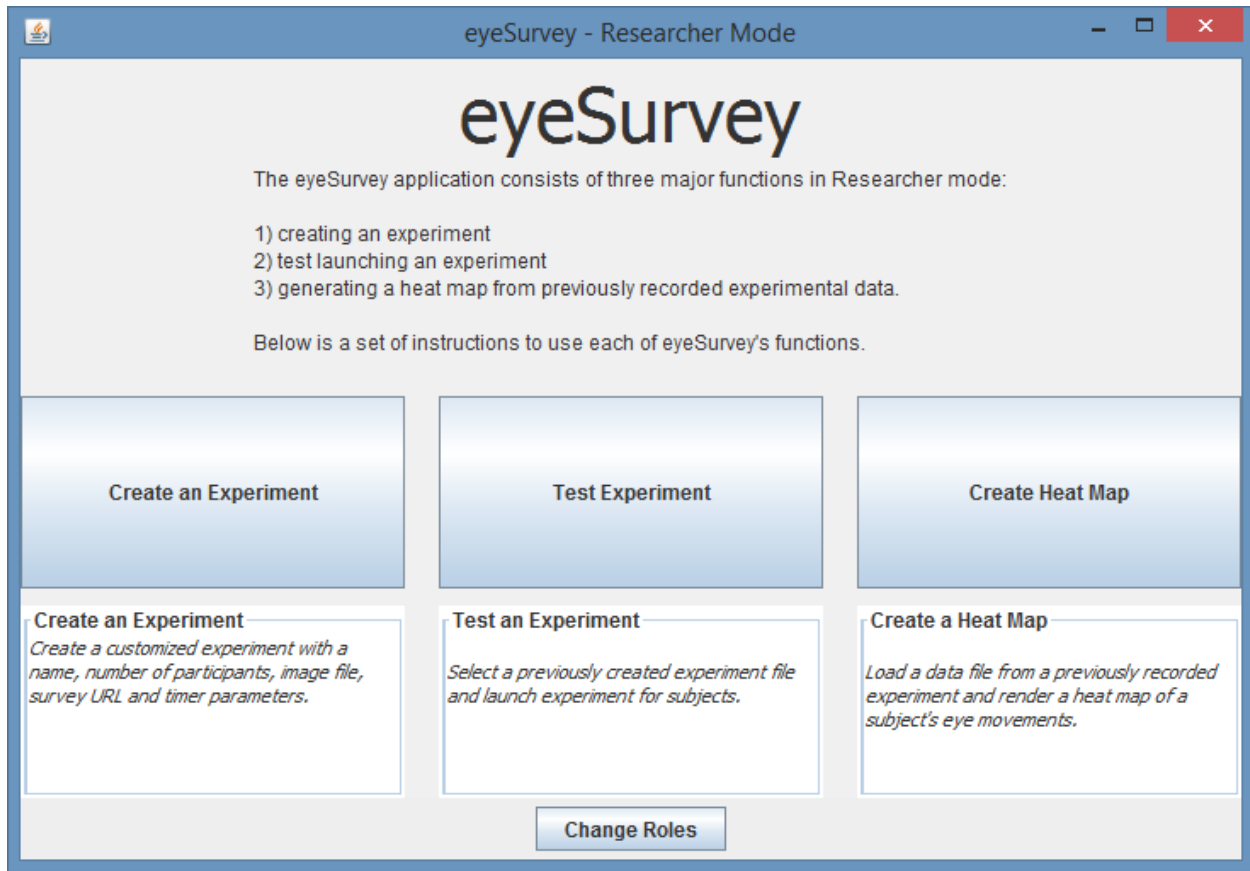


Figure 2: eyeSurvey Homepage – Researcher

Experiment Creation

Given the abundance of existing online survey tools, this application will leverage external surveying tools for the creation and administration of survey questions. This requires a researcher to create a survey using Qualtrics, or another external survey website, and storing the URL of the created survey. After creating an external survey, a researcher will select the “Create a Survey” process inside the application. From there, the researcher will be presented with several parameters required to deploy a survey (see Figure 4). First, the researcher must name the experiment being created. The researcher will also be asked for the number of participants in the experiment. The application creates an eye tracking data file for each of the participants and stores them in the default directory. The researcher would also be asked to use the “Choose an Image” button to select the desired image for this experiment. Researchers must also enter the URL of the survey created outside of eyeSurvey, e.g.

Qualtrics. Finally, the researcher will be asked for a time limit to restrict the length of time a participant will be exposed to the image, as well as the duration of eye tracking data recorded. Each of these requested items are stored in a survey parameters file, denoted with a “.expt” extension, and used in the deployment of a survey. This experiment file is saved within an experiment folder, named as in the Experiment Name field, and the experiment folder is stored at the root of the default directory (C:\Users\username\eyeSurvey).

As part of the Qualtrics survey, a researcher may include “pre-image” survey questions for a participant to answer. The structure of the Qualtrics survey allows for a page break between sets of questions, in which instructions to return to eyeSurvey may be provided to the participant. Additional details around this process flow are included in the *Test (Launch) Experiment* section.

The screenshot shows the 'eyeSurvey' application window with the title 'Create an Experiment'. The main heading is 'Create an Experiment'. Below the heading, there are instructions for creating an experiment, followed by five numbered steps. Below the instructions, there are four input fields: 'Experiment Name', 'Image File', 'Survey URL', and 'Current Directory'. To the right of the 'Image File' field is a 'Choose Image File' button. To the right of the 'Survey URL' field is a 'Test URL' button. To the right of the 'Current Directory' field is a 'Change Directory' button. Below the 'Image File' field is a slider and a text box for 'Number of seconds given to view image: 0'. At the bottom left is a 'Cancel Experiment' button, and at the bottom right is a 'Save Experiment' button.

Figure 3: eyeSurvey Experiment Creation Page

Launch Experiment

Note: Prior to the launch of any survey, the Eye Tribe tracker must be calibrated by the user with assistance from the researcher or experiment administrator. Calibration instructions are included in the “Recommended Setup” appendix.

Once a survey has been created externally and the parameters for deployment stored for the experiment, a researcher is able to launch a survey from the home page (Refer to Figure 2 above). If a user selects “Participant” during the role selection page, a home page only presenting the option to launch a survey will appear (See Figure 4a below). Researchers will click the “Test Experiment” button to proceed to the “Test Survey” screen (See Figure 4b below). The user will be asked to select an experiment file to load. Using a file chooser, the user will choose the appropriate file to load and launch. This file includes the experiment name, image file name, survey URL, and the time limit to view an image. The launch screen will also display the auto-generated Participant ID, if Participant role is used. If a Researcher is testing an experiment, the Participant ID field and results will be marked “TEST”. After a file has been selected, the user will click the “LAUNCH” button to begin the experiment.

eyeSurvey

Launch an Experiment

Please select an experiment file to load: Experiment file location will go here...

Experiment Name:

Image file name:

Survey URL:

Number of seconds given to view image:

Participant ID:

Figure 4a: eyeSurvey Experiment Launch Page

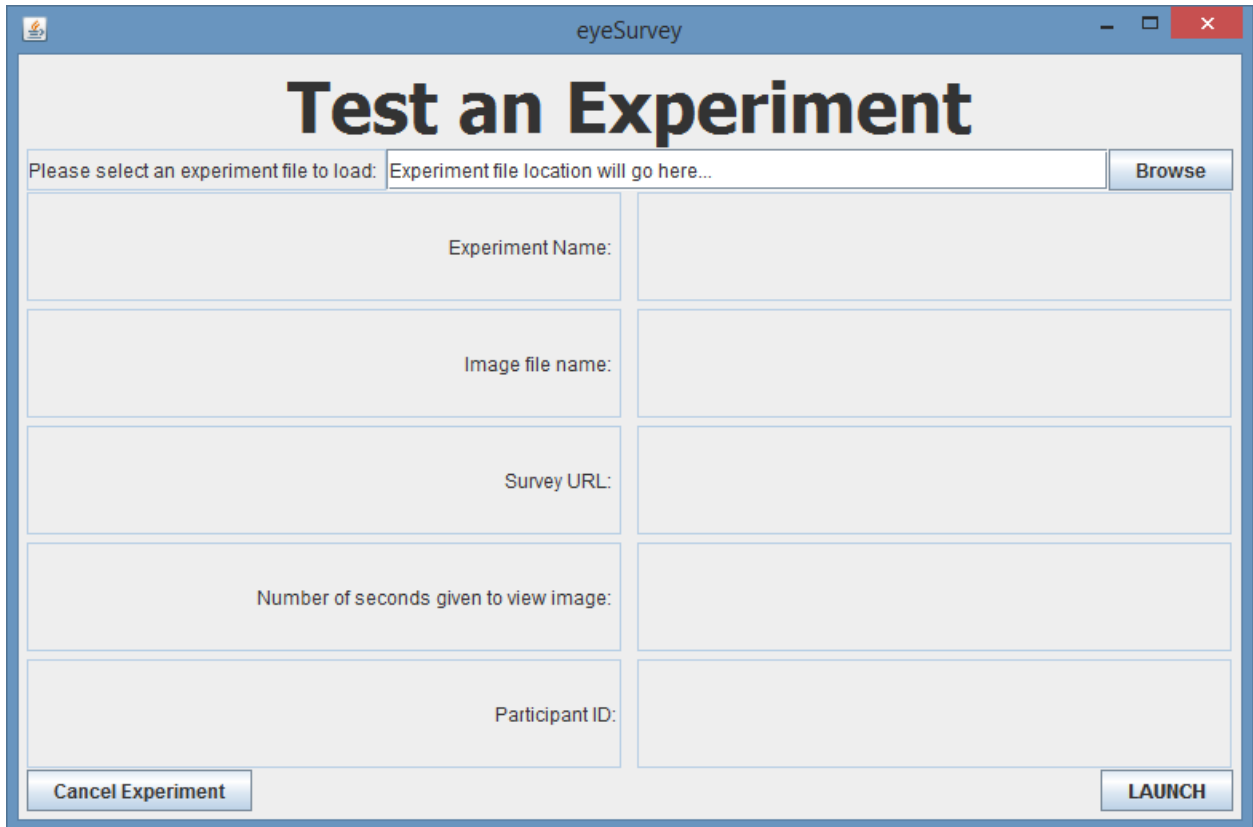


Figure 4b: eyeSurvey Experiment Launch Page

After launching, the user is given an instruction window asking to complete pre-image questions.

Clicking the “Pre-Image Questions” button will open the external survey in the user’s default web browser (See Figure 5). As mentioned above, a page break may be created within a Qualtrics survey which allows for pre-image questions to be included in the same survey as post-image questions. The page break will include an instruction to return to the eyeSurvey application after pre-image questions are complete. A participant then clicks the “View Image” button to begin viewing the image with eye tracking. The image will be rendered within the application and eye tracking data are recorded by the Eye Tribe tracker and written to the tracking data file corresponding to a given participant. Data to be recorded include the (X,Y) coordinates, the adjusted (X,Y) coordinates for any scrolling within an image and the angular velocity, or distance in degrees of motion, between one point and the previous point. Again, the tracking is limited to the time parameter specified during survey creation. Upon

reaching the end of specified tracking time, the eye tracking will stop recording and a pop-up message will request the user to complete the remaining questions within the external survey.

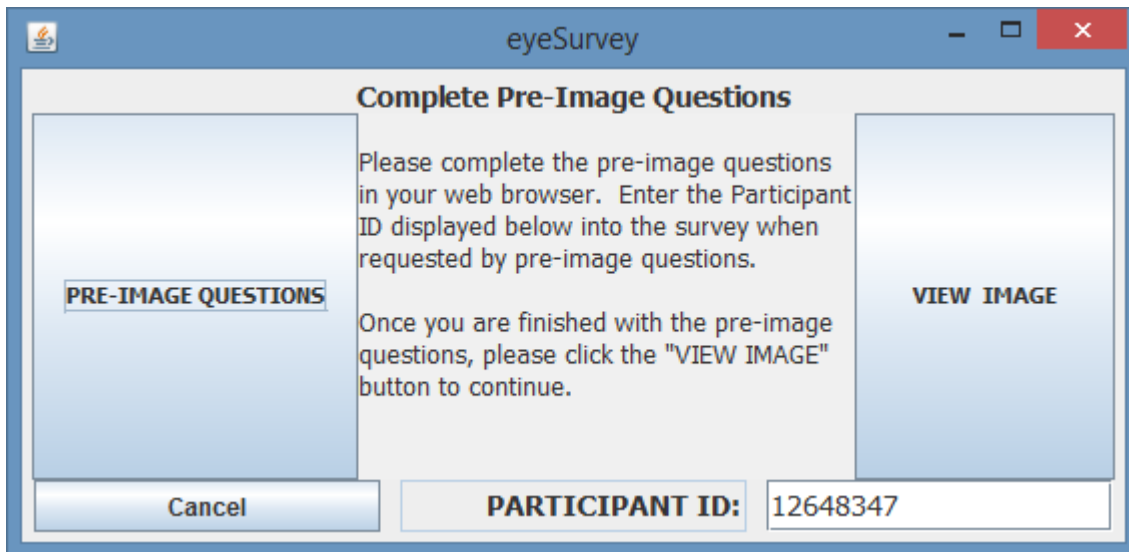


Figure 5: eyeSurvey Experiment Pre-Image Questions and View Image screen

Once the eye tracking is complete, the image window will close and the user will be returned to the Qualtrics survey. A participant will answer questions within this browser and will be prompted to return to the application once the survey is complete. Inside the application, a user will click the "Finish Survey" button and the application will display a message indicating the survey is complete.

Output Data Processing

The final function of the application will be to load existing eye tracking data and render a heat map based upon that data. To access this function a researcher will select "Create Heat Map" from the application's home page. A file chooser will allow the researcher to select the image associated with the experiment and the appropriate corresponding data file to process (see Figure 6). Once selected, the application will copy the original image into a secondary image and reduce the secondary image's HSB brightness factor to 30%. Each data point from the eye tracking data file is parsed and the corresponding pixel's brightness in the secondary image is restored to the original brightness. This

creates the visual effect of illuminating only the pixels, and a radius around the pixel, to display a participant's gaze locations. The secondary image is written to the "Heat Maps" folder in the given experiment's eyeSurvey directory.

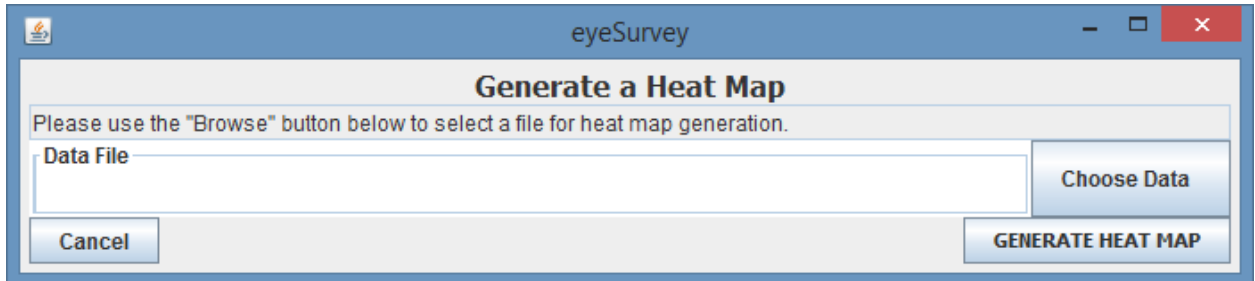


Figure 6: eyeSurvey Heat Map Creation Page

VII. Challenges/Issues

The development of this application has presented many challenges and learning opportunities. The most significant challenges are presented as follows:

i. Image size

One of the first challenges in this project was around image sizing within the application frame. Certain test images were larger than the frame size and a user would not be able to view the entire image at one time. Adding a scrollbar to the frame solved the problem of viewing an entire image, but presented the next issue of relative positioning.

ii. Relative position

The Eye Tribe tracker records a user's eye movements Cartesian coordinates as they relate to the screen. However, if an image does not take up the entirety of the screen, the recorded data points may not exist within the image. This requires the translation of recorded coordinates relative to the screen to coordinates relative to the image. This translation was achieved by adding a listener onto the scrollbar which calculates the number of pixels scrolled along the X and/or Y axis. Using this listener, an "adjusted" (X,Y) coordinate was calculated by measuring the pixel relative to the screen and adding any adjustments along the X or Y axis. If no

scrolling occurred, the adjusted coordinates would be equal to the original coordinates.

Therefore, when plotting the heat map, only the adjusted (X,Y) coordinates were used to plot gaze points.

iii. Heat map

Visually representing the participant's gazes with a heat map required a way to superimpose those gazes over an image. However, rendering a smaller image object over top of another will hinder a researcher's ability to see what participants viewed. Instead, this heat map captures the hue, saturation and brightness (HSB) values of an original image's pixels with each gaze point. A copy of the image is made for creation of the heat map. The brightness factor in the copy is reduced to approximately 30% of the original value, causing the overall image to darken, but retain original colors. Using the adjusted coordinates, recorded data points are parsed and plotted to the duplicate and dimmed image. During plotting, the brightness factor of each gaze point is restored to the original value. This method results in gaze points appearing brighter than the rest of the image and a participant's focus on an image is clearly defined.

iv. Timing

Setting a standard duration for all participants to view an image presented a challenge in the form of a "timer". The SDK does not include a built in timer functionality that will terminate eye tracking after a given time period. However, the Eye Tribe has a sampling rate of 30 frames per second. This means one frame, which contains a gaze point, is transmitted once every 33 milliseconds. Using this conversion, a counter was placed within the gaze point listener to determine the accumulated number of frames sent during the experiment session. Once the frame limit has been reached, the tracker shuts down and the eye tracking portion of the experiment ends.

v. Integrating external tool

Because survey tools exist and are built so well, to independently build a survey tool would be redundant and inferior. Instead, the integration of an external tool is required by this application. A web-based survey tool was determined to be the best choice for this application because the integration would be less complex. In this application, a web browser window is opened and populated with the URL of a survey constructed outside the application.

vi. Output files

The formatting and data retained in eye tracking output files presented two challenges. The first is what format would be most useful to researchers. Currently, the application exports data into a CSV file format which can be imported into Excel and other applications easily. The second challenge is what information would be the most useful. This application will present a heat map to visually display participants' gazes. The heat map does not necessarily require a time dimension as a pixel map will be adjusted based upon the frequency of gazes toward specific pixels. However, the time factor may be more important to future research, so a timestamp with each gaze is retained in data files.

VIII. Pilot Study & Findings

As part of this capstone, a pilot study was conducted in which six participants completed a walkthrough of the application, using test case instructions. The instructions guided each participant through the creation of an experiment, the launch of an experiment and the creation of a heat map based upon their experimental data. (Detailed test case instructions are included in Appendix A.) After completion of the test cases, each participant was debriefed to understand their perceptions of the application. Based on these post-test observations, the following adjustments were suggested and implemented:

i. Timer slider vs. text input

During the creation of an experiment, multiple testers attempted to manually type the number of seconds to display an image. As of the test, the time slider was the only method of inputting the timer duration. Because of this observation, the text box was enabled as an input method in addition to the slider.

ii. Right-click functionality

Testers also noticed that during the creation of an experiment, a user could not right-click and paste text into input boxes. Specifically, multiple users attempted to right-click and paste a link to the Qualtrics survey in the appropriate box. An adjustment was made in the “Create an Experiment” function to enable right-clicking through a JPopupMenu with the appropriate actions.

iii. Redundant buttons

As of the pilot test, users selected an experiment to launch with a JFileChooser button. In order to launch the experiment, the user had to click a “Load Experiment” button to read the experiment file prior to launch. After the pilot test, the load button was removed and the file loads after being selected.

iv. Heat map brightness

Multiple users noted difficulty viewing the image in the heat map that was not brightened. The reduction in HSB brightness factor was increased from 20% of the original brightness to 30% of the original brightness.

v. Output Data File

a. Coordinate Values

The values of X and Y coordinates taken from the Eye Tribe tracker were “double” data types, meaning decimal values were included in the values. When users looked at the data, the decimals related to pixel coordinates had no significance in interpretation. As such, the decimal values were removed and coordinates were represented as integer data types.

b. Variable titles

When examining the eye tracking data, it was noted that raw data had no key or titles. Therefore the data was challenging to interpret in its raw form. As a result, the first line of data files now includes a title for each of the elements in their respective order.

IX. Future Uses

One of the pilot test participants was an academic researcher and provided additional consultant around what functionalities would be most useful from a research standpoint. In academic research, empirical evidence is vital. The eyeSurvey application records empirical evidence based upon eye movements across images. However, the heat maps alone would be difficult to decipher visually. Instead, the ability to manipulate the existing data would be most beneficial to researchers. Based upon discussions with the consulting academic researcher, the utility of the eyeSurvey application would be augmented most with the following three functions:

i. Aggregated heat map

While reviewing individual results for each participant is important, the ability to see an aggregated heat map of all participants would be useful at a macro level. The aggregation would allow a researcher to view overall results in a much more efficient manner than reviewing all participant heat maps individually.

ii. Region identification within images

Another useful function is a researcher's ability to create regions within an image and see how many gaze points fall within a given region. For example, a researcher sections off a LinkedIn profile into an Experience region, Education region and Connections region. If the eyeSurvey application could process eye tracking data to determine that 75% of the gaze points were in the Experience region and only 25% of the remaining point fell within the Education and Connections regions, the researcher would have stronger empirical evidence upon which to base conclusions.

iii. Pooling based upon demographic metadata

Demographic data would likely be collected in the pre-image questions of an experiment. Connecting the eye tracking raw data to the metadata gathered in the survey would add another means of splicing data and compare results. Currently, eyeSurvey only maintains the raw eye tracking data, but adding demographic tags to participants would greatly expand the filtering and manipulability of data.

iv. Multiple images in a survey

Currently, eyeSurvey only allows for a survey to include one image. However, to make this tool more useful, the ability to display multiple images would make eyeSurvey more functional in an academic research environment. Enabling eyeSurvey to use multiple images would involve creating multiple data files and associating a single file with a

single image. This could be achieved through repeating the eye tracking steps currently in place and writing to different files at the end of timers.

v. User control over image display

Alongside having multiple images in a survey, another feature would be to allow a user (researcher or participant) to control how long an image is displayed and when to move on to the next image. While progressing through images is important, this feature would also allow a user to return to a previous image and begin eye tracking on that image again. An experiment could then be structured differently so participants could review previous images in response to a given question.

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Appendix A: Pilot Test Instructions & Comments

Create Experiment Pilot Test

Steps:

1	Action	Click the "Continue" button on the eyeSurvey Tool launch screen.
	Post-Condition	Welcome screen should be displayed, with buttons for Admin and Participant.
	Comments:	1, 2, 4, 5: Second screen redundant.

2	Action	Click the Admin button.
	Post-Condition	Window housing build, launch and heatmap choices should be displayed.
	Comments:	1, 2: How do I change roles within a single session?

3	Action	Click the Create Experiment button
	Post-Condition	Create an Experiment window should appear with boxes to input experiment name, image file locations, survey URL and time slider.
	Comments:	2, 3, 4, 5, 6: The language used in the instructions does not match identically to button/field labels

4	Action	Set the (1) experiment name, (2) image file, (3) url and (4) timer to the setting of your choice. Click the "Save Experiment" button.
	Post-Condition	Text boxes will populate with your desired input. A pop-up will appear stating the experiment you named above has been successfully saved.
	Comments:	5: Timer not captured when manually typed into text box. 3: Slider should be in more common increments. Single seconds aren't typically used. 2: Right-click to copy/paste in the window is non-functional.

5	Action	Click OK on pop-up to return to Admin home.
	Post-Condition	Admin home screen should be displayed.
	Comments:	No comments.

Launch Experiment Pilot Test

Steps:

1	Action	Click the "Continue" button on the eyeSurvey Tool launch screen.
	Post-Condition	Welcome screen should be displayed, with buttons for Admin and Participant.
	Comments:	1, 2, 3, 4, 5, 6: Second screen redundant.
2	Action	Click the Participant button.
	Post-Condition	Window housing launch experiment option should be displayed.
	Comments:	1, 2, 4, 6: How do I change roles within a single session?
3	Action	Enter your participant ID and click the begin experiment button
	Post-Condition	Launch experiment window should appear with button to browse for experiment file.
	Comments:	1, 5: Error checking should exist around input type mis-matches
4	Action	Click browse button to select experiment file: _____ Open experiment file and click "Load Selected File".
	Post-Condition	Text boxes will populate with the experiment parameters.
	Comments:	1, 2, 4, 5, 6: The loading of an experiment file should take place automatically. Clicking a "load" button is redundant.
5	Action	Click LAUNCH to begin experiment.
	Post-Condition	Window for pre-questions and image should open.
	Comments:	1, 2, 4, 5, 6: The loading of an experiment file should take place automatically. Clicking a "load" button is redundant.

6	Action	Click "Pre-Image Questions" button and complete the questions given in the survey.
	Post-Condition	Survey will prompt user to return to the application after pre-questions completed.
	Comments:	1, 2, 4, 5, 6: The positioning of the pre-image question button is not intuitive. 3, 4, 6: The instructions need to be rephrased to force pre-image questions to be answered.

7	Action	Answer pre-image questions via Qualtrics website
	Post-Condition	Image should appear with scroll bar functional. Image will disappear and pop-up will state "Eye tracking complete. Please return to web browser to complete survey."
	Comments:	No comments.

8	Action	Click "VIEW IMAGE" to open the experiment image and begin eye tracking software.
	Post-Condition	Image should appear with scroll bar functional. Image will disappear and pop-up will state "Eye tracking complete. Please return to web browser to complete survey."
	Comments:	No comments.

9	Action	Click "OK" on pop-up stating eye tracking is over and answer remaining survey questions.
	Post-Condition	Image frame has closed and only the web browser with completed survey remains.
	Comments:	3, 6: "Finished" window redundant.

Create Heat Map Pilot Test

Steps:

1	Action	Click the "Continue" button on the eyeSurvey Tool launch screen.
	Post-Condition	Welcome screen should be displayed, with buttons for Admin and Participant.
	Comments:	1, 2, 3, 4, 5, 6: Second screen redundant.

2	Action	Click the Admin button.
	Post-Condition	Window housing build, launch and heatmap choices should be displayed.
	Comments:	1, 2, 4, 6: How do I change roles within a single session?

3	Action	Click the Create Heat Map button
	Post-Condition	Generate a Heat Map window should appear with buttons to choose both the image file and eye tracking data set.
	Comments:	2, 3, 4, 6: Instructions language does not match button labels.

4	Action	Use the buttons to select the appropriate image file and data set to load.
	Post-Condition	Text boxes will populate with your desired input.
	Comments:	No comments.

5	Action	Click GENERATE HEAT MAP button to view the heat map of your image and data set.
	Post-Condition	Heat map and original image should be displayed in different windows.
	Comments:	3, 4, 5: The brightness level of the heat map is too low for the non-viewed areas. 3: The tracking data output file should include variable titles for import into another software.

Appendix B: User Documentation

eyeSurvey: A Research Survey Application Using Eye Tracking Technology

User Documentation and Guide

Outline

1. Overview

2. Recommended Setup

3. Calibration

4. Qualtrics Basic Guide

5. Directory and File Structure

Default Directory

Filing Structure

Experiment Folders

6. Application Instructions

Create an Experiment

Launching an experiment

Creating a Heat Map

1. Overview

The eyeSurvey application is a research tool that allows academic researchers to integrate a custom survey with the ability to a participant's eye movements during visual processing of an image. The application also records eye movements to a file and allows researchers to generate a heat map based upon those movements. Using a recommended setup and the completed application, a researcher can administer the survey to a participant and collect the objective eye tracking data, such as Cartesian coordinates, distance between two gaze points and type of gaze (fixation or saccade). Researchers can compare the more subjective responses provided in a survey to the objective eye tracking data, enabling the ability to draw conclusions about what image elements a participant considered when completing the survey.

This user guide provides step-by-step instructions for each function of the eyeSurvey application, as well as setup recommendations and file storage information.

2. Recommended Setup

The physical setup of the survey environment and hardware are important to recording accurate results.

Below are specifications and instructions for a proper setup:

- Survey room should be well lit, using overhead lighting.
- Ensure no direct sunlight is shining either at the camera or participant's face. Sunlight contains a large amount of infrared light and will distort measurements.
- Elevate the screen used for the experiment to approximate head height. Participants should not have to raise or lower their heads to comfortably view the screen.
- Select a room reasonably free of distraction around the survey. The EyeTribe tracker will lose its tracking abilities if a participant moves their head or body after calibration.
- The EyeTribe is to be placed below the screen at approximate arm's length from the participant.
- Tracker is to be calibrated using the EyeTribe software calibration tool.
- Contacts, glasses and bifocals can sometimes cause difficulty with tracking eye movements. If they can be comfortably removed, ask the participant to do so.

3. Calibration

Before accurate data points can be gathered by the eyeSurvey application, the Eye Tribe tracker must be calibrated properly. To properly calibrate the tracker, a researcher or experiment administrator would use the Eye Tribe UI application and follow the below steps:

- 1) Connect Eye Tribe tracker into available USB port.
- 2) Open Eye Tribe UI application.
- 3) Position participant directly in front of monitor at approximately arm's length from the screen.
- 4) Place the tracker on a level surface in front of the participant. The tracker must be below the participant's line of sight and "looking up" at the participant's eyes.
- 5) Ensure the participant's eyes are registering on the Eye Tribe UI application. The grid on the left side of the application will guide the administrator/researcher to proper placement of the tracker. Eyes that are registering will have a green background in the grid (see Figure 7a below). Eyes not registered by the tracker will have a red background (see Figure 7b below).

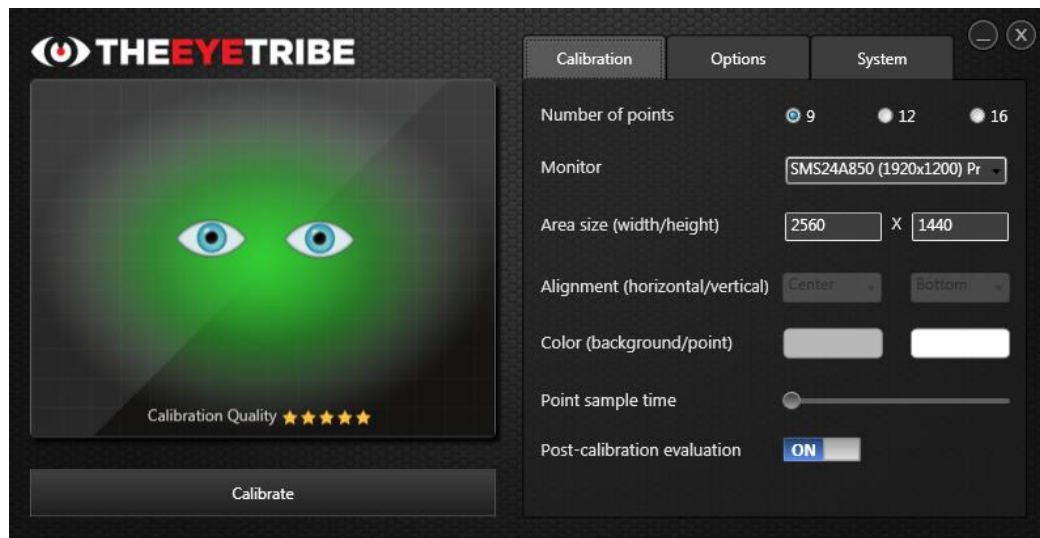


Figure 7a: Eye Tribe UI: Successfully Registering Eye Positions

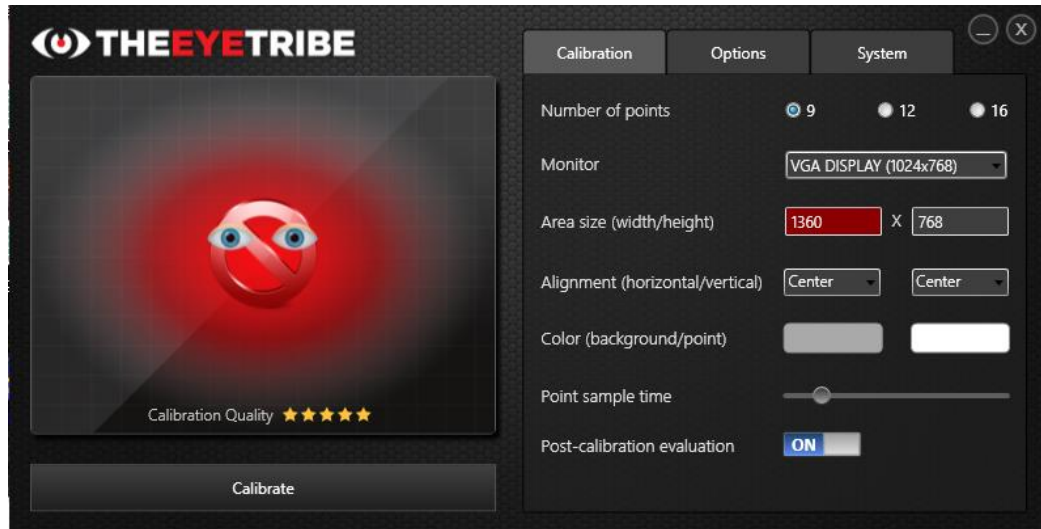


Figure 7b: Eye Tribe UI: Failing to Register Eye Positions

- 6) Click “Calibrate”.
- 7) During calibration, the user will follow the circles moving across the screen with his or her eyes (see Figure 7c below).



Figure 7c. EyeTribe SDK Calibration

- 8) Calibration will complete and display an accuracy rating. Repeat process if accuracy is less than 2-stars or calibration fails. Make moderate adjustments to positioning of participant and eye tracker in the event of calibration failure.

4. Qualtrics Basic Guide

The following is a basic guide to setting up a Qualtrics survey to work best with the eyeSurvey application. Instructions for using Qualtrics exist in much greater detail at:

http://www.qualtrics.com/university/researchsuite/?utm_campaign=Help%20Button&utm_medium=Product&utm_source=EditSection

Steps:

1) Log in to your Qualtrics account.

If you do not have an account, register at www.qualtrics.com to begin creating surveys. After login, your user dashboard will appear as in Figure 8.

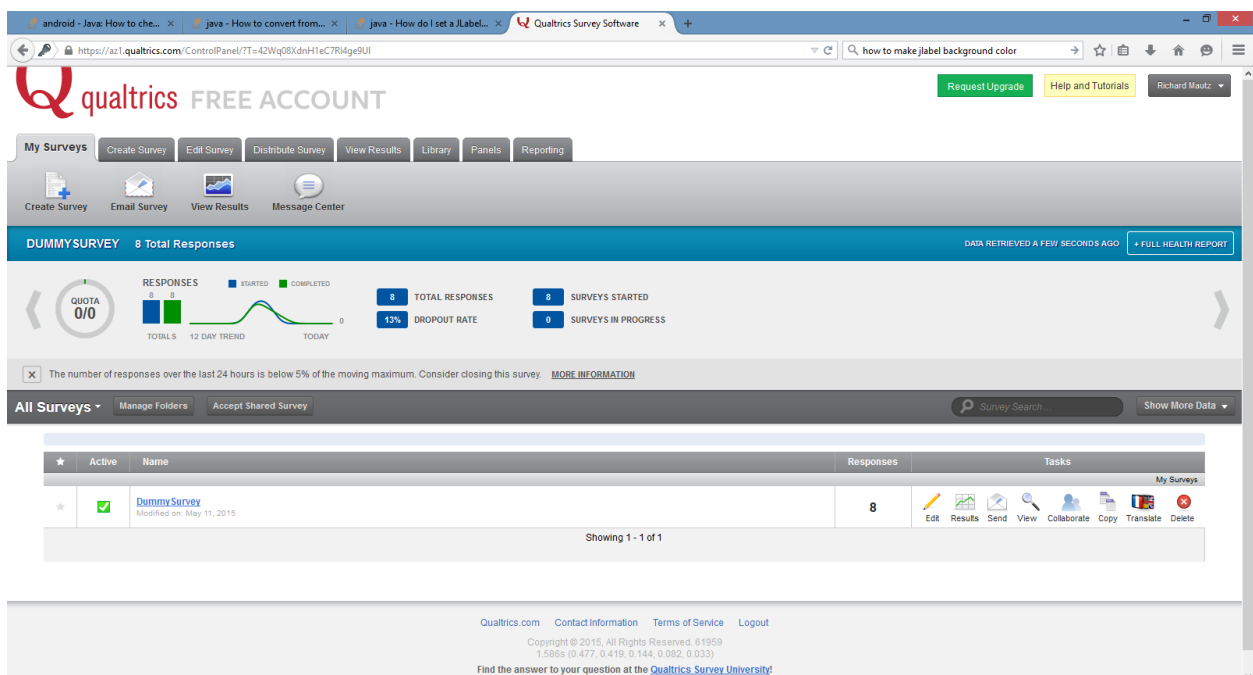


Figure 8: Qualtrics Dashboard

2) **Create a new survey by clicking “Create survey”.**

“Create survey” found in the upper left-hand corner of the Qualtrics dashboard under the “My Surveys” ribbon (Figure 9).

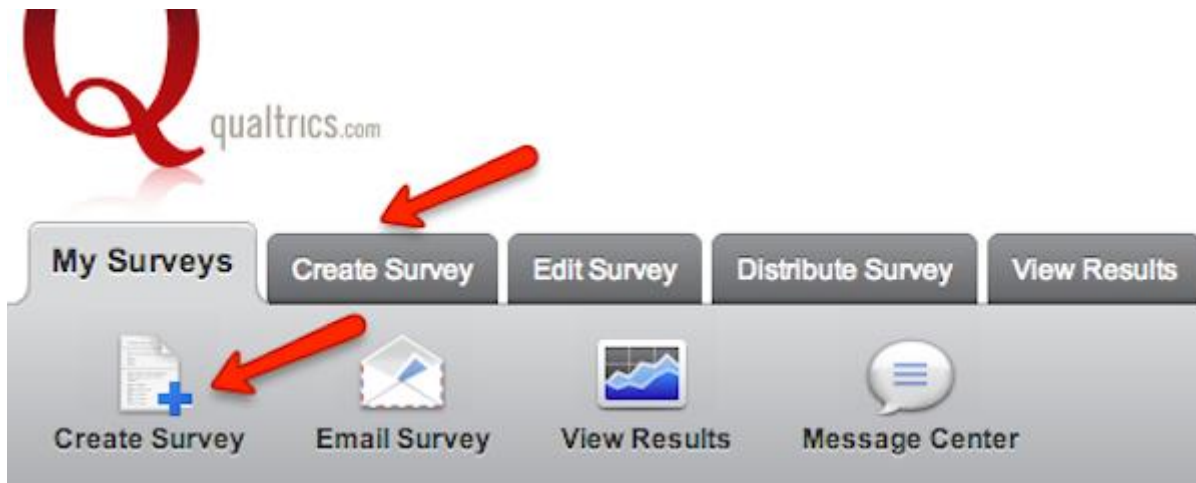


Figure 9: Create New Survey

3) **Select how you would like to build a new survey.**

The Quick Survey Builder is recommended as it includes all the necessary functionality needed for a new survey (Figure 10).

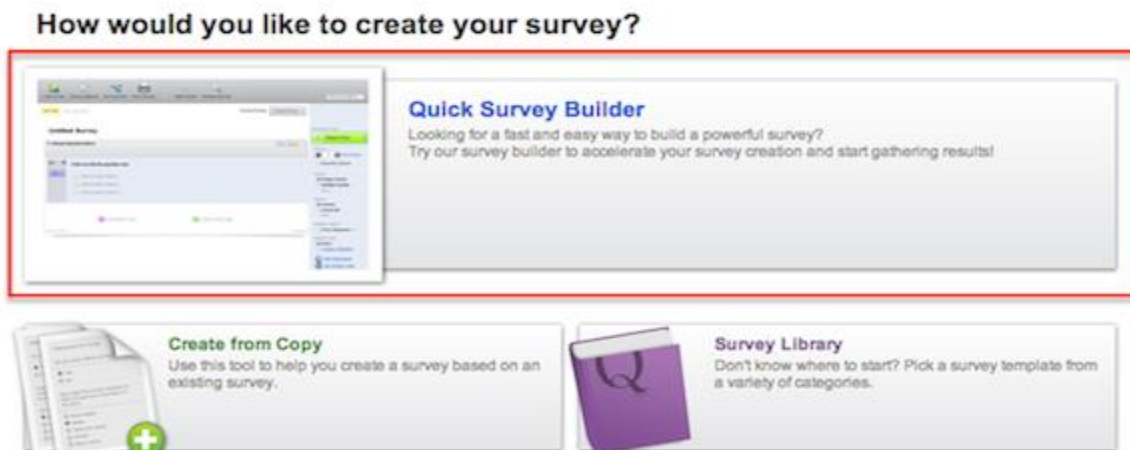
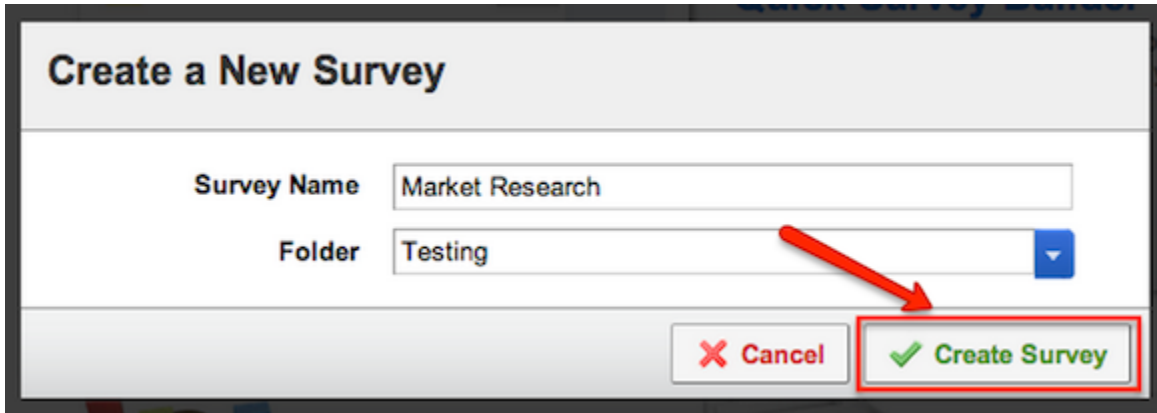


Figure 10: Create New Survey – Quick Survey Builder

4) Name your new survey and click “Create Survey” to proceed (Figure 11).

A folder name is not required to create a new survey. If you wish to create a folder and add surveys to it, you may do so later using the “Manage Folders” feature.



The screenshot shows a web form titled "Create a New Survey". It contains two input fields: "Survey Name" with the value "Market Research" and "Folder" with the value "Testing". A red arrow points from the "Folder" field down to the "Create Survey" button. The "Create Survey" button is highlighted with a red border and contains a green checkmark icon. To its left is a "Cancel" button with a red X icon.

Figure 11: Create New Survey – Naming

5) Add questions to your new survey.

The pre-image questions referred to in the application overview would typically go near the top, with a line for entering a Participant ID being the first line. Once a question is added, you can change the type of question by clicking the green box on the right-hand side of the page labeled “Change Item/Question Type” (Figure 12a). A dropdown menu will appear and the “Text-Entry” selection will allow participants to enter their IDs (Figure 12b).

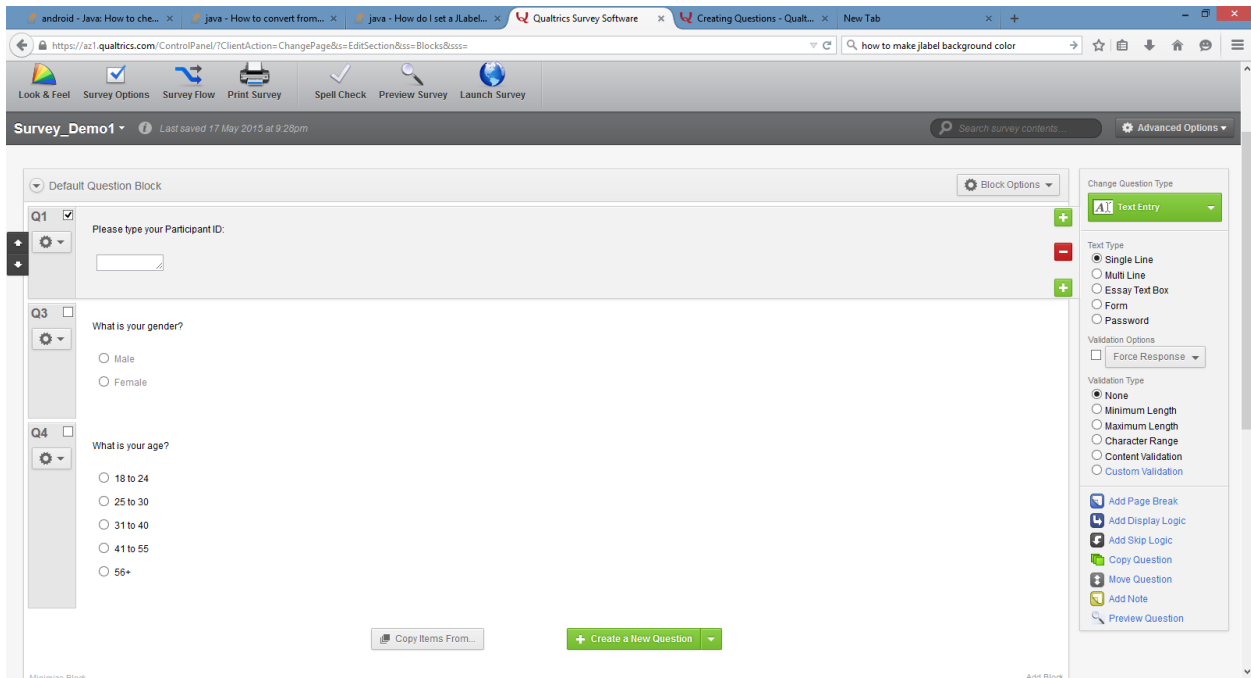


Figure 12a: Add Pre-Image Questions

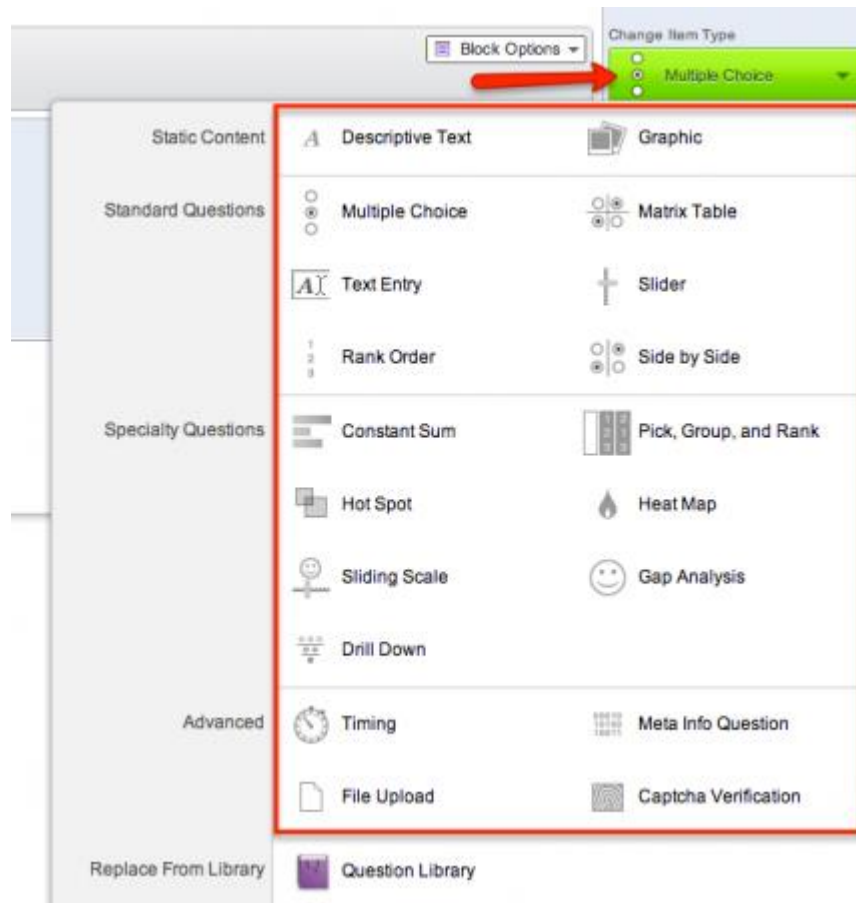


Figure 12b: Change Item/Question Type

6) Adding page breaks between pre-image questions and post-survey questions.

You may add a question type “Descriptive Text” with a message asking the participant to stop and return back to eyeSurvey to view the image before continuing. In order to best facilitate this, add a page break between the pre-image questions and the “stop” message to the user, as well as between the “stop” message and the post-image questions. This requires a user to click a red continue arrow before viewing the next page. Refer to Figure 13 for an example of this.

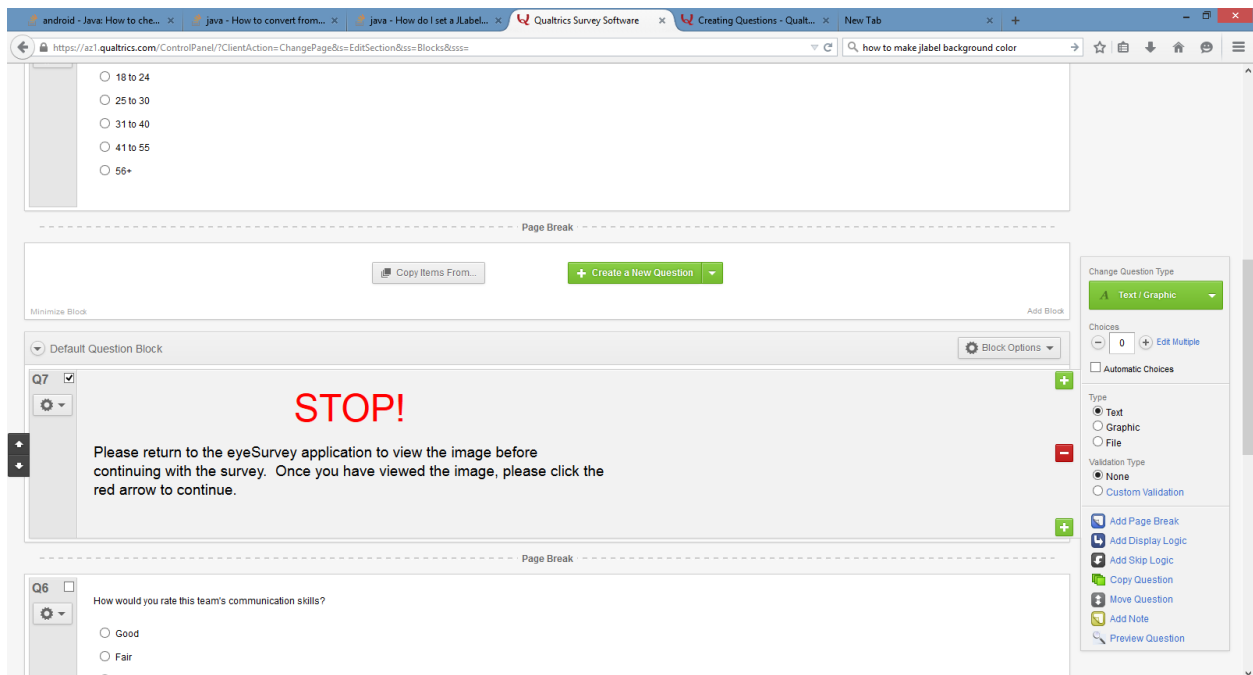


Figure 13: Adding Page Breaks and a “Stop” Message

7) Add a survey termination message.

Once questions have been added and formatted, you may also add a survey termination message to the user. Click on “Survey Options” under the “Edit Survey” ribbon (Figure 14).

Within options, the “Survey Termination” section allows for a custom end of survey message.
Create a custom message providing custom instructions for your experiment as needed.

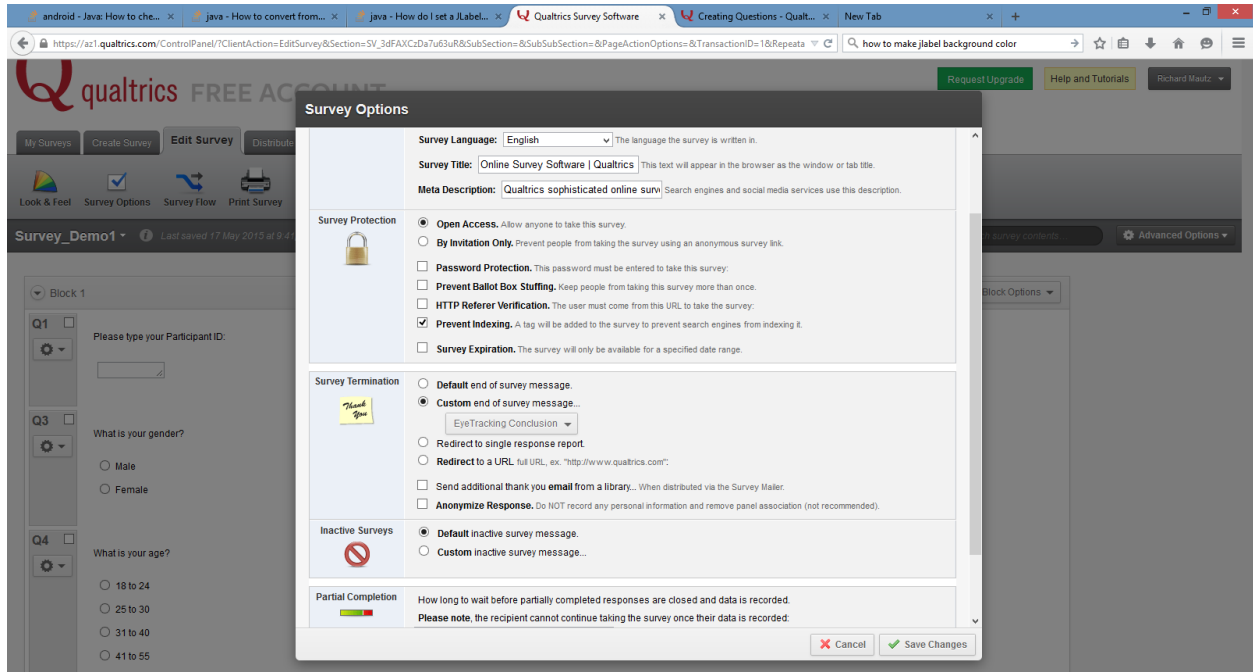


Figure 14: Custom Termination Message

5. Directory and File Structure

The eyeSurvey application has a filing structure designed to house experiments and related files in a central location. Details around that structure are as follows:

Default Directory

When eyeSurvey launches, it will automatically set up the default directory on a user's hard drive. The default directory is: "C:\Users\username\eyeSurvey", where *username* is based upon the Windows login name. If an eyeSurvey directory already exists, no additional directory is created. (Refer to Figure 15 below.)

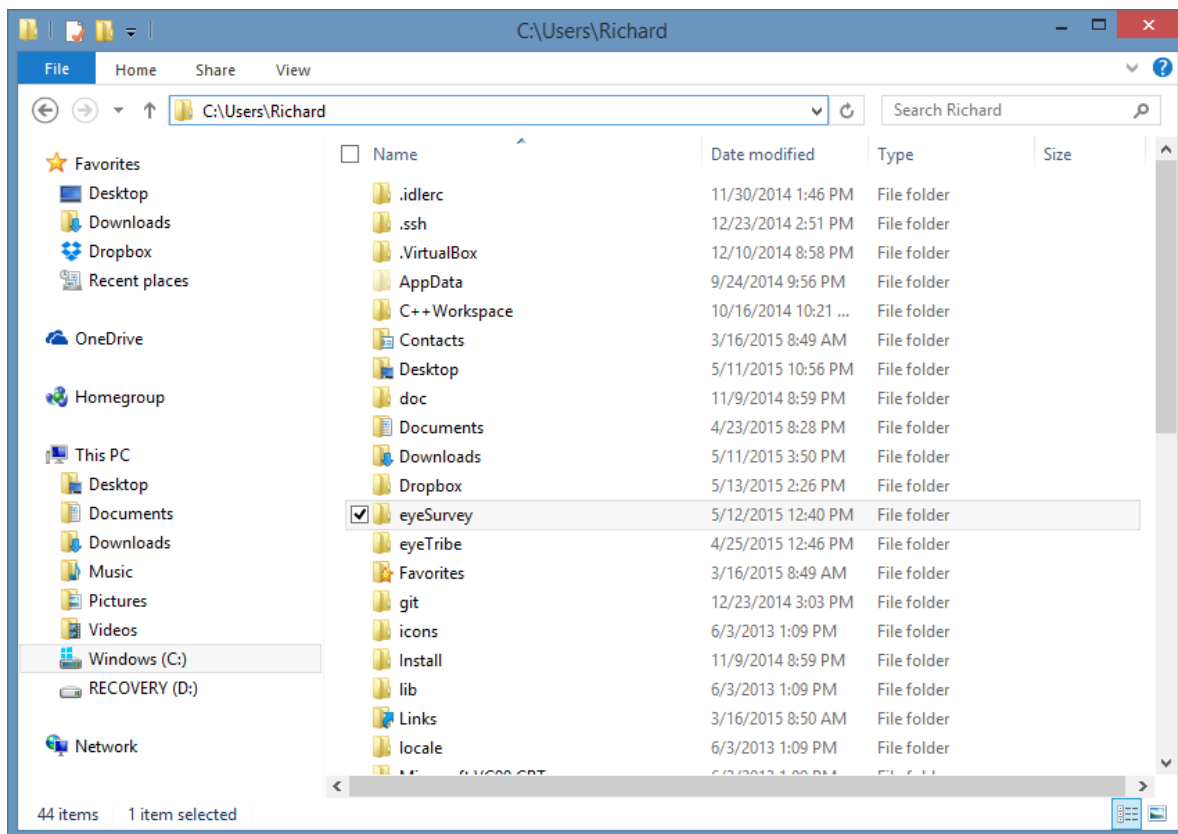


Figure 15: Default directory location

Filing Structure

The goal of the filing structure for this application is to centralize the storage of all elements related to an experiment. Within the eyeSurvey folder, folders are created for each individual experiment. A folder is not created until the Create an Experiment function is complete within the application. Therefore, the

eyeSurvey folder should be empty prior to use. For example, the “Test513” folder represents an experiment created named “Test513”. (Refer to Figure 16 below.)

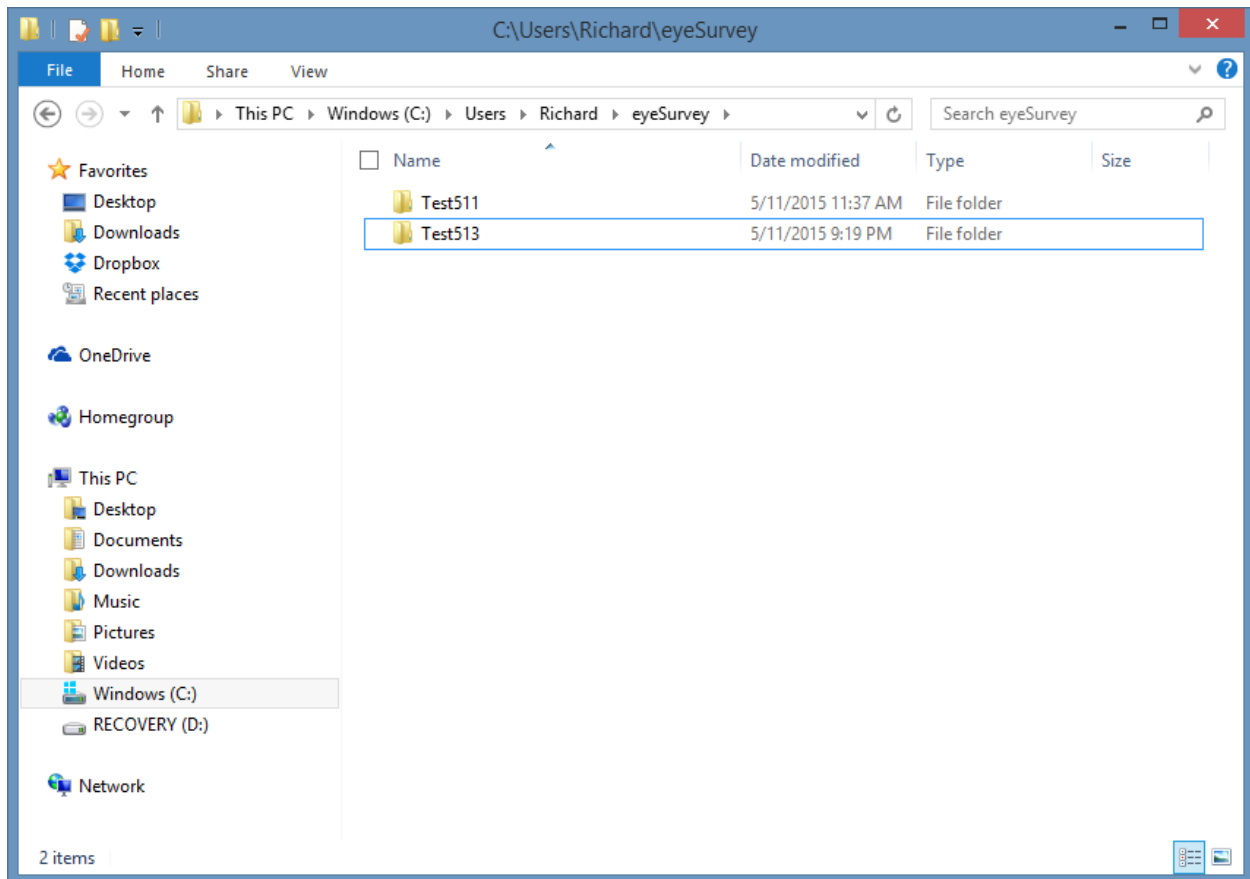


Figure 16: eyeSurvey Folder Contents: Experiment Folders

Experiment Folders

In each individual experiment folder are four items: An experiment parameter file, an images folder, a heat maps folder, and a tracking data folder. The experiment parameter file is the file loaded into the application during the launching of an experiment. Experiment parameter files are identified by having the extension “.expt”. Additional details around the experiment parameter files is covered in the Creating an Experiment section.

When an experiment is created and the user selects an image to load, a copy of that image is written into the Images folder, regardless of the original image’s location. All eye tracking data files are written into

the “TrackingData” folder with the extension “.idata”. The corresponding participant ID numbers are also included at the end of the file name for tracking data files. For example, the file “TrackingData_2.idata” is the eye tracking data file for participant number 2. Heat maps are saved in the “HeatMaps” folder, again with the participant ID number at the end of the file name. These files are images with a “.jpg” extension. (Refer to Figure 17 below for an example of an experiment folder.)

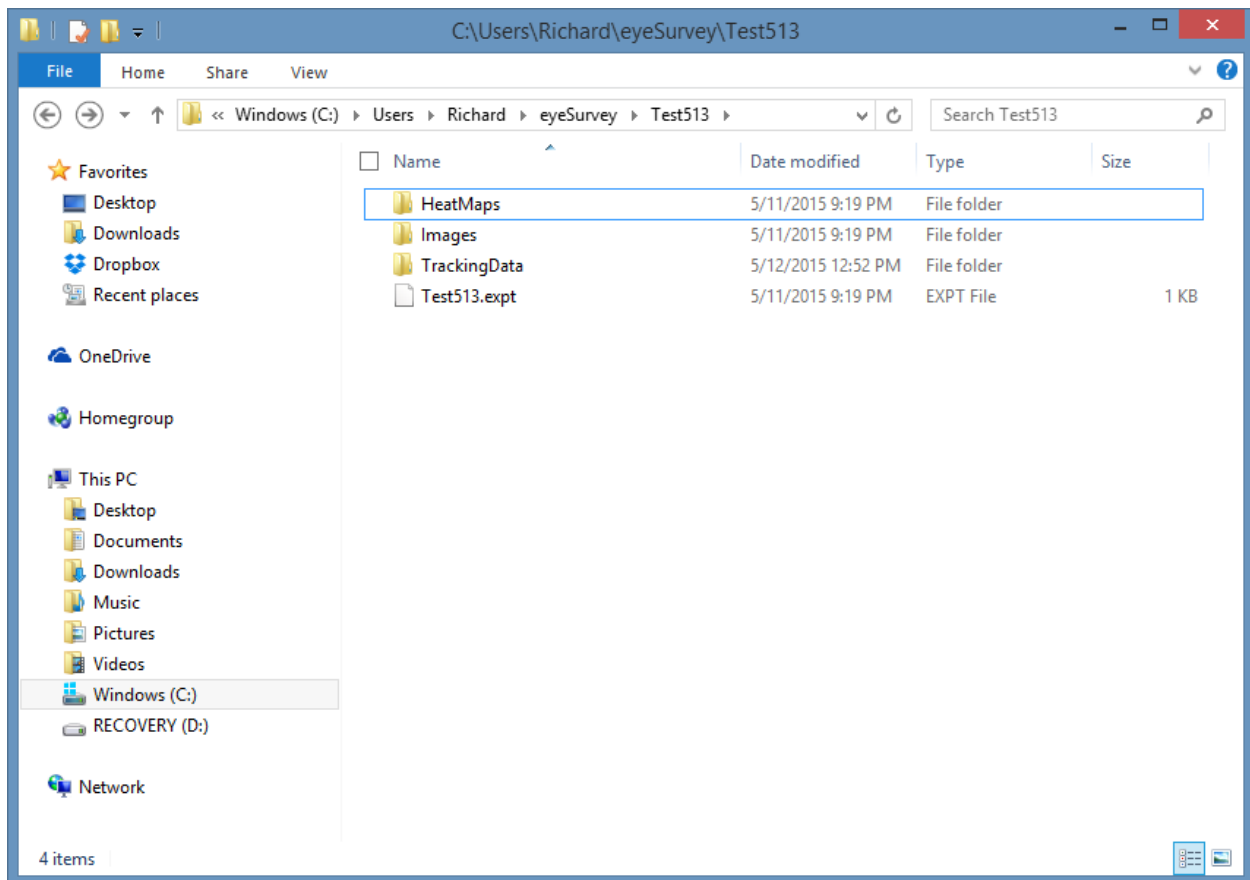


Figure 17: eyeSurvey Experiment Filing Structure.

6. Application Instructions

Create an Experiment

Steps:

- 1) Launch the eyeSurvey application (Figure 18).

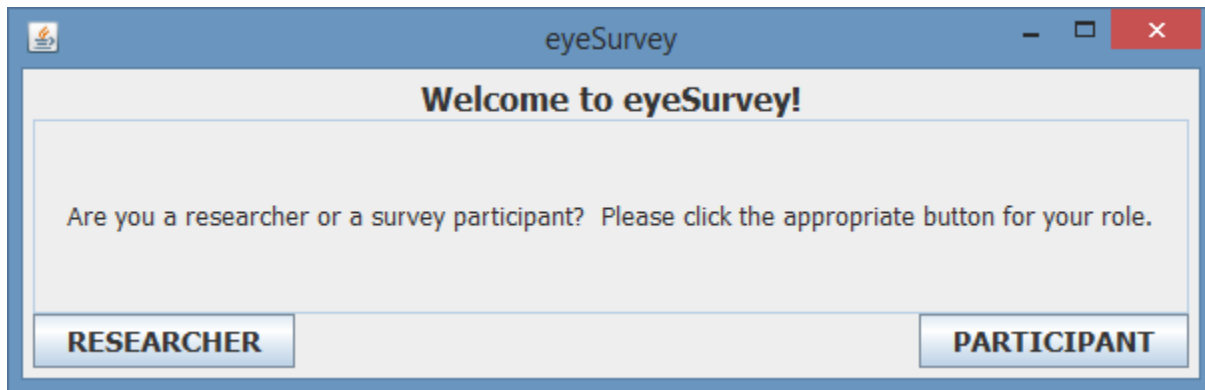


Figure 18: eyeSurvey Welcome Screen

- 2) Click the “Researcher” button to continue to functions available to researcher role.

Note: The Researcher role has the ability to create experiments, test-launch existing experiments and generate heat maps. Selecting the Participant role would only allow a user to launch an experiment.

Using the Researcher role will bring up the Researcher home screen, with all three options available (Figure 19).

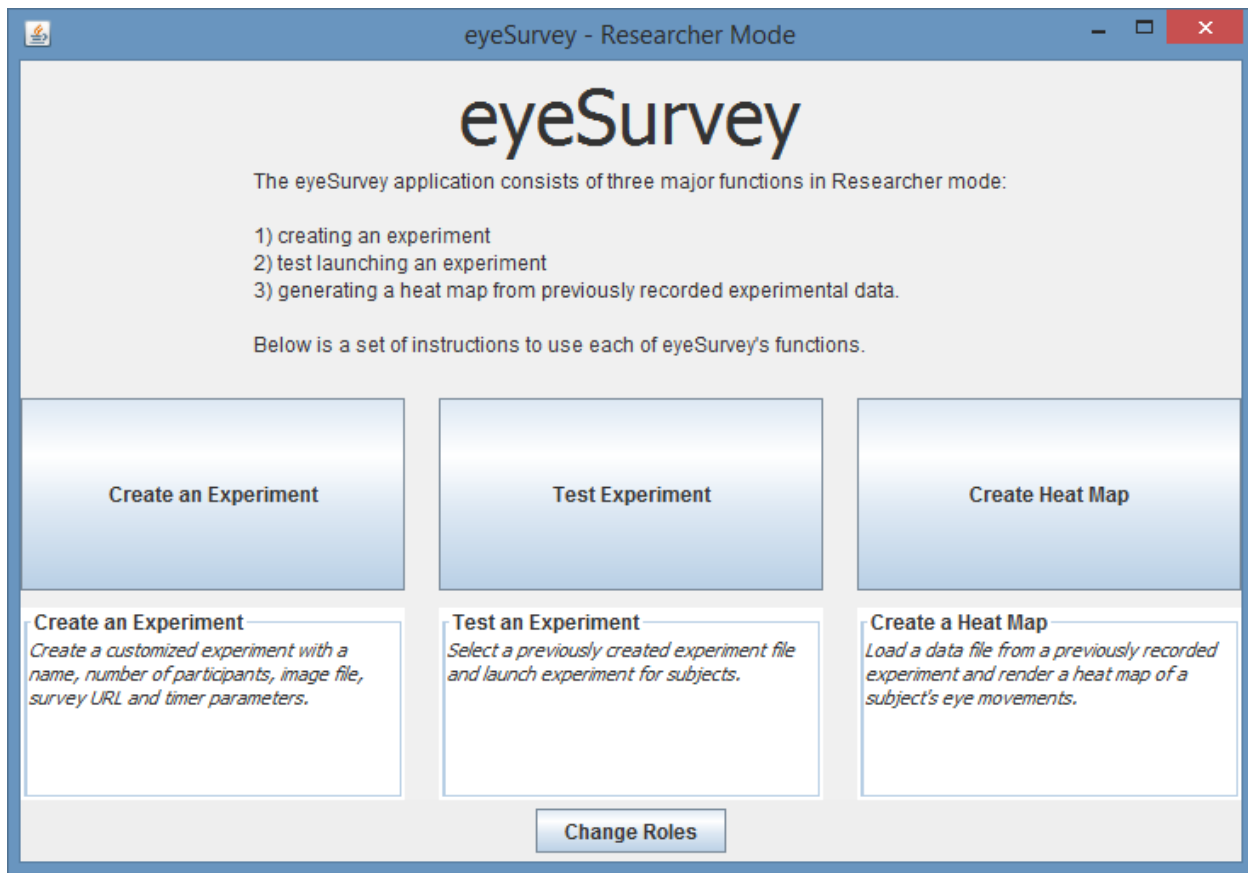


Figure 19: eyeSurvey Researcher Home Screen

- 3) Click the Create an Experiment button.

This function allows a user to create a new experiment within eyeSurvey. Create an Experiment window should appear with boxes to input experiment name, image file locations, survey URL and time limit (Figure 20).

Note: This function will not create the Qualtrics survey. The Qualtrics survey must be completed outside of the eyeSurvey application, and the URL for the survey will be stored when creating an experiment in eyeSurvey. Refer to the “Qualtrics Basic Guide” for additional detail around creating a Qualtrics survey.

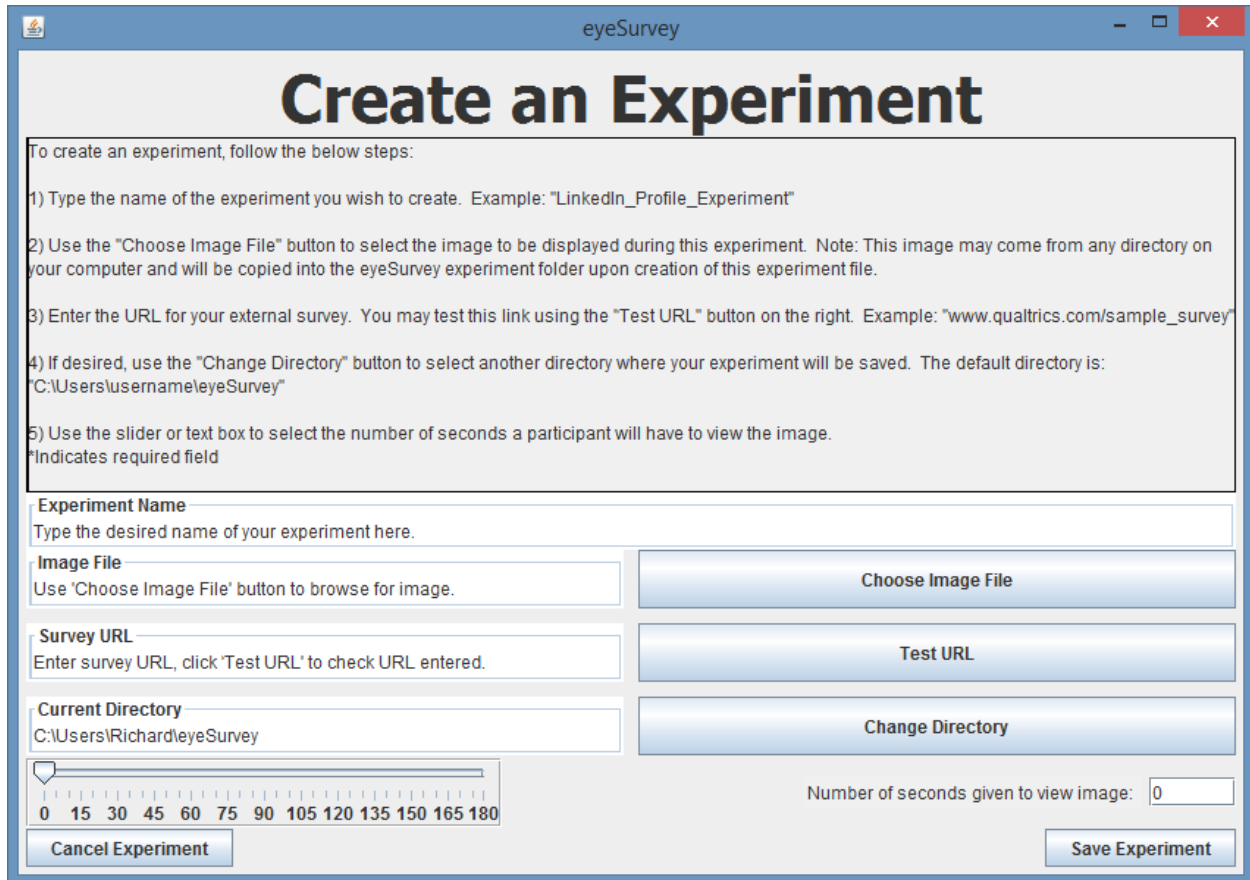


Figure 20: Create and Experiment Screen

- 4) Input the (1) experiment name, (2) number of participants, (3) image file, (4) survey URL and (5) timer to the setting of your choice.

Manually type the name of the experiment and the URL link to the survey. The “Choose Image File” button will open a browser from which you can select the desired image file. The image selected for the experiment will also be copied into the “Images” folder within an experiment folder. Use the timer slider at the bottom, or manually type into the textbox, to choose the number of seconds to display an image during the experiment.

You may also change the directory where the experiment will be saved by clicking “Change Directory” and selecting an alternative location.

Click the "Save Experiment" button when complete.

5) Click “OK” on the pop-up window stating an experiment file has been created.

Once this window appears, an experiment folder, subfolders and file have been successfully created (Figure 21).

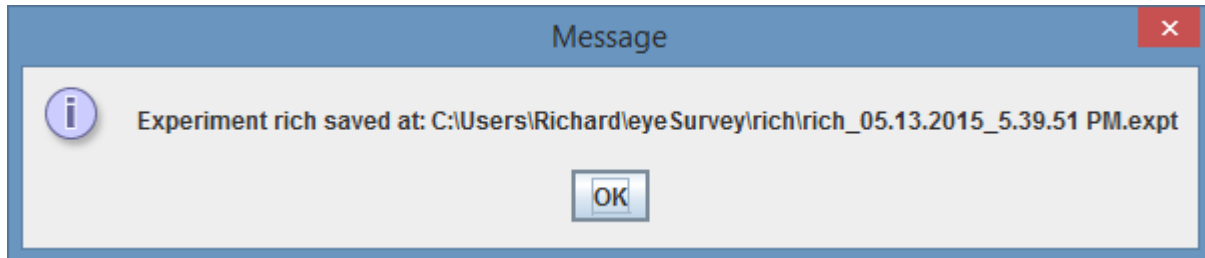


Figure 21: Successful Creation of Experiment Message

Launching an experiment

Steps:

- 1) Launch the eyeSurvey application (Figure 22).

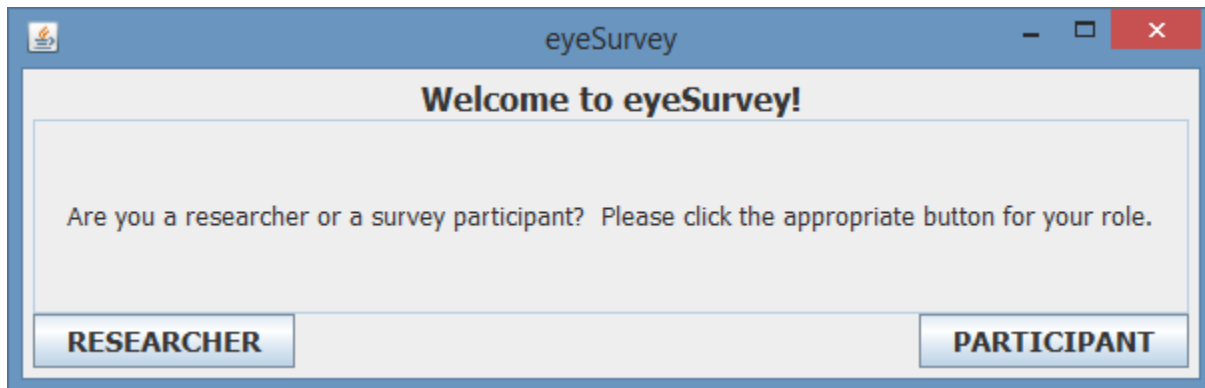


Figure 22: eyeSurvey Welcome Screen

- 2) Click the "Participant" button to continue to experiment launch.

Note: The Researcher role has the ability to create experiments, test-launch existing experiments and generate heat maps. Selecting the Participant role only allows a user to launch an experiment.

Using the Participant role will bring up the participant experiment launch screen (Figure 23a).

The Test Experiment screen for Researchers is included at Figure 23b for reference as well.

eyeSurvey

Launch an Experiment

Please select an experiment file to load: Experiment file location will go here...

Experiment Name:	
Image file name:	
Survey URL:	
Number of seconds given to view image:	
Participant ID:	

Figure 23a: Participant Launch Experiment Screen

The screenshot shows a software window titled "eyeSurvey" with a standard Windows-style title bar (minimize, maximize, close buttons). The main content area has a large heading "Test an Experiment". Below the heading, there is a form with the following elements:

- A text box with the prompt "Please select an experiment file to load:" and a text input field containing "Experiment file location will go here...". To the right of the input field is a "Browse" button.
- A row with the label "Experiment Name:" and an empty text input field.
- A row with the label "Image file name:" and an empty text input field.
- A row with the label "Survey URL:" and an empty text input field.
- A row with the label "Number of seconds given to view image:" and an empty text input field.
- A row with the label "Participant ID:" and an empty text input field.

At the bottom of the form, there are two buttons: "Cancel Experiment" on the left and "LAUNCH" on the right.

Figure 23b: Researcher Test Experiment Screen

- 3) Click the “Browse” button to select the appropriate experiment file.

Experiment files are found in the individual experiment folders under the eyeSurvey default directory (“C:\Users\username\eyeSurvey”) and can be identified by the “.expt” extension in file name. The experiment name, image name, URL, and time limit boxes will load data from the selected experiment file. The Participant ID box will be populated with a randomly generated number. This Participant ID will need to be input into the Qualtrics survey pre-image questions.

Note: In Researcher mode, the participant ID field will populate as “TEST”. All eye tracking data recorded from Researcher launches will be stored at:

C:\Users\UserName\eyeSurvey\ExperimentName\TrackingData\TrackingData_TEST.idata

- 4) After experiment file is selected, click the “Launch” button to begin the experiment.

- 5) At the start of an experiment, a screen will appear requesting the completion of pre-image questions (Figure 24). Click the “Pre-Image Questions” button and answer questions in web browser.

Be sure to input your Participant ID into the Qualtrics survey when asked during the pre-image questions.

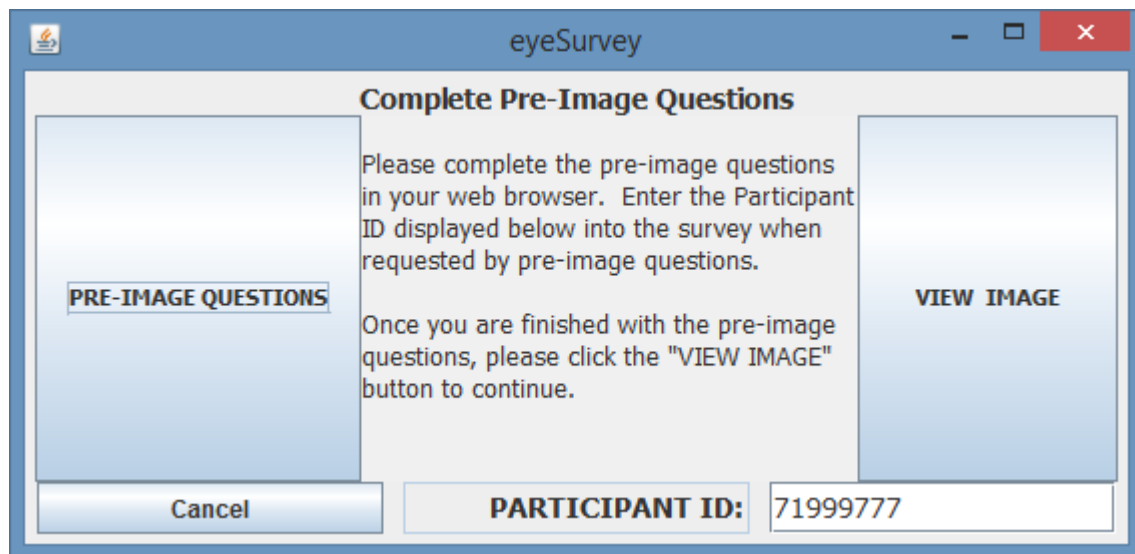


Figure 24: Launched Experiment Pre-Image Questions and View Image buttons.

- 6) After completing the pre-image questions, the survey will instruct you to return to the application and view the image. Minimize your web browser and click the “View Image” button in eyeSurvey (Figure 24).

- 7) The experiment image will appear in a new window. At this point, eye movements are being recorded. Use the scroll bar(s) to view the entire image, as necessary. When eye tracking is complete, a pop-up message will appear instructing the user to return to the web browser to complete the survey (Figure 25). Click “OK” and the image window and pop-up will close. The application will then return to the “Welcome” screen and be ready for the next user.

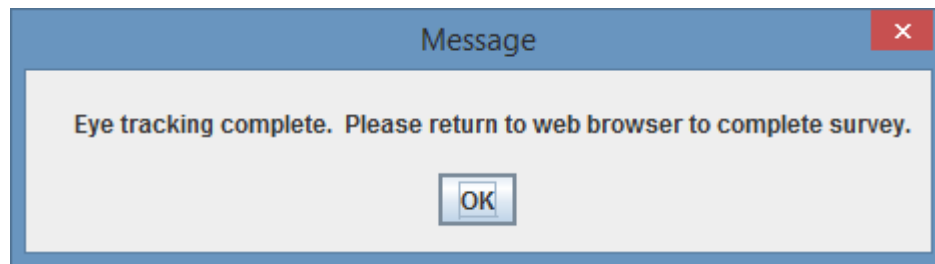


Figure 25: Completed Eye Tracking Message

- 8) Complete the remaining survey questions in Qualtrics as directed.

Creating a Heat Map

Steps:

- 1) Launch the eyeSurvey application (Figure 27).

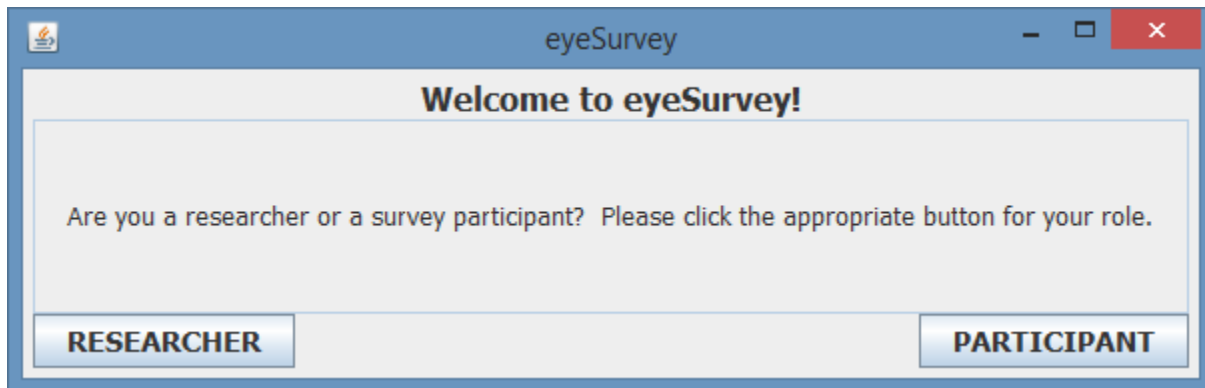


Figure 27: eyeSurvey Welcome Screen

- 2) Click the “Researcher” button to continue to options available to researcher role.

Note: The Researcher role has the ability to create experiments, launch existing experiments and generate heat maps. Selecting the Participant role would only allow a user to launch an experiment.

Using the Researcher role will bring up the Researcher home screen, with all three major functions available (Figure 28).

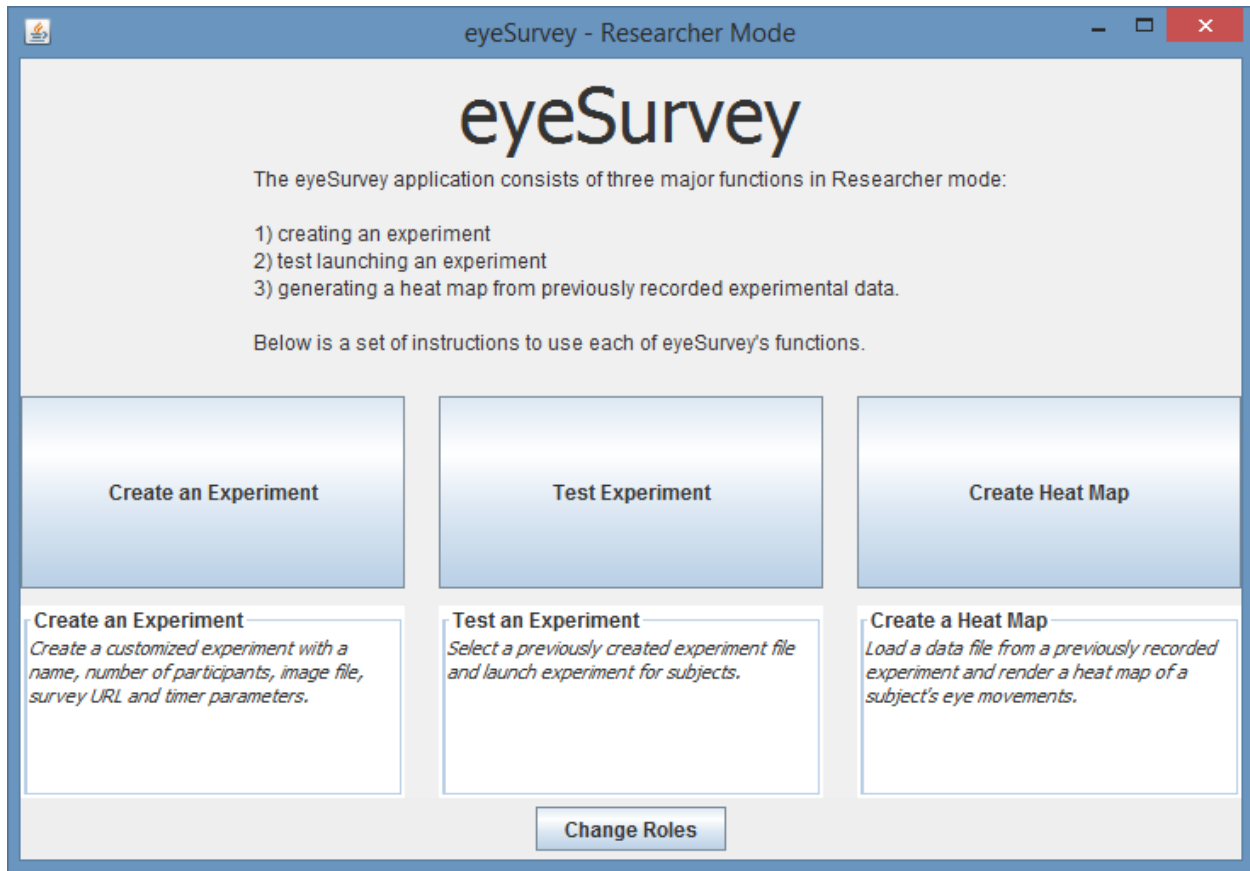


Figure 28: eyeSurvey Researcher Home Screen

- 3) Click the “Create Heat Map” button. The “Create a Heat Map” window should appear with boxes to input the image file and eye tracking data file name (Figure 29).

When creating a heat map, eyeSurvey retrieves the image associated with the data file and the eye tracking data out of the file selected. The application reduces the image’s brightness to 30% of the original and plots each eye tracking data point. Data points are displayed in the heat map by increasing the brightness of data points to their original level. This produces a dimmed image with illuminated points where a participant looked during an experiment. The heat map is then saved to the “Heat Maps” folder in the given experiment’s eyeSurvey directory.

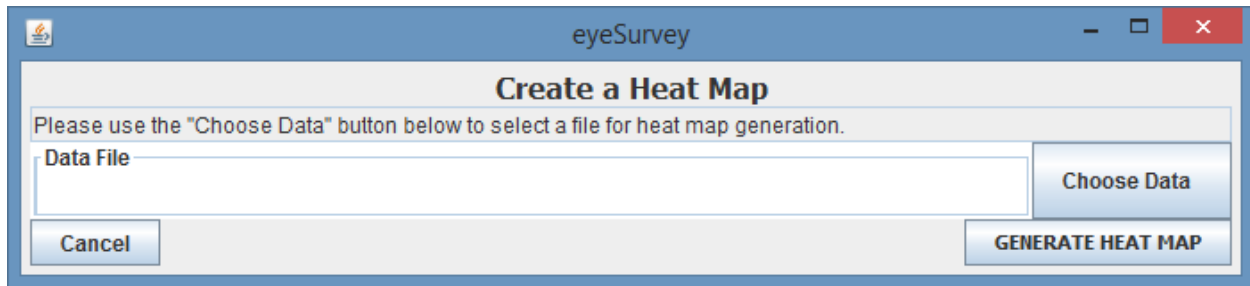


Figure 29: Create a Heat Map Screen

- 4) Use the “Choose Data” button to select the tracking data file for heat map generation.

Again, tracking data files are stored in the “TrackingData” folder of an experiment and contain the participant ID number in the file name. Tracking data files are also identified by the “.idata” file extension. For example, eye tracking data for participant ID #8 would be found in the file named “TrackingData_8.idata”. The data file text box will populate with the selected file names.

- 5) Click the “Generate Heat Map” button to create a heat map for that given image and eye tracking data file.

The application will use the image file from the data to create a new image file with brightness reduced to 30% of the original. Eye points from the data file are rendered onto the new brightness-reduced image by increasing the brightness of the coordinate and pixels within a five-pixel radius. The heat map will be saved in the same directory as the experiment and is located in the heat map folder. The file will be named “*ExperimentName_DataFileName*”, with *ExperimentName* being the name given to the experiment during experiment creation and *DataFileName* being the name of the participant data file used to populate eye point coordinates.

- 6) A pop-up box stating that the heat map has been successfully created will appear. Click “OK” to close the given heat map and return to the Researcher home screen.