Webcam-based Eye Tracking to Assess Cognitive Function in Middle-School Children Using On-Line Math Tutorials

Oyindamola Ogunlade, Joshua I. Gold, Ph.D

University of Pennsylvania, Department of Neuroscience

Abstract

Eye-tracking measures can be useful in the study of cognition by serving as indicators of processes such as physiological arousal, attention and mental effort. These measures have been used extensively to study cognition in adults but to a much lesser degree in children. The goal of the present study is to use measures of gaze patterns to gain insights into cognitive processes used by neurotypical middle school children performing on-line math lessons. To achieve this goal, we are developing a novel system that combines on-line learning tools with web camera-base eye tracking. Here we present promising preliminary data that demonstrates the potential effectiveness of this system. We intend to finish developing this system and then use it to relate gaze patterns to lesson performance and probe questions to identify the specific conditions under which students do and do not learn effectively from these lessons and use that information to help design more effective lessons.

Introduction and Challenges

Gaze has long been used as a measure of cognitive processing. These measurements have traditionally required eye tracking equipment only available in laboratory settings. Our goal, as well as our primary challenge, is to obtain gaze measurements outside of the lab using standard webcams.
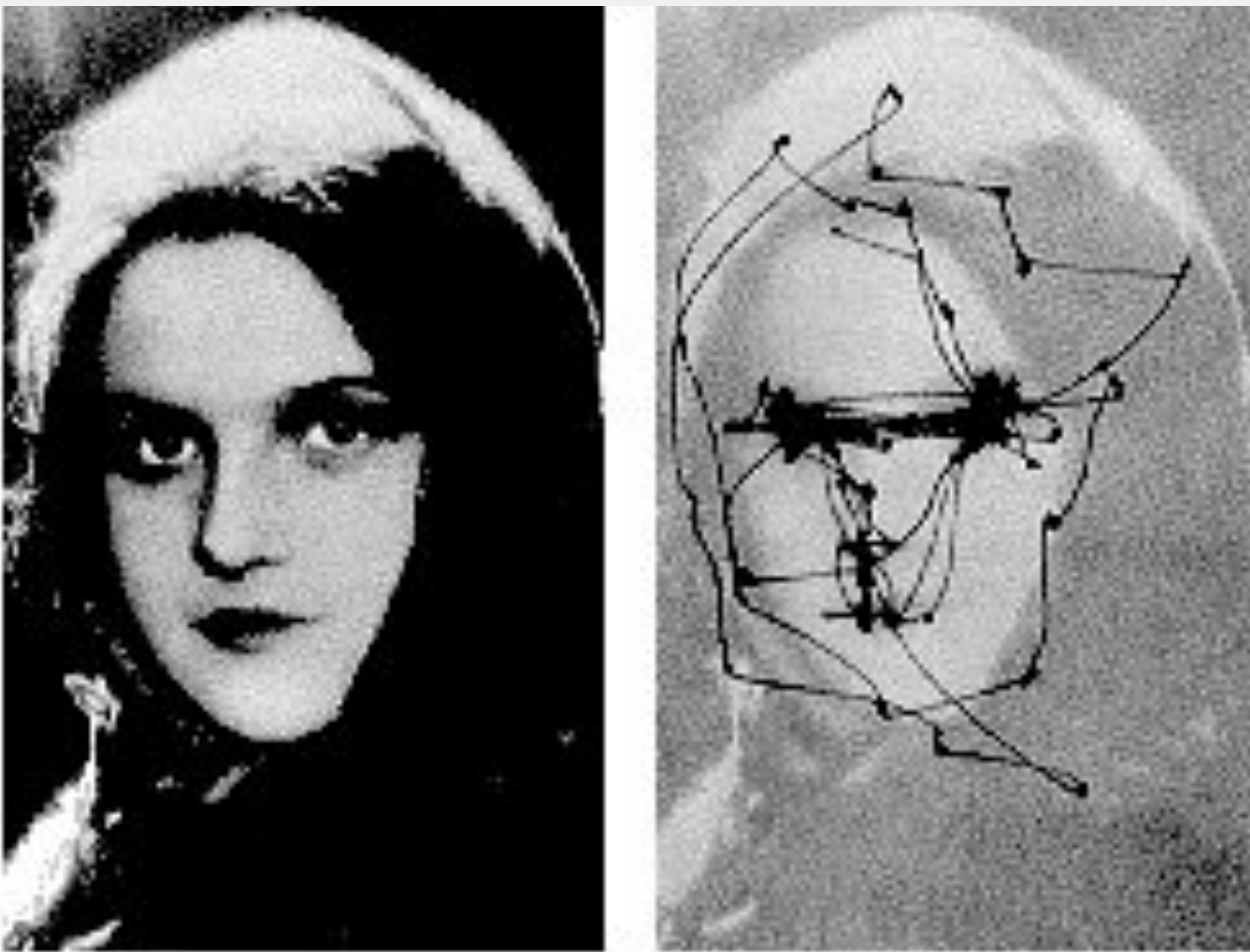

Figure 1. Photograph of a woman on the left and gaze pattern of a subject viewing the photograph on the right [1].

Methods

- We developed an online math learning task which utilizes webcam-based eye tracking.
- The learning task consists of a multiple-choice math quiz.
- Following each question, we probabilistically ask 4 probe questions relating to cognition
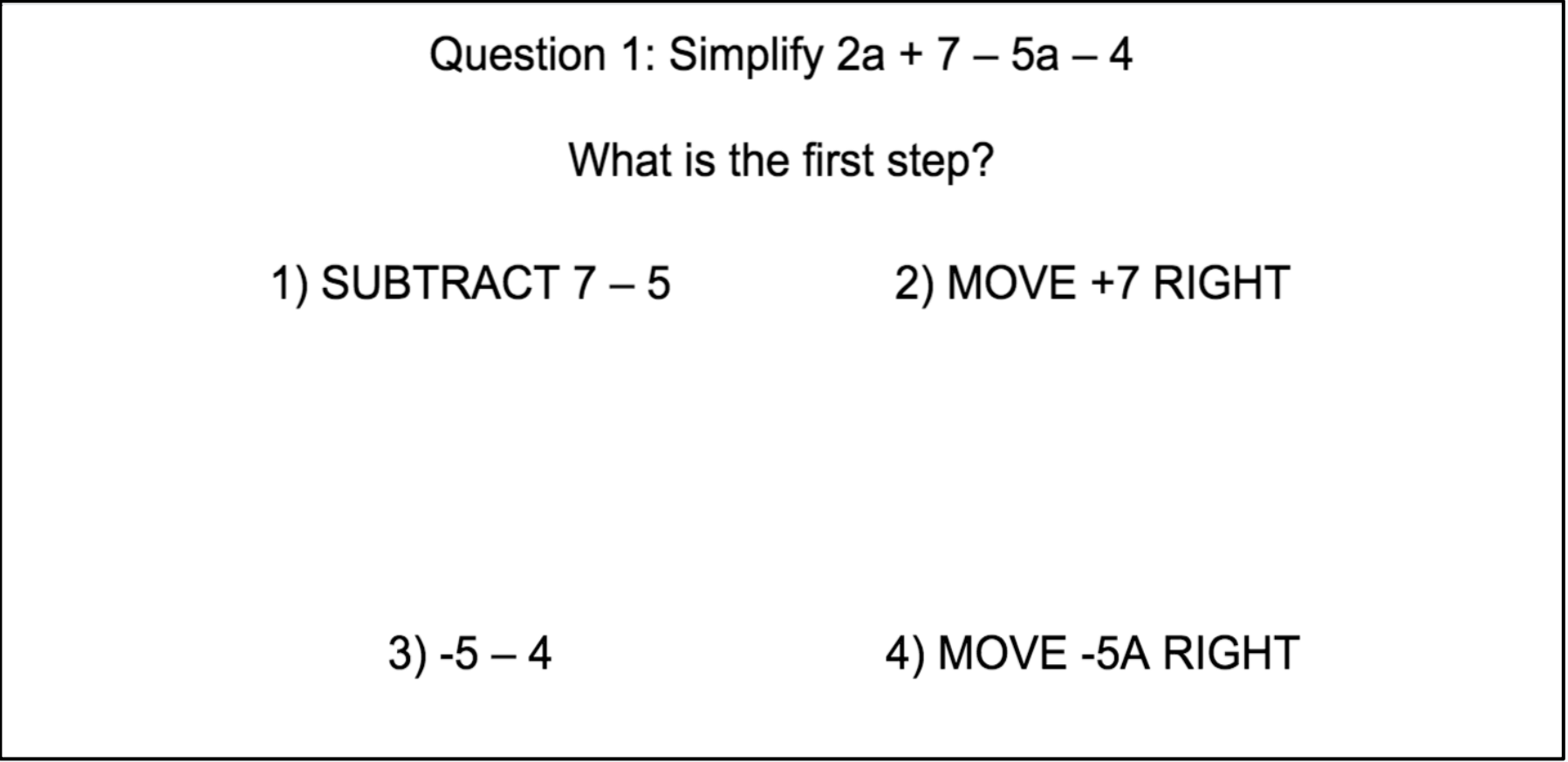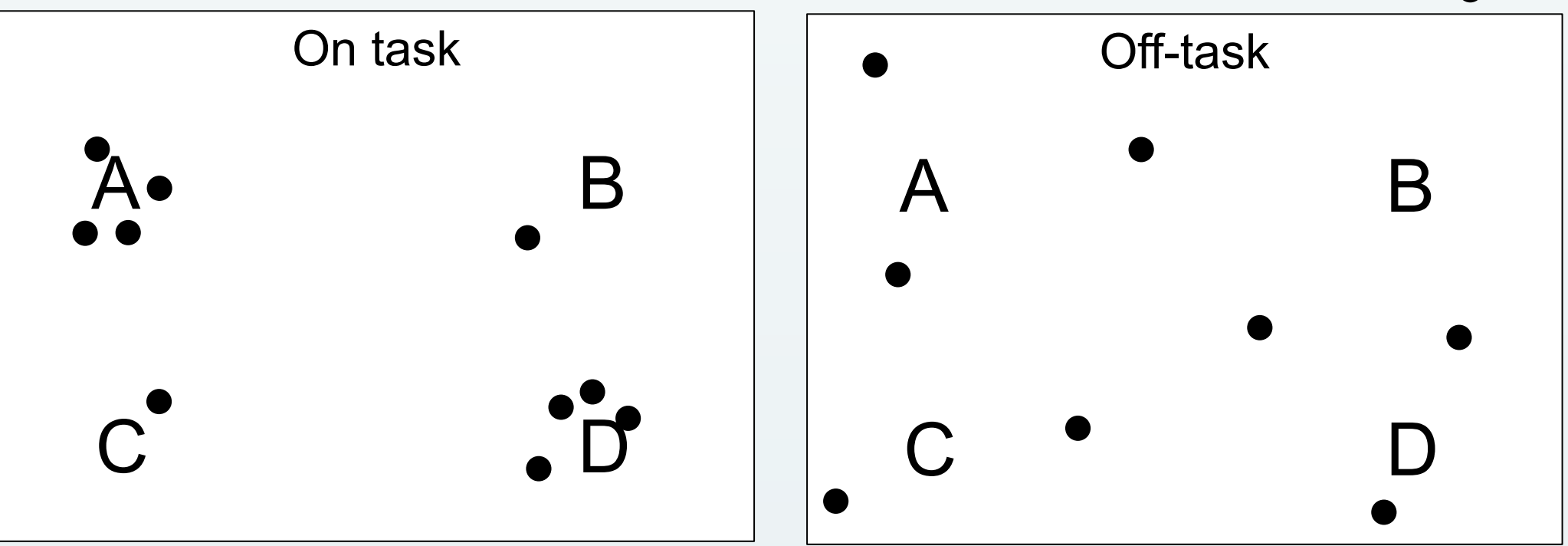

Question 1: Simplify 2a + 7 − 5a − 4

What is the first step?

1) SUBTRACT 7 − 5   2) MOVE +7 RIGHT

3) -5 − 4   4) MOVE -5A RIGHT
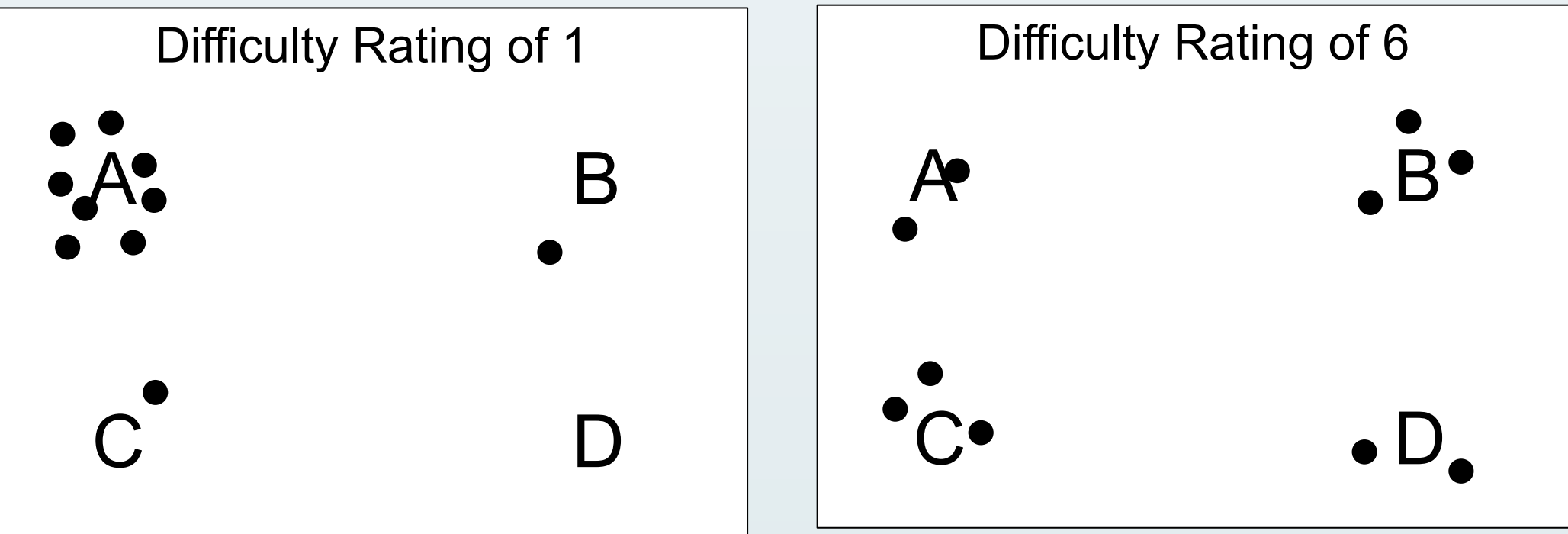
Figure 2. Example task screen

Hypotheses

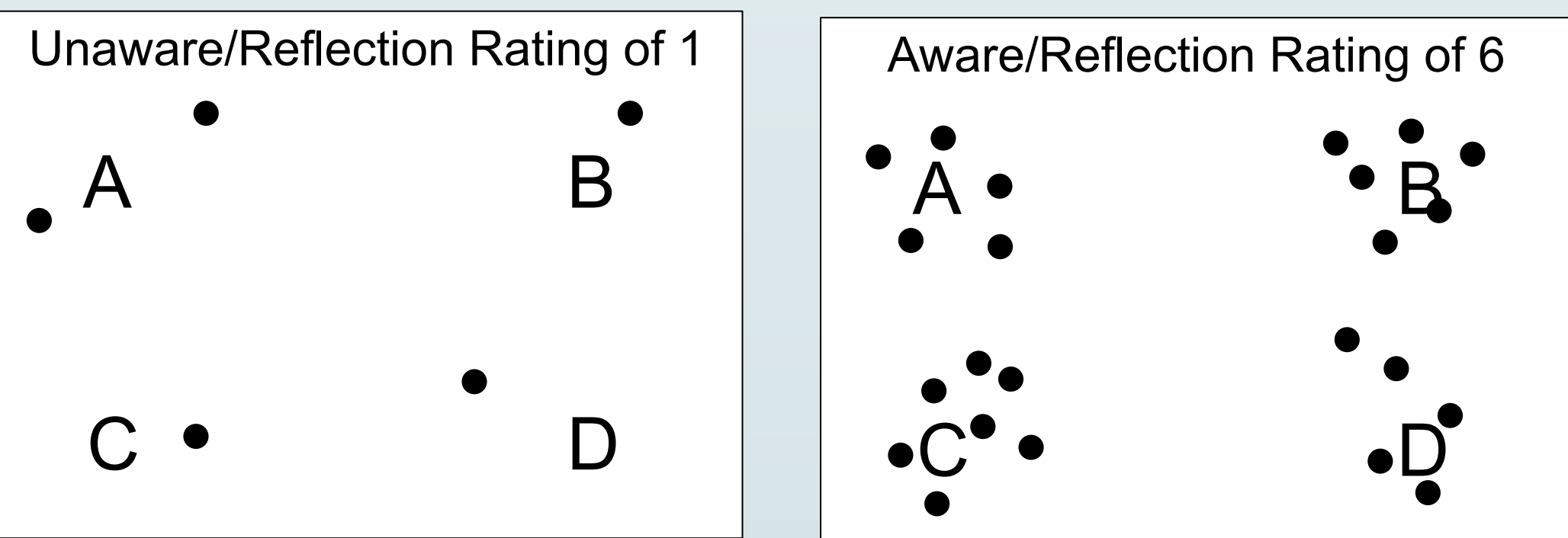- We hypothesize that certain gaze patterns will correspond with certain probe question responses:

Probe question 1: Are you on or off task?

Probe question 2: Rate question difficulty on a scale 1-6

Probe question 3: Are you aware or unaware of your thoughts?
Probe question 4: How much did you engage in reflection on a scale 1- 6?

Preliminary Results

- We tested the calibration of the eye tracker after each trial by directing the gaze to each quadrant of the screen
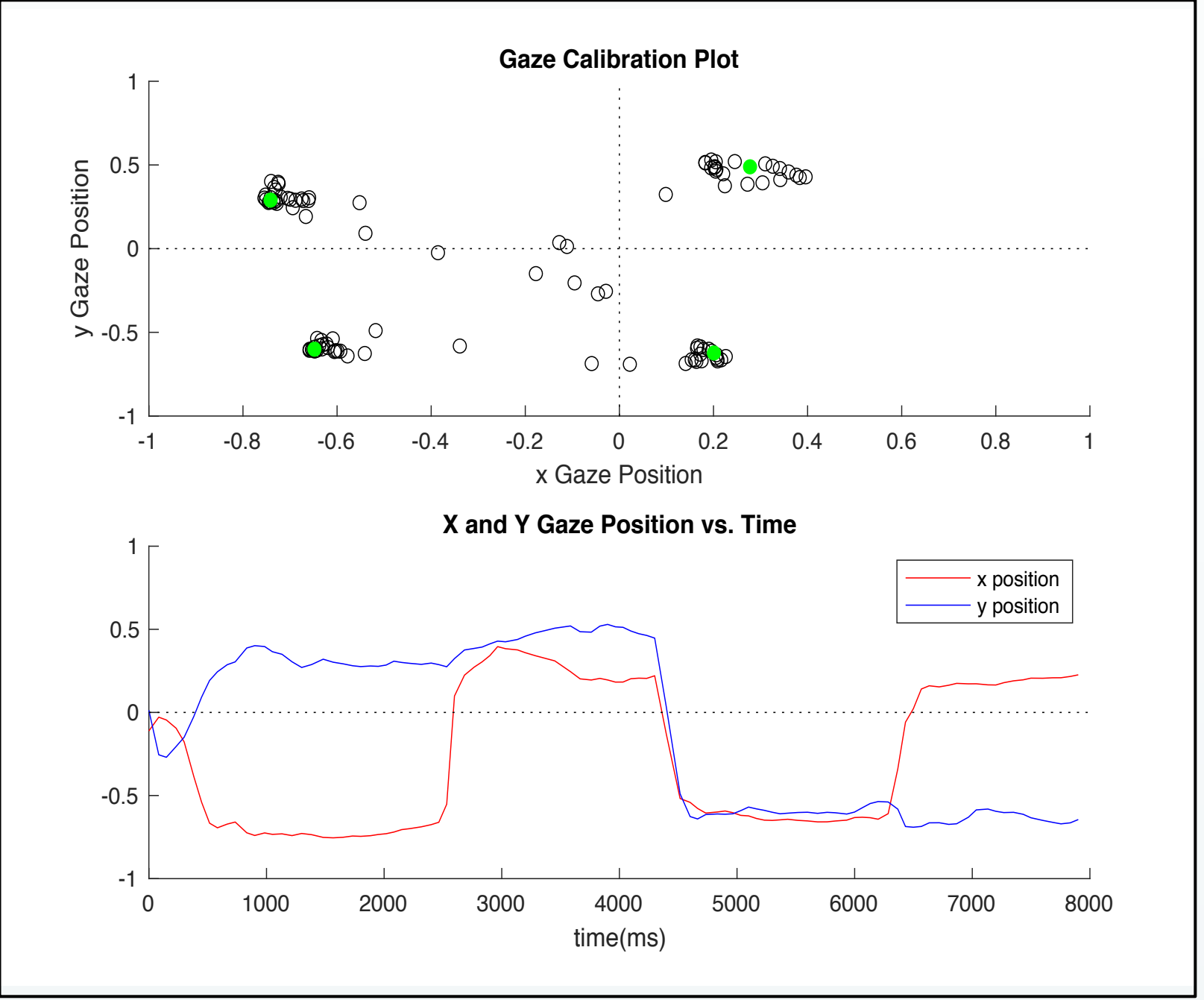- Our plot shows that the gaze tracking is reasonably calibrated throughout a trial

Figure 4. Gaze calibration plot for one trial. The median xy positions for each quadrant (targets) are highlighted in green.

- We were able to get interpretable gaze data that matched our expectations based on probe responses:
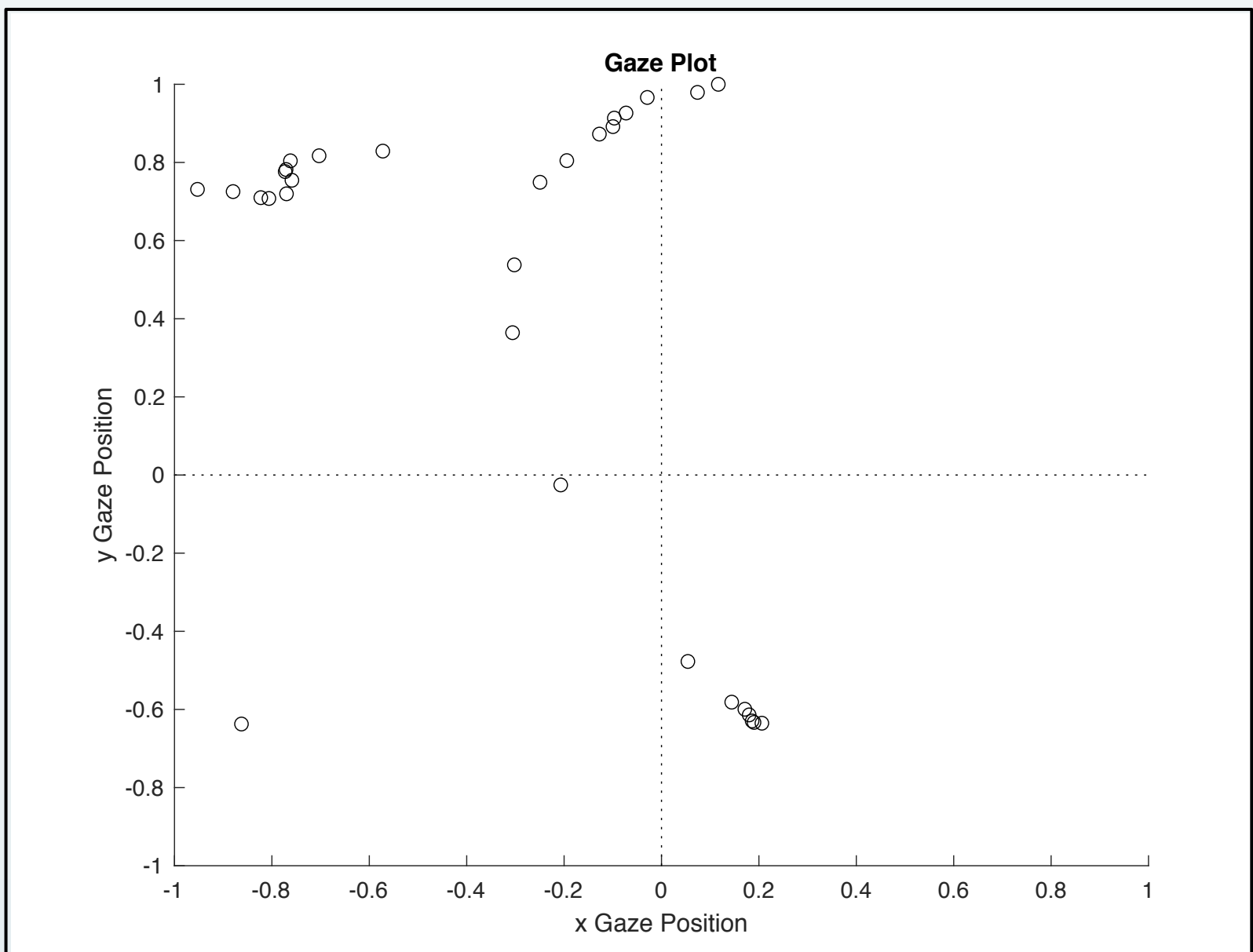

Figure 5. Gaze plot corresponding to a question difficult rating of 1
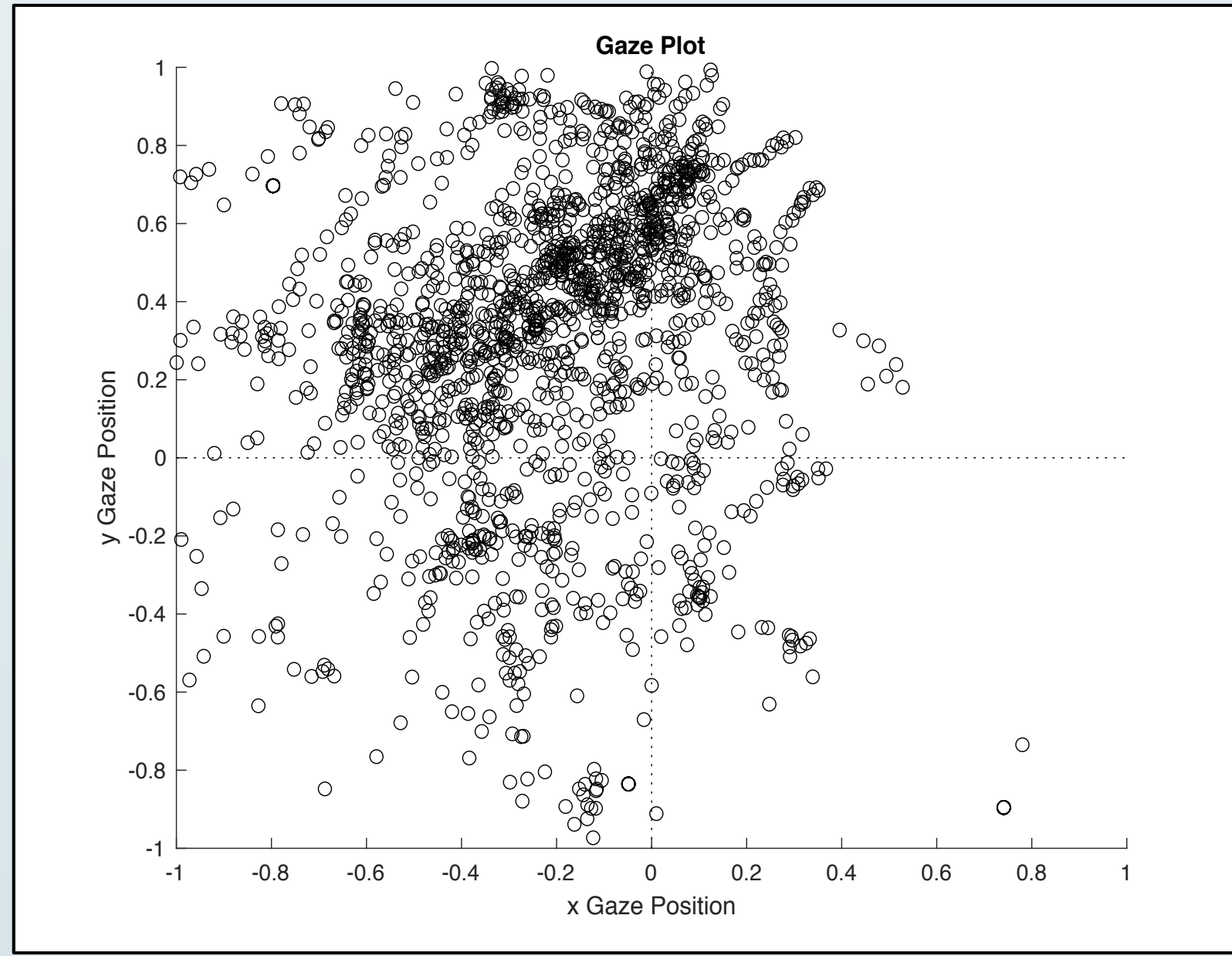

Figure 6. Gaze plot corresponding to a reflection rating of 4

Discussion

These preliminary data suggests that webcam-based eye tracking can collect gaze data reasonably well. The next step in this project will involve determining a metric for how close a participants' gaze pattern is to the gaze calibration "targets". From this we can more accurately determine which multiple-choice option a participant is looking at as well as what fraction of the time a participant is looking at each option. We will also obtain more data to better understand how gaze patterns relate to the probe questions.

Future directions for this project may include incorporating pupillometry into our eye-tracking measures. Measuring changes in pupil size is a useful method for determining changes in neural activity that are linked to cognitive processes such as attention and effort which may be meaningful for our learning task.

Through this eye tracking project, we hope to gain insight into the cognitive processing involved in learning and ultimately devise ways to improve learning in middle school students.

References

1. Yarbus A L. Eye Movements and Vision. New York: Plenum Press; 1967.
2. Liversedge, Simon & Findlay, John. (2000). Saccadic Eye Movements and Cognition. Trends in Cognitive Sciences. 4. 6-14. 10.1016/S1364-6613(99)01418-7.
3. Eckstein MK, Guerra-Carrillo B, Miller Singley AT, Bunge SA. Beyond eye gaze: What else can eyetracking reveal about cognition and cognitive development?. *Dev Cogn Neurosci*. 2017;25:69-91. doi:10.1016/j.dcn.2016.11.001
4. Joshi, S., & Gold, J. I. (2019, December 3). Pupil size as a window on neural substrates of cognition. https://doi.org/10.31234/osf.io/dvsme

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