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www.realeye.io

RealEye Eye-tracking system Technology Whitepaper

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1. Introduction

RealEye (<https://www.realeye.io>) is an online platform designed to conduct screen-based webcam eye-tracking research. Creating studies, gathering the results and analyzing the data is done in the web browser.

To participate in such a study a webcam and internet connection are required. RealEye uses the computing power of a regular PC/laptop to run AI (Deep neural network) that analyzes images coming from a webcam. The AI detects the panelist's face, pupils and predicts a gaze point. Everything is performed entirely in a web browser in real-time. Panelists do not have to worry about their privacy as no image nor sound is sent to servers. The only data stored are the gaze point predictions from the AI in the form of basic text data similar to "Timestamp: 10, GazePointX: 200, GazePointY: 330".

The demo study is available here:

<https://www.realeye.io/test/172d467f-b8bf-45e4-b11a-d2f24f788d12/run>

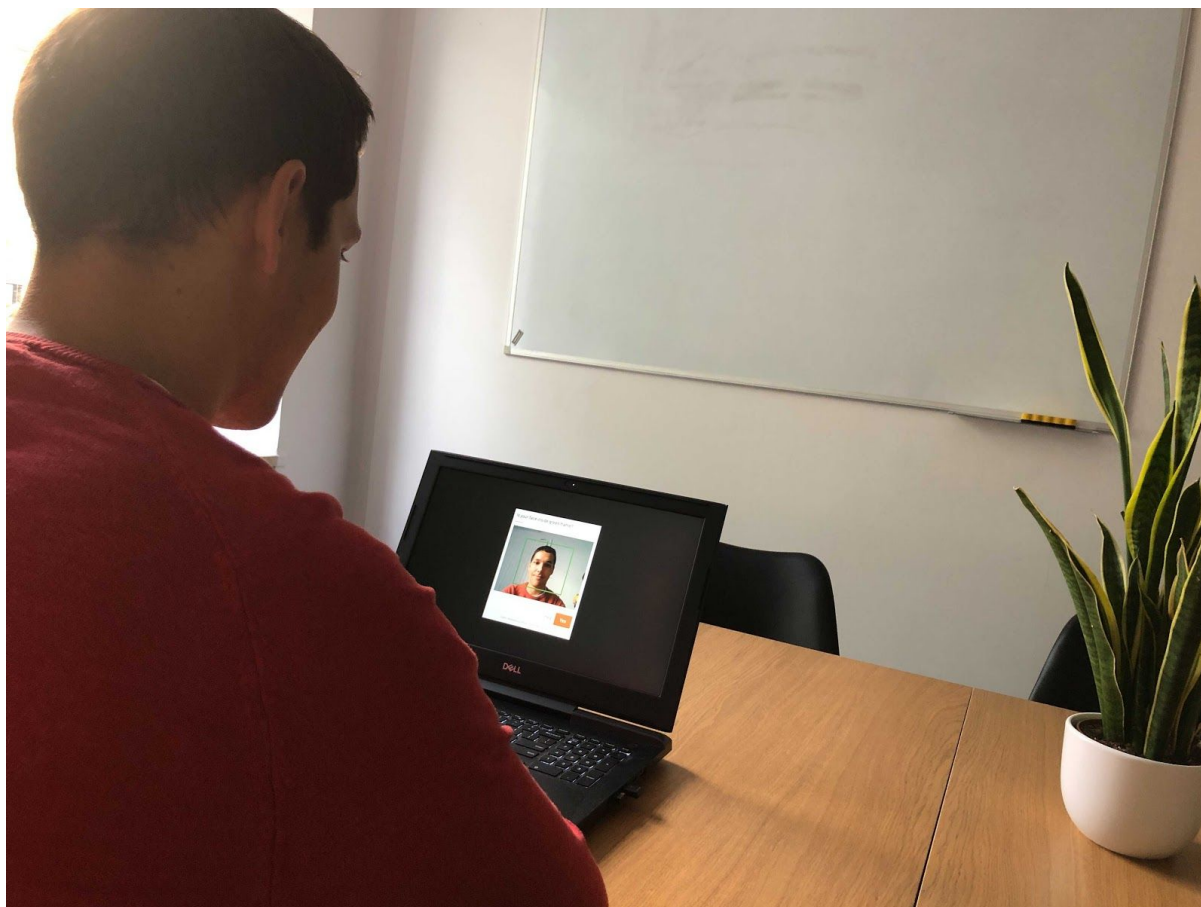


Figure 1: Sample tester environment: Laptop/PC with webcam

The purpose of this paper is to measure the accuracy of the RealEye eye-tracking system in different, realistic conditions, regarding different faces, hardware, lighting (illumination), etc. As the tests were completed on different devices (with various screen resolutions) the best way to make such measurements was to compare the coordinates of a

gaze-point with coordinates of a click-point (a distance between both in pixels) for each of the measuring points. The study was created in a way that can be easily recreated by any RealEye user.

The study was conducted entirely remotely, which is one of the biggest advantages of this tool, but it also makes it impossible to check whether participants followed the instructions properly to gain the best quality. They were not contacted and they had no motivation to complete the task properly, which creates realistic circumstances.

These results were also presented as heatmaps to show that the tool can be successfully used for various third party purposes.

2. Methodology

2.1 Software

Software used in this study was the RealEye eye-tracking tool v6.9 run in a web browser (thus there's no need for users or participants to download anything and the study can be conducted 100% remotely). Tests are done on participants' laptops/PCs using their webcams (test can't be done on mobile devices).

To take part in the study a PC with Microsoft Windows 10 or Mac (Macbook, iMac) with MacOS is required with an integrated webcam or USB webcam. Required screen resolution is 1024x968 pixels or more. Only horizontal screen orientations are supported. Moreover the page can't be zoomed. A Chrome web browser (study done on Chrome version ≥ 85) is recommended (read more: <https://support.realeye.io/how-to-make-a-webcam-to-work/>).

Once the study is created, the researcher needs to send the participation link to all testers.

First, each participant sees the basic instructions and needs to enable the camera access. Then basic instructions are displayed and the 40-points calibration begins. It's conducted on 3 different backgrounds - white, black and grey to minimize the influence of the monitor's light intensity during the eye-tracking test (it differs from the color of the items being displayed). The calibration is then validated on 9 points - only by completing this step participants were allowed to continue the task. Predicted gazes must be no more than 300 pixels away to be validated

Data is captured with a sampling rate of about 30 Hz (depends on a webcam and internet connection). A 60 Hz sampling rate is also possible to obtain (<https://support.realeye.io/webcam-eye-tracking-at-60-hz/>). No image from a webcam is captured or transmitted, the webcam is used only to calculate the eyes positions and stored in the form of basic text data (like the eyes and cursor coordinates, where the top left corner of the screen is (0;0) point).

2.2 Study design

With this software studies based on images, videos or live websites can be created. For the purpose of this project, an image-based study was conducted, as this kind of stimuli is the most commonly used.

In order to measure the accuracy, 35 measuring points (evenly distributed on the screen) were chosen, as shown in Figure 1. Participants were asked to click on each point

(cross) while looking at it, because the accuracy was measured by comparing the predicted eyes position coordinates with the click coordinates.

There was a risk of incorrect execution of commands (not clicking on all the crosses) by the testers, so the test was split into 35 separate boards with only one measuring point (cross) on each board.

Results were captured in whatever environment testers were sitting (most probably in their homes). No methods were employed to ensure that participants followed all instructions and looked at the coordinates requested during clicks, but it was assumed that most participants did so. Samples collected incorrectly were then recognized as gross errors and removed manually.

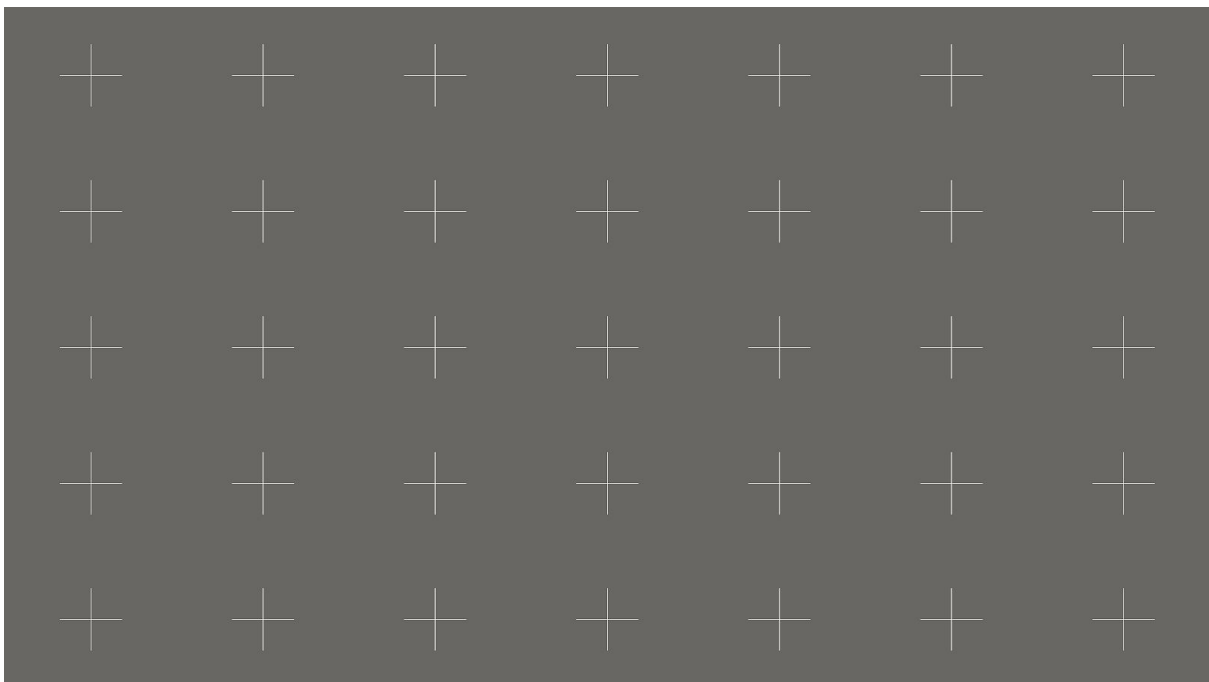


Figure 2. The board presented to participants in the study (each point separately in random order). Participants were asked to click on each cross while looking at it

2.3 Participants

2.3.1 Sample

The study was conducted on 36 participants - RealEye team members, their personal contacts and (mostly) participants hired with a panel provider used by the company. All participants were English - speaking, random people. Most of them (except the team members) had only a basic understanding of the difficulties posed by lighting variation and no

understanding of the computer vision methods used in the software. All results were gathered in different circumstances (device, lightning conditions, head movements, correct execution of the instruction). It can be assumed that these results should be replicable in real-world conditions.

2.3.2 Instructions

Before taking part in this study, all participants saw the following instructions:

In this study, we'll ask you to participate in an eye-tracking session using your webcam. It's an accuracy test, so please, read and follow the instructions carefully:

- *use a desktop device like a laptop,*
- *sit at a comfortable distance from the computer like for normal use,*
- *use Chrome web browser, with only 1 tab open (the one with eye-tracking study),*
- *make sure you have a good quality webcam plugged in,*
- *make a webcam very steady and below your eyes level,*
- *make sure you're in **good lighting conditions - the light source is in front of you and illuminates your face evenly***
- *DO **NOT** wear glasses if possible,*
- *try to **keep your head still during the whole test,***
- ***don't rush through the calibration** (click about 1 dot per second, not faster),*
- *you'll see 35 images with 1 cross on each; **click in the middle of each cross WHILE looking at it,***
- *take your time, the being accurate is the most important,*
- *if you're using a laptop, make sure it's plugged in.*

Don't worry - we don't record anything, we use your camera to calculate eyes position, have fun!

3. Results

3.1 "Gaze vs Click" Accuracy

As mentioned before, the gaze accuracy was measured by comparing the predicted eyes positions with the measured position of the mouse pointer while clicking on each cross. Of course, not all of the participants were looking exactly at the mouse pointer, so the accuracy is probably slightly better than the obtained results indicate.

Raw gaze data were filtered using the moving median algorithm (of the last 10 measurements) to make the results a bit more realistic - a sample obtained while clicking may be collected in a random way, not representing the actual point of where a participant was looking.

No data was removed from the results, even if the participant was moving his/her head or doing the test in poor lighting conditions.

For each measurement point, average accuracy was calculated as shown in the table below:

Table 1. Average accuracy (in px)

103	108	125	100	122	131	129
108	104	106	112	135	151	136
123	108	113	102	115	111	94
127	128	105	101	153	136	116
156	135	120	90	132	108	167

The average accuracy for all measurements equals 113 px.

Then, watching all the gaze recordings, 14 points were assumed to be gross errors and rejected. The assumptions were made if the gaze was located on the cross and then was moving far away from the cross during the clicking process (as shown in Figures 2 and 3).



Figure 3. Low accuracy result accepted - gaze was stable while clicking



Figure 4. Gross error - participant's gaze was moving down while clicking on the cross

After rejecting those gross errors, the average accuracy was calculated again (Table 2.). As you can see, even such big errors (even over 1000 px gaze-click accuracy) haven't influenced much the results, as they weren't a common issue in the study.

Table 2. Average accuracy - rejected gross errors (in px)

103	108	109	100	103	131	121
108	104	106	112	117	130	124
123	108	106	102	115	111	94
127	128	105	101	105	90	116
156	135	120	90	110	108	147

It was also calculated what percentage of the results falls within the given accuracy range (without gross errors). This indicates the utility of the tool in eye-tracking research.

Table 3. Percentage of predictions in the given accuracy range

Accuracy in px	Percentage of predictions
50	19.4
100	50.5
150	75.5
200	88.5
250	94.9
300	97.5
All: 1245	

See the data spreadsheet:

https://docs.google.com/spreadsheets/d/1s4b5dKin_6mDEsNggJAnZs7AKnIYIE8USXII7Umf31c/edit?usp=sharing

Also, for each of the measuring points, the best accuracy obtained was found and presented in Table 3. Note, that for more participants these values could be even smaller and their distribution more similar to the distribution of average values.

Table 4. Best accuracy obtained for each of the measuring points.

5	7	10	8	12	17	11
2	1	15	12	19	20	33
18	15	3	19	13	8	8
11	18	23	5	16	12	13
18	39	24	18	15	11	14


You can see sample results from this study here:

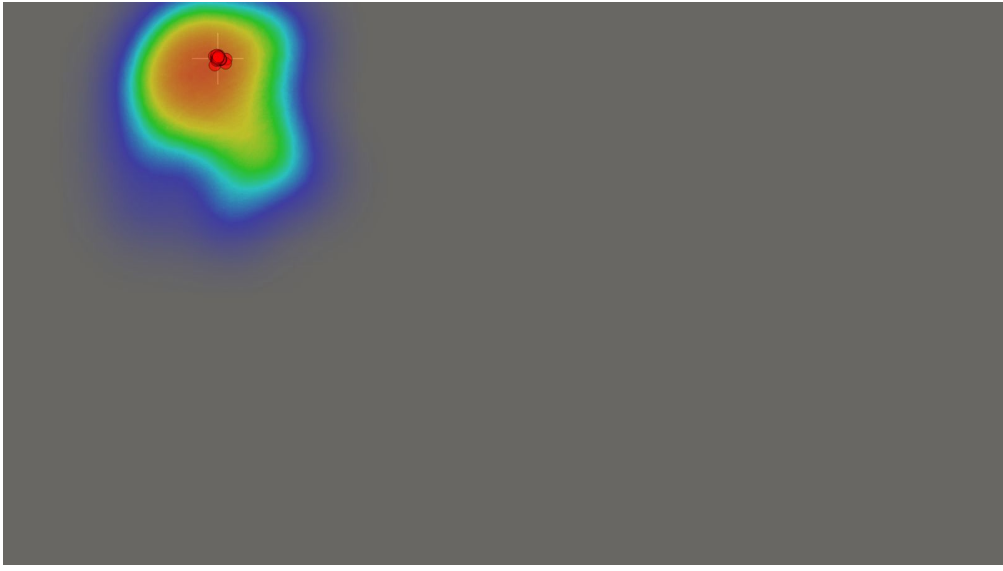
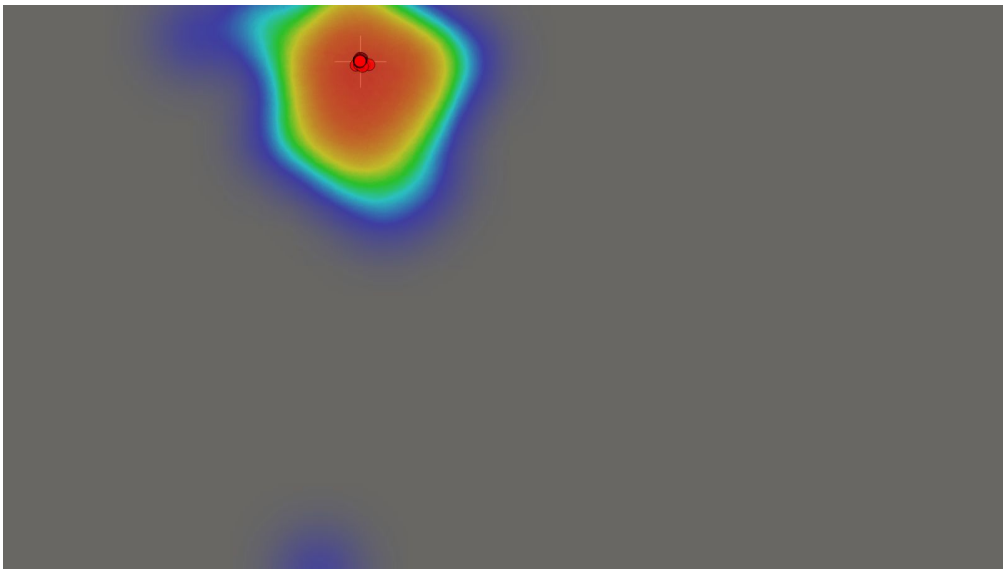
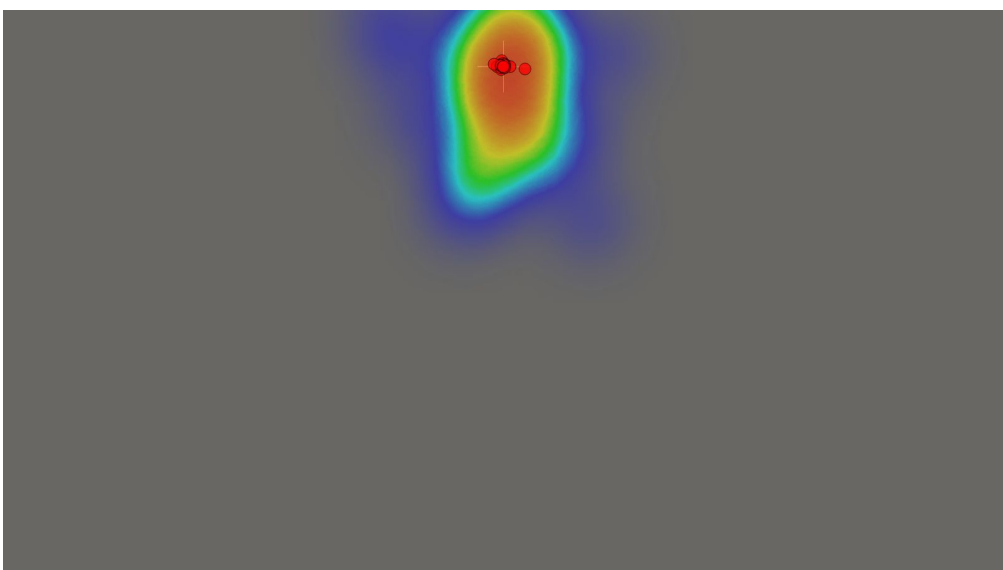
- Sample recording:
<https://www.realeye.io/study/2c766359-344f-4383-9dcb-6315050a07d2/recordings/f9ebd1a9-b7b9-4556-ac90-25e50b27b044/>
- Sample heatmaps:
<https://www.realeye.io/item/85b2f582-3a24-45fd-82ea-141ce8651cc8/>

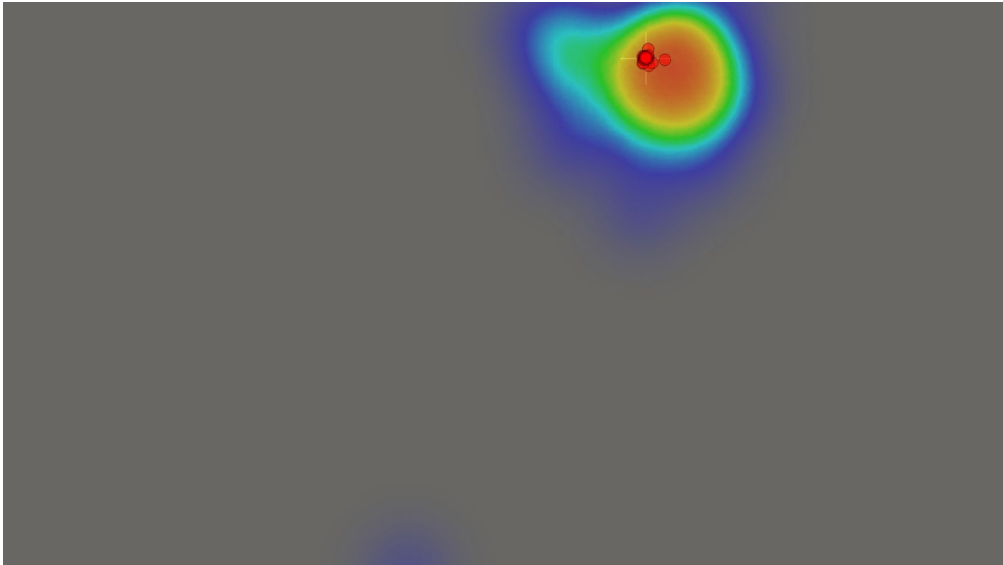
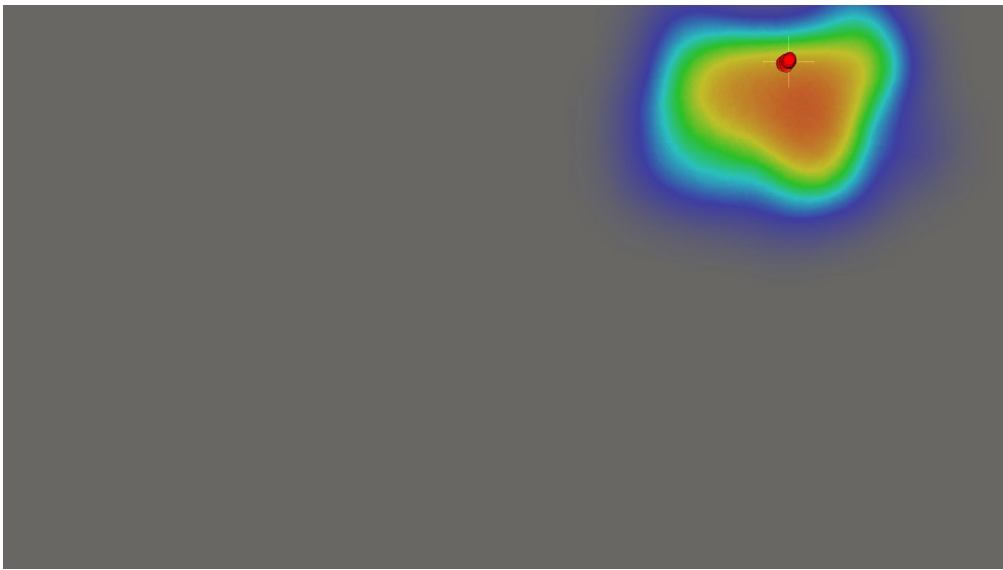

3.2 Accuracy vs heatmaps


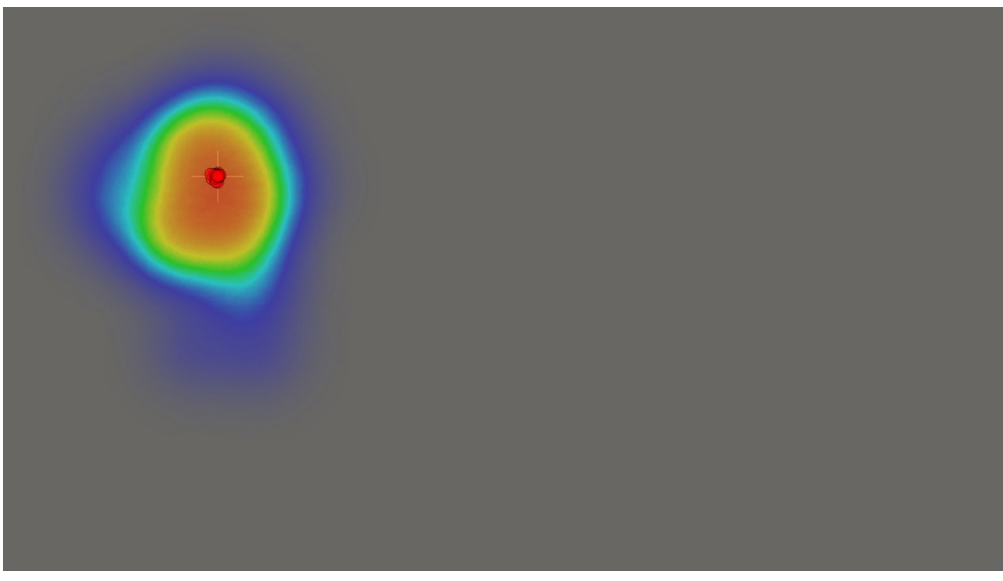
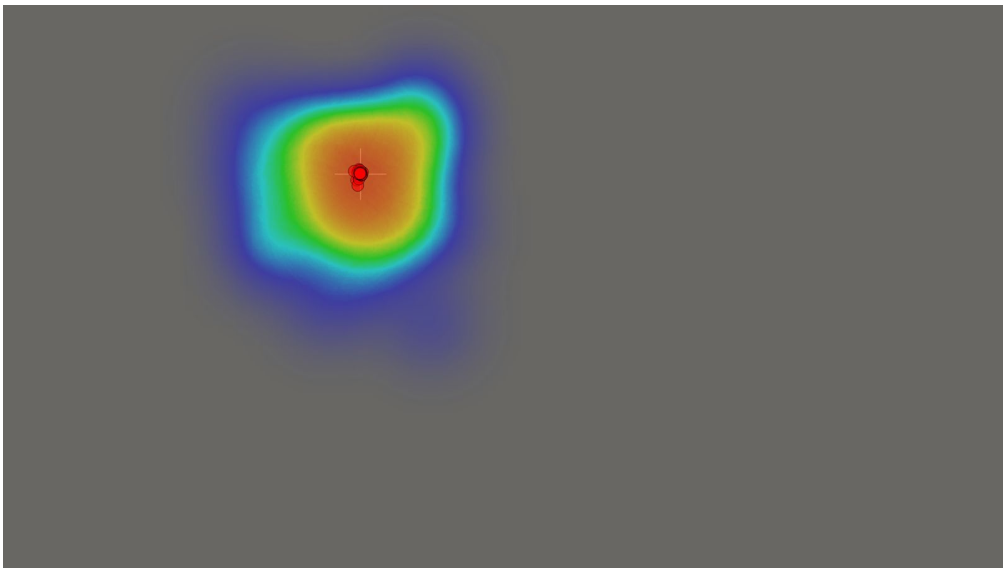
Table 5 represents a comparison of an average accuracy obtained for each point with the aggregated heatmap. Heatmaps were created based on a gaze point collected for all testers in the moment of click (each participant had a different time of noticing each cross). This part shows the visual representation of accuracy. Please remember, that for a larger number of participants the aggregated heatmaps would probably be even more concentrated in the area of each cross.

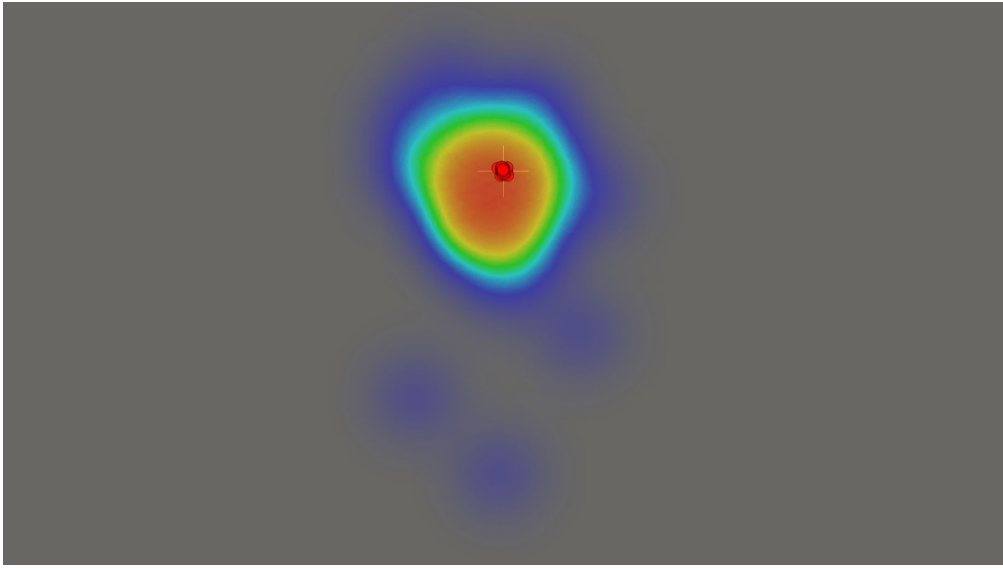
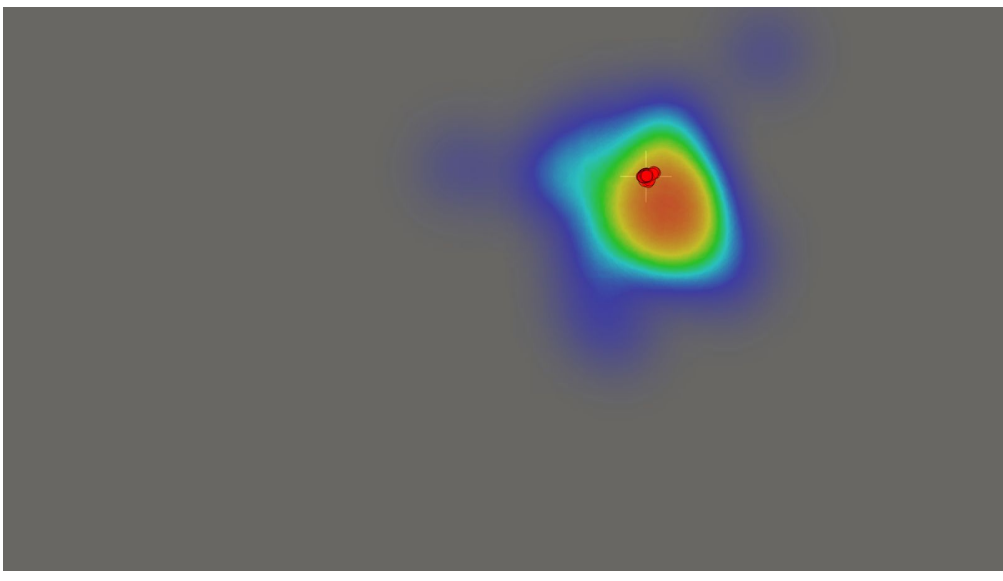
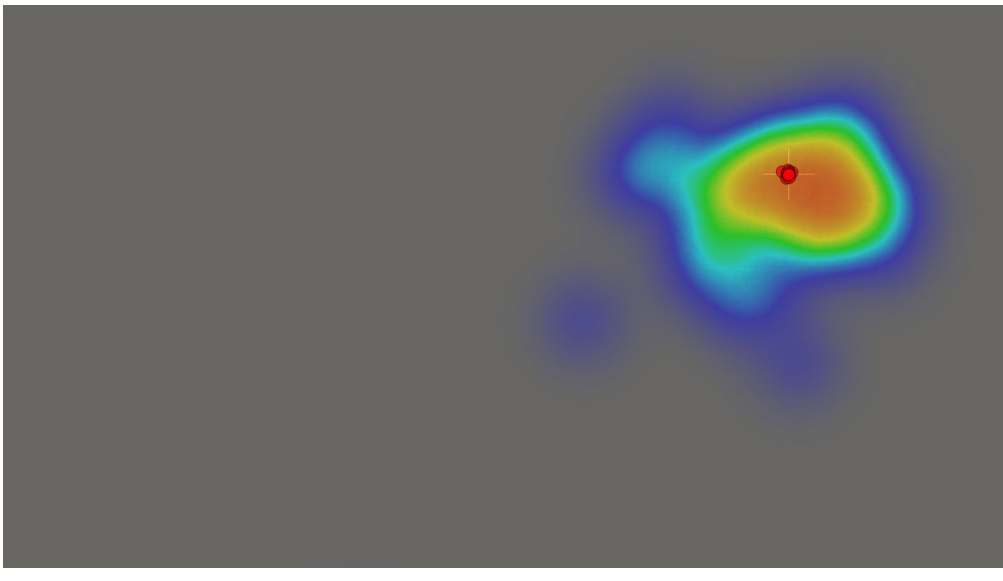
Table 5. Average accuracy obtained for each point and the aggregated heatmap

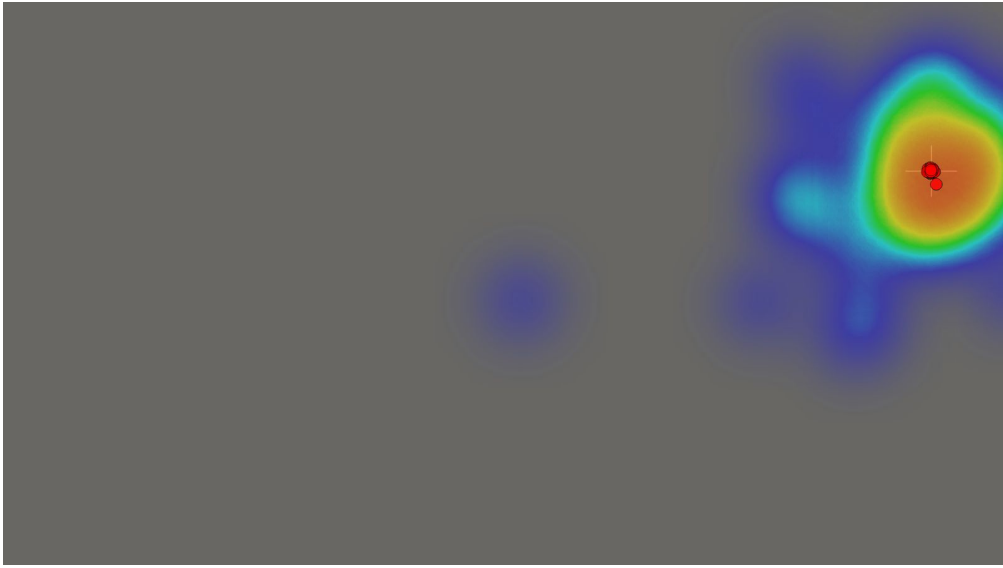
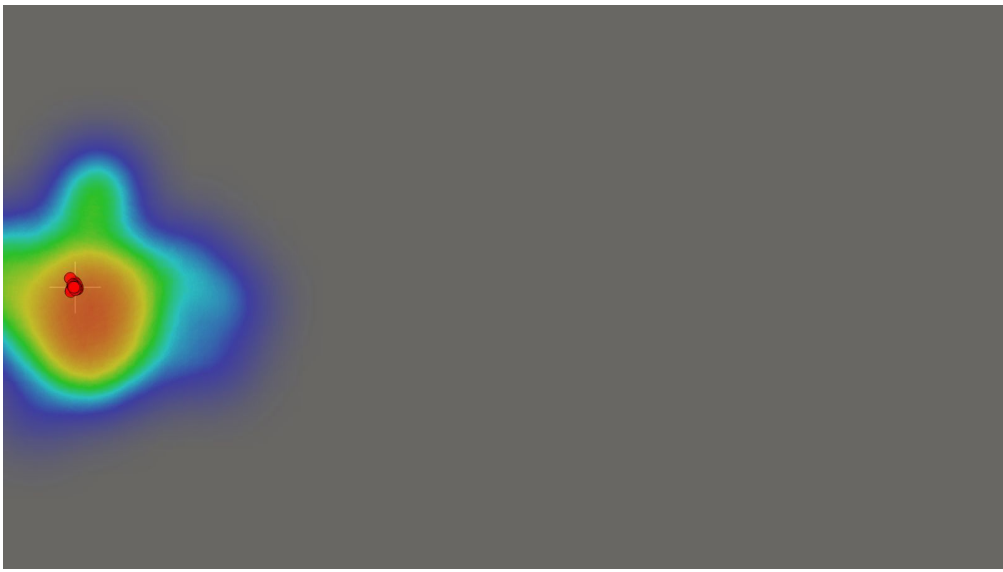
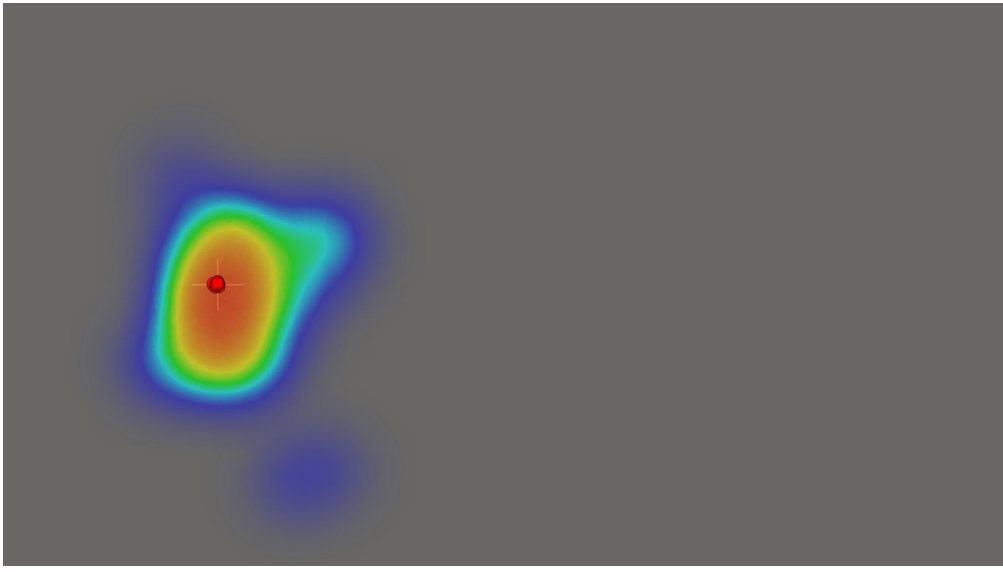
point	Average accuracy	
	px	heatmap (point size ~50px, shadow size ~100 px, opacity ~0.6)
1.	120	

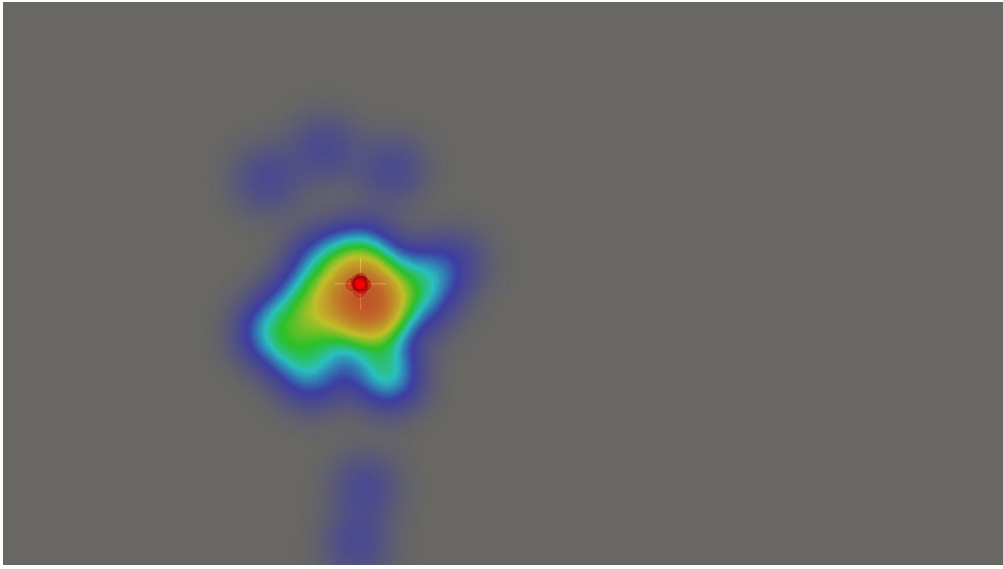
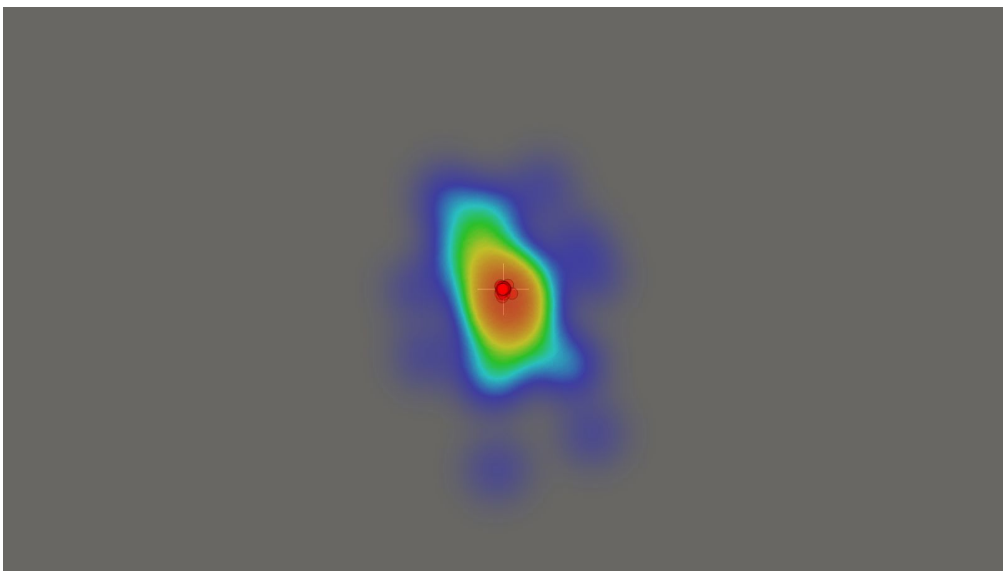
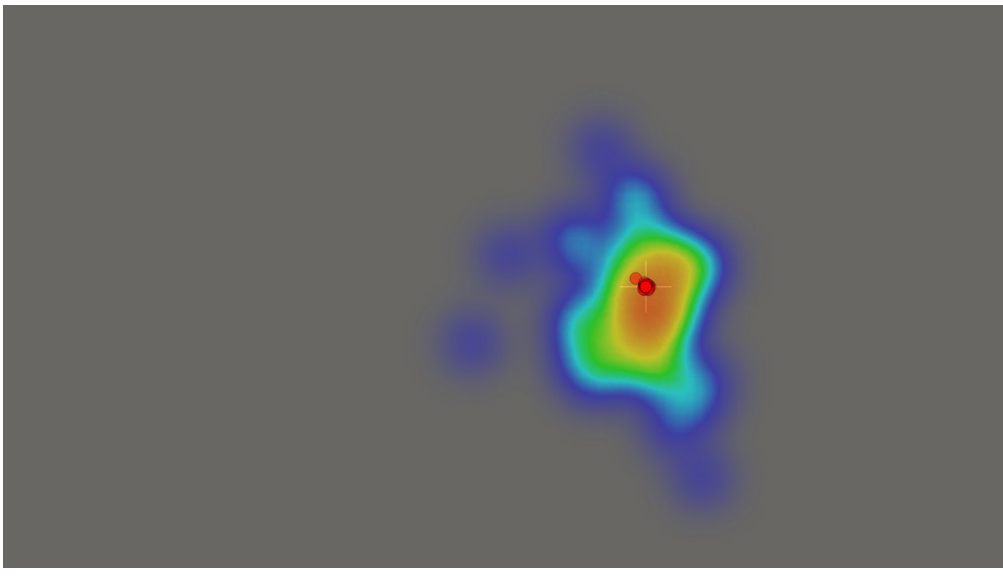
2.	121	 A heatmap visualization on a dark gray background. A single, irregularly shaped peak is located in the upper-left quadrant. The peak's core is red, transitioning through orange and yellow to green and blue at its edges. A small red circle with a white crosshair is centered on the peak's maximum.
3.	124	 A heatmap visualization on a dark gray background. A single, roughly circular peak is located in the upper-middle region. The peak's core is red, transitioning through orange and yellow to green and blue at its edges. A small red circle with a white crosshair is centered on the peak's maximum.
4.	101	 A heatmap visualization on a dark gray background. A primary peak is located in the upper-middle region, similar to case 3.124. It has a red core and transitions through orange and yellow to green and blue. A second, smaller red peak is visible to the right of the primary peak's core. A small red circle with a white crosshair is centered on the primary peak's maximum.

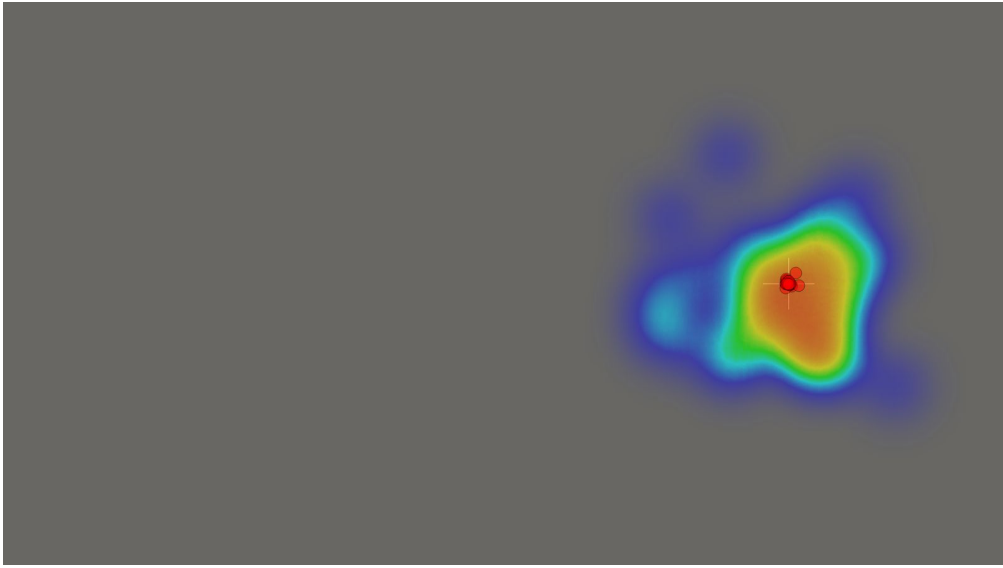


5.	124	
6.	130	
7.	147	

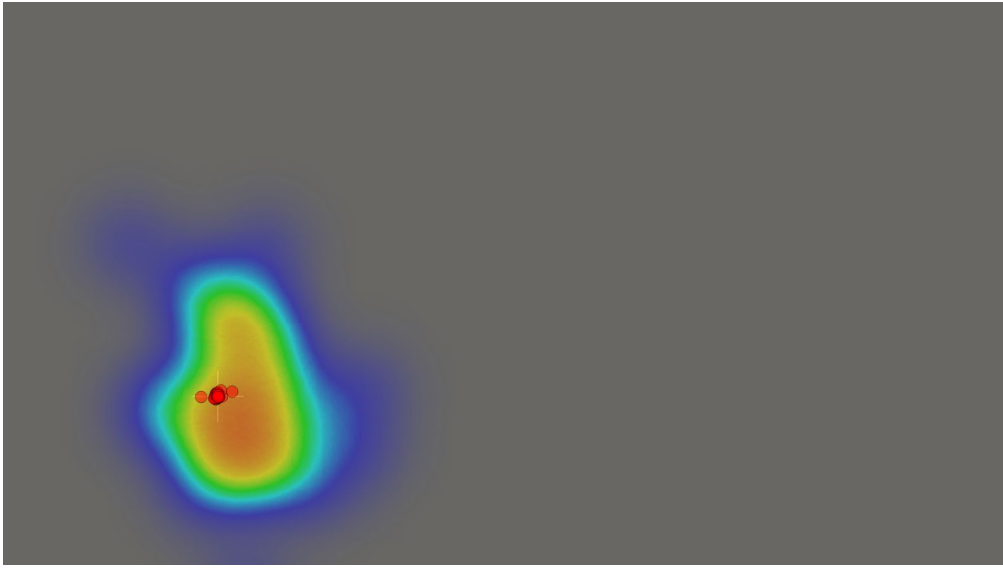
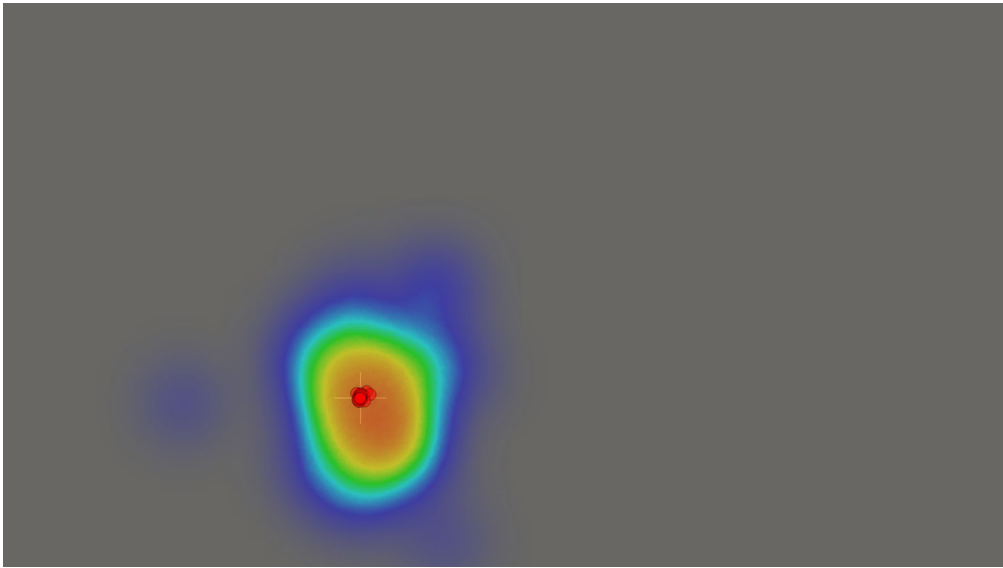
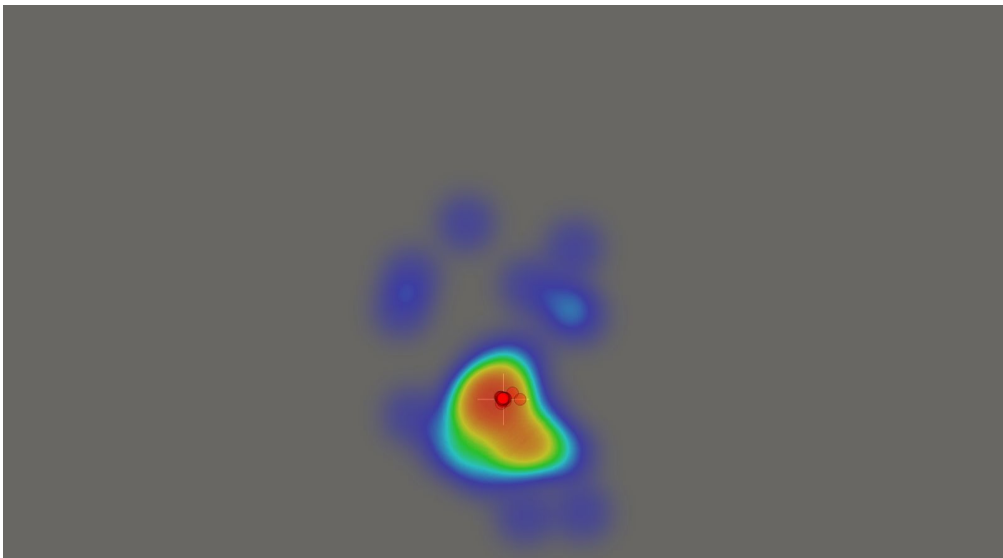
8.	110	 A heatmap visualization on a dark gray background. The central feature is an elongated, vertically-oriented shape. The core of this shape is a bright red circle, surrounded by concentric rings of orange, yellow, and green, fading into a blue outer boundary. The rest of the background is dark gray.
9.	110	 A heatmap visualization on a dark gray background. The central feature is a roughly circular shape. The core is a bright red circle, surrounded by concentric rings of orange, yellow, and green, fading into a blue outer boundary. The rest of the background is dark gray.
10.	110	 A heatmap visualization on a dark gray background. The central feature is a roughly square shape. The core is a bright red circle, surrounded by concentric rings of orange, yellow, and green, fading into a blue outer boundary. The rest of the background is dark gray.

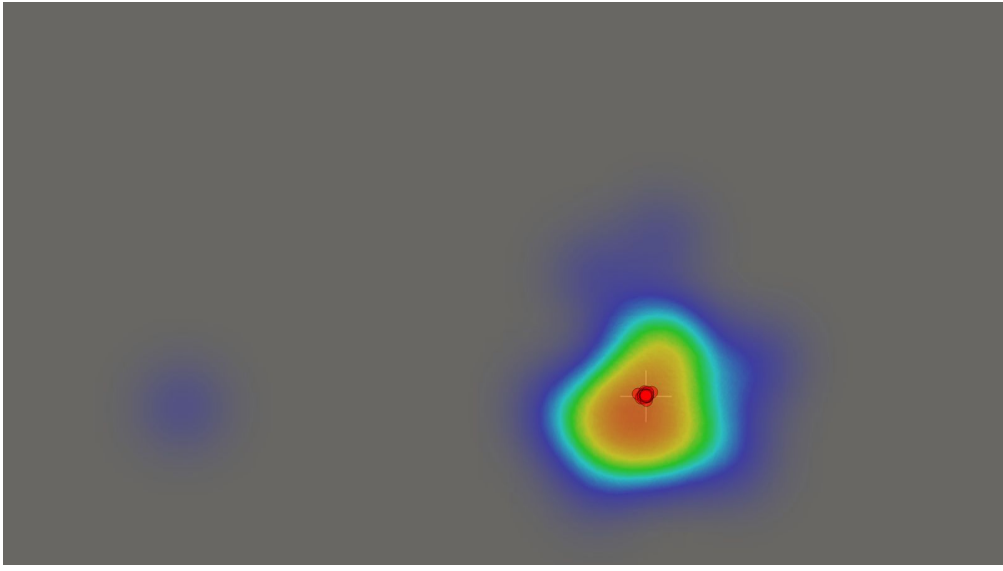
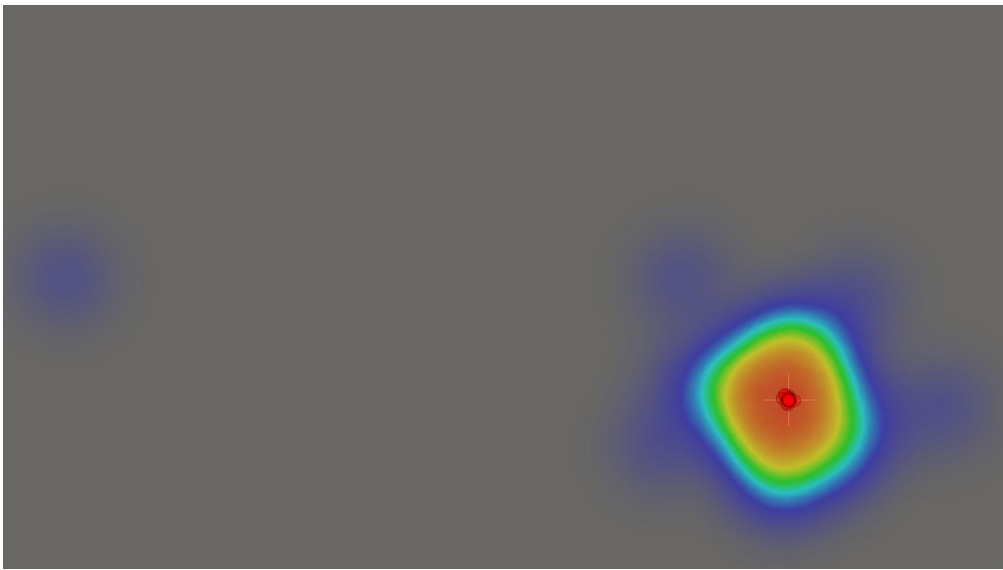

11.	111	 A heatmap visualization on a dark gray background. A single, roughly circular peak is centered in the upper half of the frame. The peak's core is red, transitioning through orange and yellow to a green outer ring, and finally fading into a blue halo. A small red dot with a white crosshair is positioned at the center of the peak.
12.	133	 A heatmap visualization on a dark gray background. A single, roughly circular peak is centered in the middle of the frame. The peak's core is red, transitioning through orange and yellow to a green outer ring, and finally fading into a blue halo. A small red dot with a white crosshair is positioned at the center of the peak.
13.	154	 A heatmap visualization on a dark gray background. A single, roughly circular peak is centered in the lower half of the frame. The peak's core is red, transitioning through orange and yellow to a green outer ring, and finally fading into a blue halo. A small red dot with a white crosshair is positioned at the center of the peak.


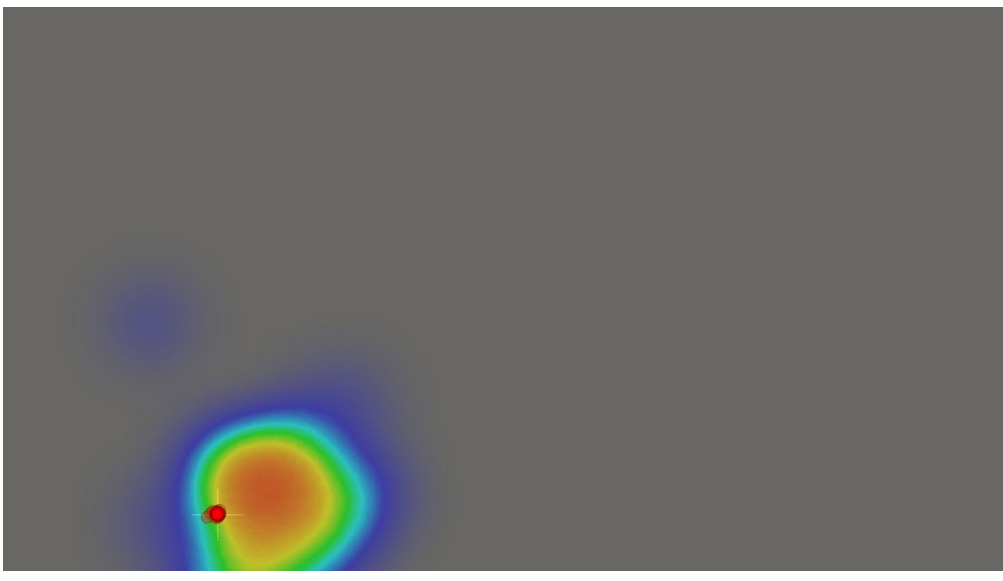
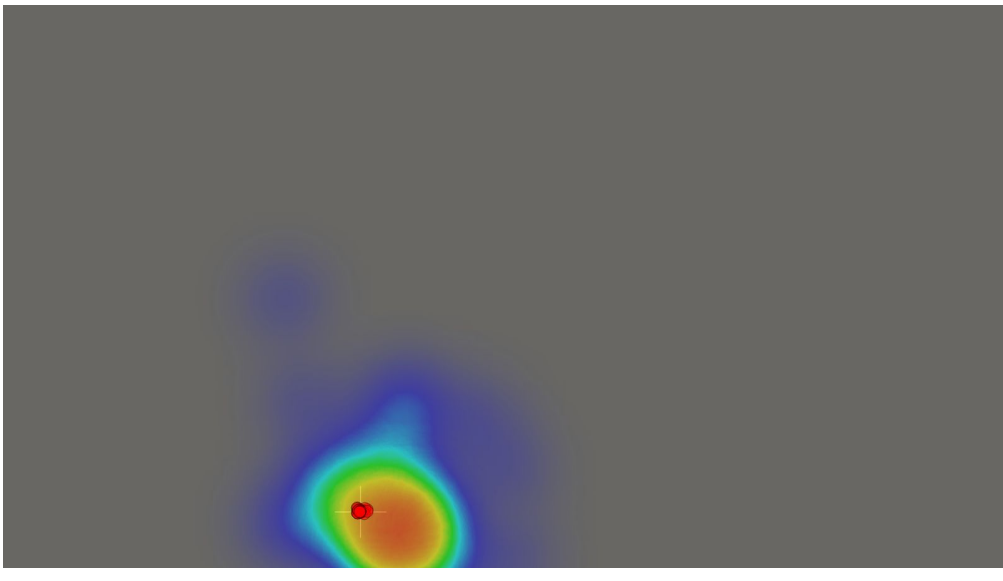
14.	142	
15.	119	
16.	106	

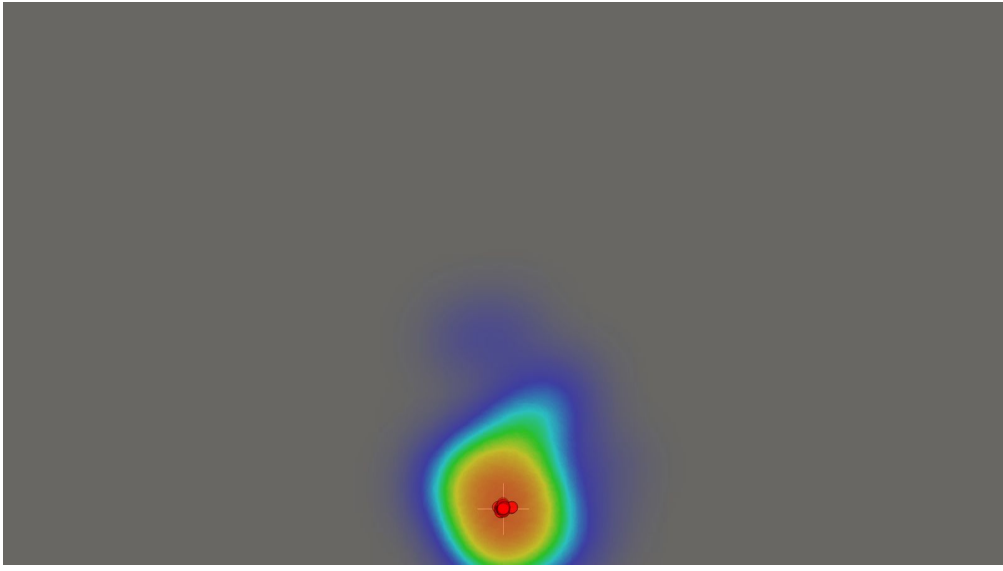
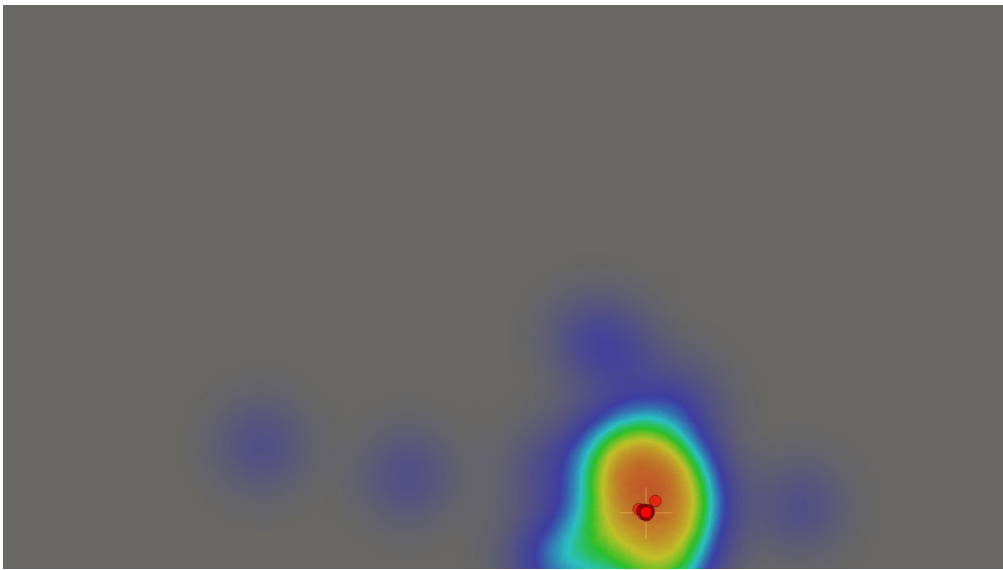
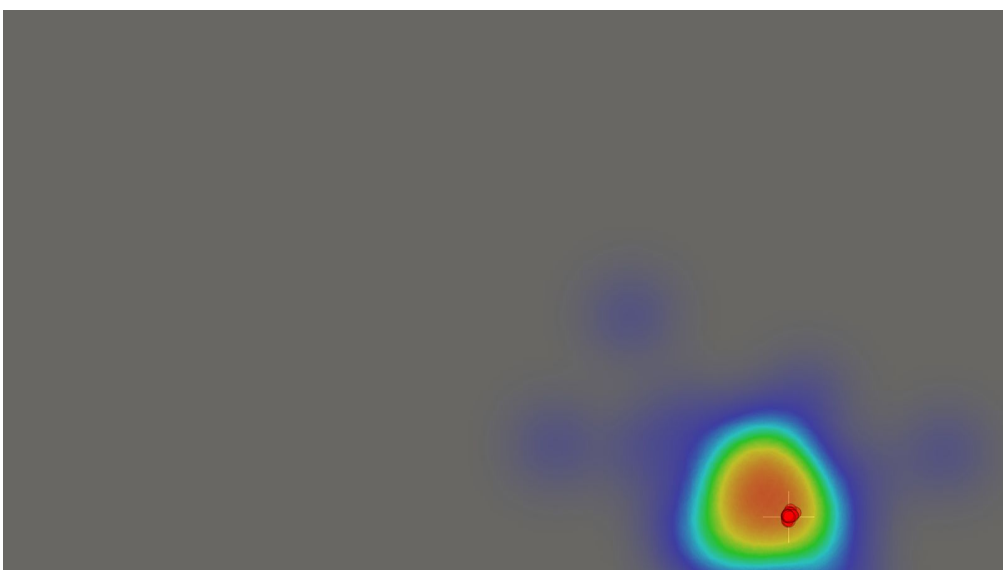
17.	114	 A heatmap visualization on a dark gray background. It features a central, irregularly shaped peak. The peak's core is red, transitioning through orange and yellow to green and blue at the edges. A red crosshair is centered on the peak.
18.	99	 A heatmap visualization on a dark gray background. It features a central, irregularly shaped peak. The peak's core is red, transitioning through orange and yellow to green and blue at the edges. A red crosshair is centered on the peak.
19.	116	 A heatmap visualization on a dark gray background. It features a central, irregularly shaped peak. The peak's core is red, transitioning through orange and yellow to green and blue at the edges. A red crosshair is centered on the peak.

20.	122	 A heatmap visualization on a dark gray background. A primary source is located in the upper right quadrant, marked with a red crosshair. The source is represented by a color gradient from blue (low intensity) to red (high intensity), with a yellow and orange core. A secondary, fainter source is visible to the left of the primary one.
21.	112	 A heatmap visualization on a dark gray background. A primary source is located in the lower right quadrant, marked with a red crosshair. The source is represented by a color gradient from blue (low intensity) to red (high intensity), with a yellow and orange core. A secondary, fainter source is visible to the left of the primary one.
22.	138	 A heatmap visualization on a dark gray background. A primary source is located in the lower left quadrant, marked with a red crosshair. The source is represented by a color gradient from blue (low intensity) to red (high intensity), with a yellow and orange core. A secondary, fainter source is visible to the right of the primary one.

23.	138	 A heatmap visualization on a dark gray background. It features a single, vertically elongated peak. The peak's core is red, transitioning through orange and yellow to a green outer boundary, and finally fading into a blue halo. A red crosshair is positioned at the center of the peak.
24.	107	 A heatmap visualization on a dark gray background. It features a single, roughly circular peak. The peak's core is red, transitioning through orange and yellow to a green outer boundary, and finally fading into a blue halo. A red crosshair is positioned at the center of the peak.
25.	98	 A heatmap visualization on a dark gray background. It features a single, roughly circular peak with a red core, orange and yellow middle, and green outer boundary, fading into a blue halo. A red crosshair is positioned at the center of the peak. Additionally, there are several smaller, faint blue spots scattered around the main peak.

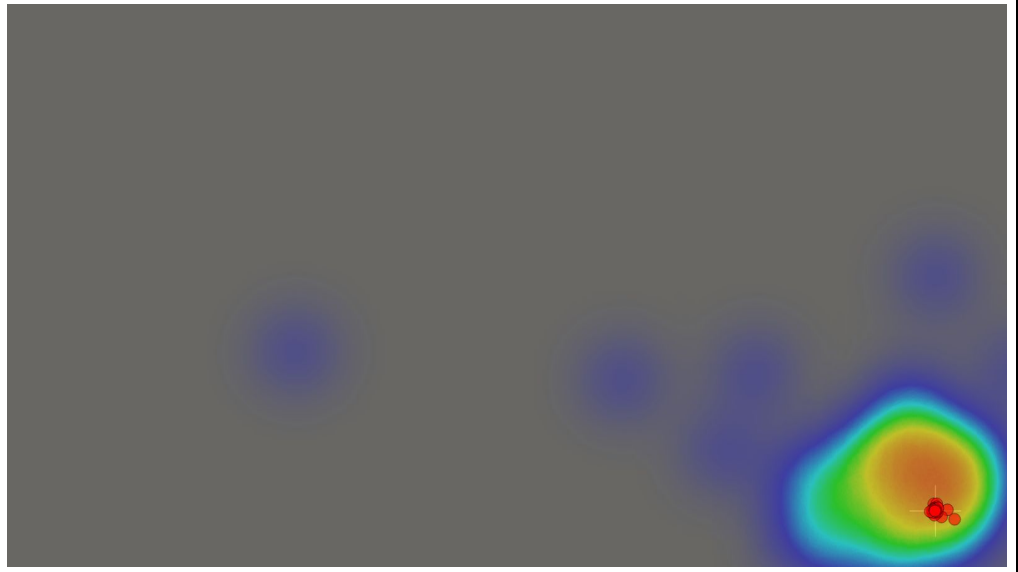
26.	149	 A heatmap visualization on a dark gray background. It features a central, irregularly shaped peak. The peak's core is red, transitioning through orange and yellow to a green outer boundary, and finally fading into a blue halo. A small red crosshair is positioned at the center of the peak.
27.	147	 A heatmap visualization on a dark gray background, similar to the one above. It shows a central peak with a red core, yellow and green intermediate layers, and a blue outer boundary. A red crosshair is centered on the peak.
28.	136	 A heatmap visualization on a dark gray background, similar to the others. It displays a central peak with a red core, yellow and green intermediate layers, and a blue outer boundary. A red crosshair is centered on the peak.

29.	157	 A heatmap visualization on a dark gray background. A primary, bright orange and red circular region is located in the lower-left quadrant. A secondary, much fainter and more diffuse blue region is visible in the lower-right quadrant. A small red dot is positioned at the center of the primary region.
30.	147	 A heatmap visualization on a dark gray background. A primary, bright orange and red circular region is located in the lower-center. A secondary, fainter blue region is visible in the lower-left quadrant. A small red dot is positioned at the center of the primary region.
31.	119	 A heatmap visualization on a dark gray background. A primary, bright orange and red circular region is located in the lower-center. A secondary, fainter blue region is visible in the lower-left quadrant. A small red dot is positioned at the center of the primary region.

32.	95	 A heatmap visualization on a dark gray background. A single, roughly circular peak is centered in the lower half of the frame. The peak's core is red, transitioning through orange and yellow to a green outer ring, and finally fading into a blue halo. A small red dot with a white crosshair is positioned at the center of the peak.
33.	140	 A heatmap visualization on a dark gray background. A single peak is centered in the lower half of the frame, similar in color and structure to the one in row 32. However, there are faint, diffuse blue and green patches scattered across the background, suggesting noise or a less clean environment. A small red dot with a white crosshair is positioned at the center of the peak.
34.	118	 A heatmap visualization on a dark gray background. A single peak is centered in the lower half of the frame, similar in color and structure to the one in row 32. There are faint, diffuse blue and green patches scattered across the background, suggesting noise or a less clean environment. A small red dot with a white crosshair is positioned at the center of the peak.

35.

175



4. Conclusions

The goal of this study was to measure the accuracy of the RealEye eye-tracking online tool. As a result, the following conclusions can be drawn:

- average accuracy is in the range from 90 to 156 px (depends on a place on the screen),
- **average accuracy for all measurements is 113 px,**
- accuracy range for testers (in total) varies from 60 px to over a 200 px,
- the most accurate measurements are made for the middle part of the screen,
- the worst accuracy is obtained in the bottom corners of the screen,
- over half of the results have accuracy up to 100 px (and 75% up to 150 px),
- almost every result contains in the range 0 - 300 px, so we can assume higher values as gross errors,
- gross errors aren't common and don't affect the accuracy,
- results were obtained from different participants (random people without a knowledge about how the technology works or how important it is to follow the instructions) in different environments like devices used, lightning conditions, head movements, etc., so they are realistic.