Gender Differences in the Perception of Ambiguous Figures

A Final Project for the Eye Tracking 2024 Course, Group H

Maxwell Njiru*†
University of Eastern Finland
Joensuu, Finland
mnjiru@student.uef.fi

Erja Kyläkorpi*
University of Eastern Finland
Joensuu, Finland
erjakyl@student.uef.fi

Nima Hadavi†‡
University Of Eastern Finland
Joensuu, Finland
nhadavi@student.uef.fi

Haris Mashood†§
University Of Eastern Finland
Joensuu, Finland
hmashood@student.uef.fi

Ibrahim Ajagbe†
University Of Eastern Finland
Joensuu, Finland
ibajagbe@student.uef.fi

Anna Staengler
University Of Eastern Finland
Kuopio, Finland
annasta@student.uef.fi

Roosa Villa
University Of Eastern Finland
Kuopio, Finland
rvilla@student.uef.fi

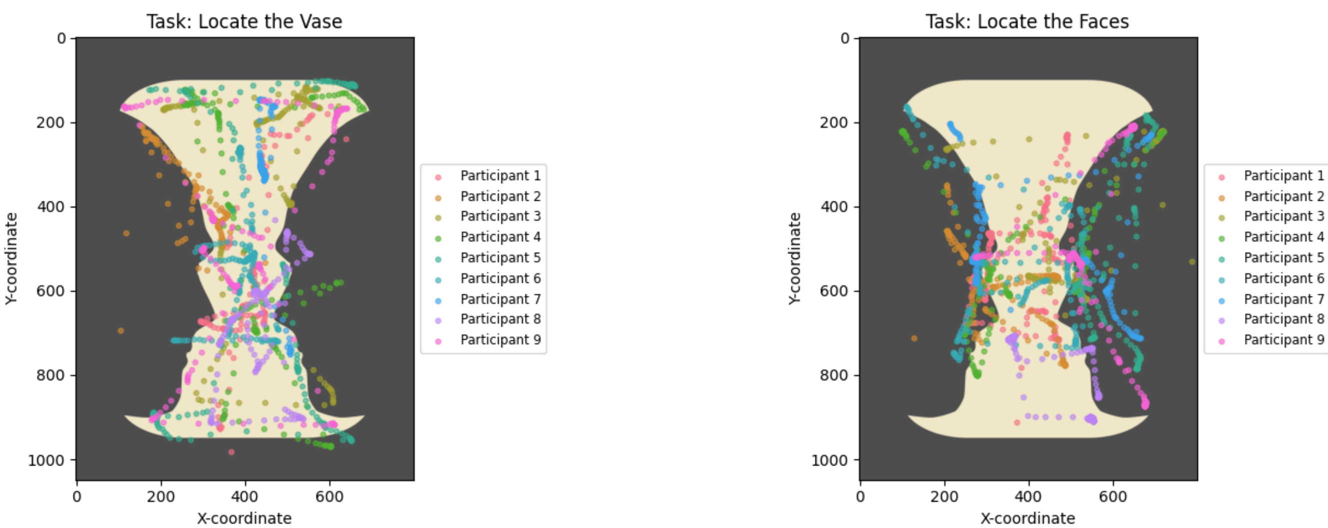

Figure 1: Combined Raw Gaze Data Points for Each Task

ABSTRACT

This study investigated the influence of gender on the perception of ambiguous figures, specifically the optical illusion of the Rubin vase. Eye-tracking technology was used to record the participants' gaze patterns while they viewed the illusion. The primary stimulus for this experiment was a Rubin's vase image and two questions to identify the vase and the faces. The results revealed potential gender differences in visual exploration strategies. Male participants tended to focus on the central region of the image, suggesting a stronger initial bias towards the vase interpretation. In contrast, the female participants exhibited a more balanced exploration of the image, paying attention to both the vase and the facial profiles. These findings suggest that gender may play a role in how individuals perceive and interpret ambiguous visual stimuli. However, further research with larger sample sizes and controlled experimental conditions is necessary to confirm these findings and explore the underlying cognitive mechanisms.

CCS CONCEPTS

• **Human-centered computing → Visualization**; • **Computing methodologies → Visual inspection**.

KEYWORDS

Eye tracking, fixation detection, saccade detection, gaze patterns, visual attention, ambiguous figure, illusion, gender differences

*Wrote the report
†Contributed equally to designing the experiment
‡Conducted analysis
§Conducted experiment

1 INTRODUCTION

Eye tracking is an experimental method used to record and analyze eye movements, such as fixations and saccades, over time during different tasks. By examining these eye movements, we can gain insight into how individuals allocate their visual attention and process visual information to understand how individuals allocate visual attention. [1]. One of the areas of research in eye tracking is understanding how people perceive optical illusions. One of these illusions is Rubin's vase, which is a picture that can appear to be a vase as well as two human faces [3].

One area of eye tracking research involves studying visual perception, including the perception of ambiguous figures such as the Rubin vase, which can be perceived as a vase or two faces [3]. Optical illusions can provide insight into the cognitive processes underlying visual perception.

In this study, we focus on Rubin's vase illusion to investigate potential gender-based differences in visual perception. To achieve this, we employed eye-tracking technology to record participants' gaze data while they viewed Rubin's vase image. By analyzing recorded eye movements, we aimed to fixation durations, and saccade patterns. Through these analyses, we aimed to understand how individuals perceive and interpret ambiguous visual stimuli, particularly in terms of gender differences.

We will present our objectives, the experimental setup, the data analysis process and our conclusions.

2 EXPERIMENT SETUP

Nine participants, both male and female, aged between 23 and 32, participated in the study. These were all students from University of Eastern Finland. Prior to the experiment, participants underwent a calibration process to ensure accurate eye-tracking data.

The experiment involved two tasks. For each task, participants were presented with a Rubin's vase image (see Figure 2). In the first task, participants were instructed to focus on the vase for five seconds. After five seconds, participants pressed the spacebar to initiate the second task, where they were instructed to focus on the faces in the image for another five seconds. Gaze data was recorded using a Tobii Eye Tracker 5, utilizing Tobii Eye Tracking software and Hengam recording software.

2.1 Experiment objectives

Our objectives were to

OBJ1: To identify different gaze patterns when identifying the vase and faces from Rubin's vase.

OBJ2: To understand the differences in gaze behaviors between male and female participants while identifying faces and vase from the Rubin's vase.

2.2 Research questions

Based on our objectives, we developed these research questions:

RQ1: How do gaze behaviors change when participants identify the vase and faces from Rubin's vase?

RQ2: Are there differences in gaze patterns between male and female participants when identifying vase and faces from Rubin's vase?

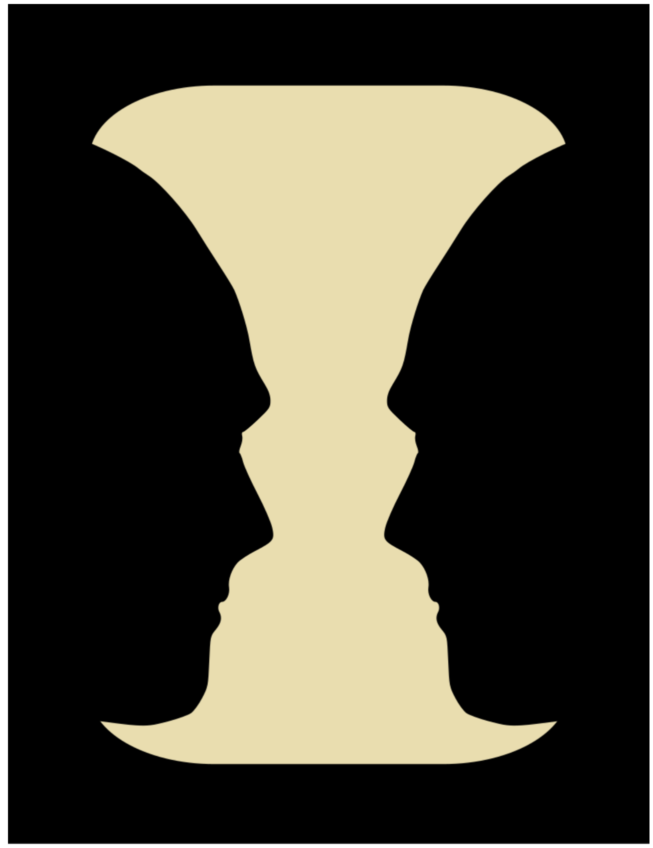

Figure 2: Rubins vase. [Public domain], Image by Nevit Dilmen, via Wikimedia Commons. (https://upload.wikimedia.org/wikipedia/commons/d/da/Face_or_vase_ata_01.svg).

2.3 Study hypothesis

Based on the research questions, we developed the following hypothesis:

H1: Participants will exhibit distinct gaze patterns depending on the task they are performing, whether identifying the vase or faces.

H2: Male and female participants will have significant differences in gaze behaviors.

3 DATA ANALYSIS

3.1 Data preprocessing

Before conducting the analysis, several preprocessing steps were taken. First, the dataset was validated to ensure the presence of all required columns, including coordinates, task, participant ID, gender and age. Subsequently, Rubin's vase image was converted from BGR to RGB color format to facilitate visualization using matplotlib. Additionally, due to inconsistencies in the original timestamp data, artificial timestamps were imputed based on the device's 33Hz sampling rate to ensure consistent time intervals between data points.

3.2 Algorithm

In this study we used the Velocity-Threshold fixation Identification (I-VT) algorithm. It is a straightforward approach to distinguishing between fixations and saccades in eye-tracking data. I-VT calculates the velocity between consecutive gaze points and classifies it as a fixation, if the velocity falls below a predefined threshold, otherwise it's considered a saccade. [2].

The core logic for the I-VT algorithm implemented in the experiment can be represented as following pseudocode:

(1) **Initialize:**
 Empty lists for fixations and saccades
 Set velocity threshold

(2) **For each pair of consecutive gaze data points (i, i+1):**

 (a) **Calculate velocity:**

$$Velocity = \frac{\sqrt{(x[i+1]-x[i])^2 + (y[i+1]+y[i])^2}}{(time[i+1]-time[i])}$$

 (b) **If velocity ≤ velocity threshold**
  Add data point to the current fixation.
 Else:
  Mark the end of the current fixation.
  Save fixation (if its duration exceeds a minimum threshold).
  Start a new saccade.

(3) **After processing all points:**
 Add the remaining fixation to the fixation list if it meets the duration threshold.

(4) **Return the lists of fixations and saccades**

For this experiment, the velocity threshold was set to 40 degrees per second. A lower threshold might overclassify small unintentional eye movements as saccades, while a higher threshold might miss slower, intentional saccades. While different threshold values could be explored, the chosen value provided acceptable results for our specific experiment and data.

Key features extracted from the data include:

(1) Fixation:
 - duration: the lenghts of time the eyes fixates on a specific point
 - location: the x-y-coordinate of the fixation point

(2) Saccade:
 - amplitude: the distance between the start and end points of the saccade
 - peak velocity: the maximum velocity during saccade

For a detailed implementation of the I-VT algorithm and the complete data processing pipeline, please refer to the following GitHub repository:

https://github.com/maxwellfundi/eyetrackingproject/blob/main/Final_project_analysis.ipynb

3.3 Results

3.3.1 OBJ1 - different gaze patterns when identifying the vase and faces from Rubin's vase. The heatmap in Figure 3 shows a strong concentration of gaze activity in the central region of the Rubin's, corresponding to the outline of the vase. This suggests that the vase captures most of the attention from all participants and tasks.

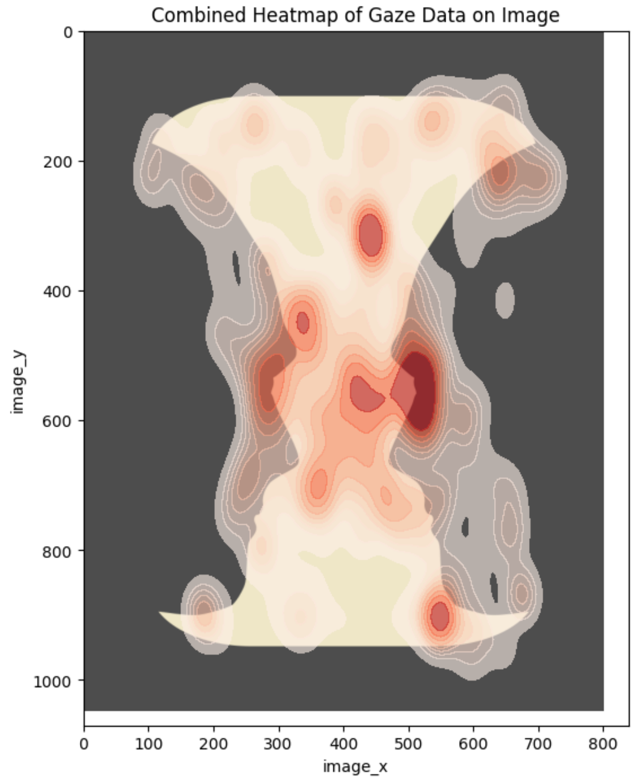

Figure 3: Combined heatmap of gaze data

There is also some gaze activity on the left and right sides of the image, aligned with the facial outlines. These clusters may suggest that the participants also spent more time finding the faces more intensely compared to the vase.

The heatmaps in Figure 4 show differences in gaze patterns based on the two tasks namely – Identity face and vase. When attention was concentrated in the central region of the image when locating the vase. They seem to focus along the vertical axis of the vase with some fixation clusters at the top, middle, and bottom.

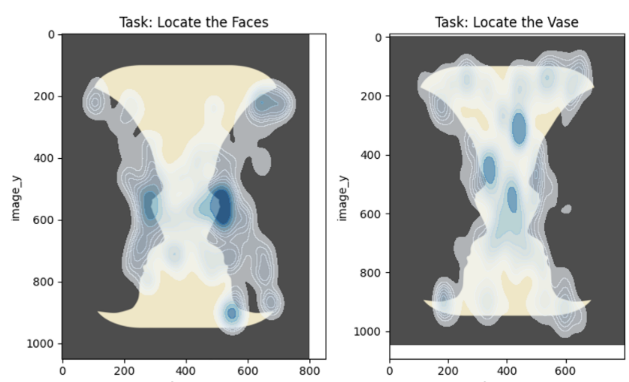

Figure 4: Task specific heatmaps

When identifying faces participants seem to have gaze clusters on the left and right sides of the image, corresponding to the facial profiles outline. Additionally, participants directed their attention symmetrically to both faces, with slightly more focus around the eye and nose areas, while giving little attention to the central vase.

3.3.2 OBJ2 - gaze behaviors between male and female participants while identifying faces and vase from the Rubin's vase. From the heatmaps in Figure 5, we saw that female participants looked at both the central vase and the faces on the sides more evenly. Their gaze was spread out, and they seemed to focus on both the vase and the faces unlike males who mostly focused on the vase in the center. While they did look at the faces on the sides a little, it wasn't as much as the females.

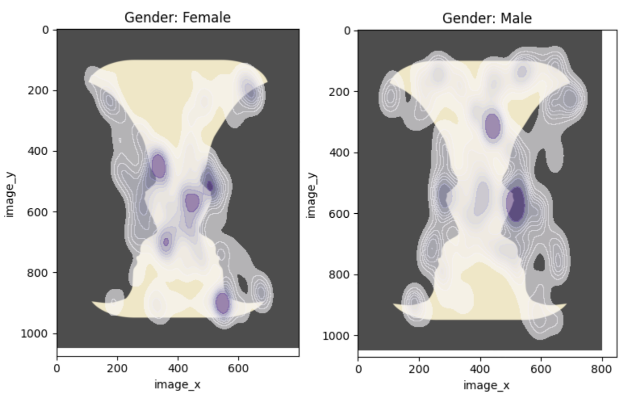

Figure 5: Heatmaps of female and male participants

The scanpath visualizations, such as those shown in Figures 6 and 7 for a male and female participant respectively, provide insights into individual differences in visual exploration strategies. For instance the male participants reveal interesting patterns in their eye movements. When tasked with identifying the vase, the participant's gaze tends to be concentrated around the central region of the image, suggesting a strong focus on the vase outline. However, there are also fixations on the sides of the image, indicating that the participant was also attending to the facial profiles.

When asked to identify the faces, the participant's gaze shifts towards the left and right sides of the image, where the faces are located. This suggests a strategic approach to locate the faces, with fixations concentrated on the eye and nose regions.

The female participants scanpaths show a slightly different pattern. While there is a clear focus on the central vase region during the "identify the vase" task, there is also a noticeable amount of attention directed towards the facial profiles. This suggests a more balanced exploration of the image, possibly indicating a greater sensitivity to the ambiguous nature of the stimulus.

When identifying the faces, the female participant's gaze is distributed more evenly between the two faces, with fixations on both the eye and nose regions. This suggests a more thorough examination of both facial profiles.

Overall, these visualizations suggest that both male and female participants exhibited task-specific gaze patterns. However, there might be subtle gender differences in how they explored the image. Female participants seemed to have a more balanced approach, attending to both the vase and the faces, while male participants might have focused more on the central vase region.

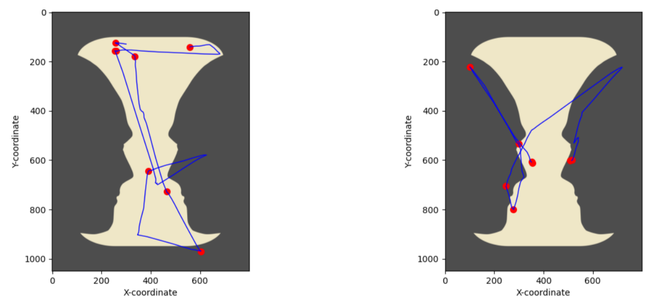

Figure 6: Scanpath visualization for one of the male participant

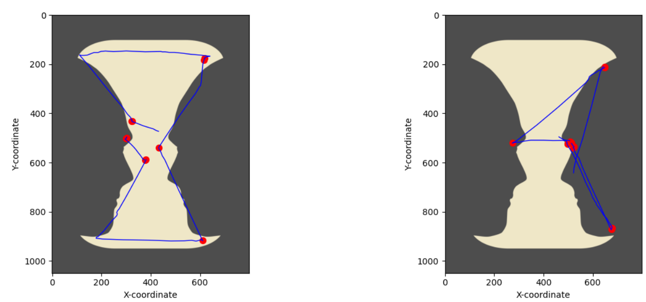

Figure 7: Scanpath visualization for one of the female participant

4 DISCUSSION

This study aimed to answer two research questions by analyzing the eye-tracking data of nine participants. The findings of this study have the following implications:

First, our findings partially support H1. Participants exhibited distinct gaze patterns depending on the task. When identifying the vase, gaze was concentrated in the central region, suggesting a focus on the vase outline. In contrast, when identifying faces, gaze was directed towards the left and right sides of the image, corresponding to the facial outlines.

Second, regarding H2, we found some evidence for gender differences in gaze patterns. Female participants seemed to distribute their gaze more evenly between the vase and faces, while male participants focused more on the central vase region. However, these differences were not statistically significant and require further investigation with a larger sample size.

The observed gaze patterns align with previous research

This study has several limitations. First, the participants were a relatively small sample size (n=9) and were limited to a specific age range (23 to 32). Additionally, the use of a consumer-grade eye tracker, the Tobii 5, may have introduced limitations in terms of accuracy and precision. Therefore, further research is needed to confirm these findings, and the results should be considered preliminary and not to be generalizable to other populations. Furthermore, the issues with timestamp accuracy may have affected the precision of the analysis.

5 GROUP MEMBERS AND CONTRIBUTION

Group members for Eye Tracking course 2024 group H and their assigned tasks:

Ibrahim Ajagbe - Experiment design
Nima Hadavi - Experiment design and analysis
Erja Kyläkorpi - Report writing and layout
Haris Mashood - Experiment design and recording data
Maxwell Njiru - Experiment design and report writing
Anna Staengler - Homework 6
Roosa Villa - Homework 6

Group members assigned to complete homework 6 participated also in general discussion on final project.

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