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Software Engineering Department

Braude College

Capstone Project Phase A

**Research on Dog - Human Communication**

**Using Eye Tracker Technology**

Project code: 24-1-R-15

Supervisors: Dr. Julia Sheidin

Dr. Samah Idrees-Ghazawi

Sara Asaad - [saraasaad5@gmail.com](mailto:saraasaad5@gmail.com)



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Table of Acronyms

|  |  |
| --- | --- |
| Acronym | Meaning or definition |
| AOI | Area of Interest |
| CNN | convolutional neural networks |
| FEIT | Facial Expression Identification Test |
| POI | Point of Interest |
| Tobii Pro Fusion | A screen-based eye tracker captures gaze data at speeds up to 250 Hz. This powerful research system supports everything from fixation to saccade-based analyses. |
| Tobii Pro Lab | Tobii Pro Lab is an eye tracking software for behavior research. |
| TOI | Time of Interest |
| VPT | Visual Processing Therapy |
| VR | virtual reality |

Link to the GIT folder:

https://github.com/SaraAs22/Final-Project..git

# Abstract

# Understanding a dog's emotions is crucial for several reasons, and it plays a significant role in responsible dog ownership. However, which parts of the animal's body or face are more informative to the observer in recognizing emotion is a problem that has not been fully researched. This research project aims to fill the gap by answering the following question: How can eye-tracking technology contribute to a deeper understanding of dogs and strengthen the connection between humans and dogs? To achieve this goal, we aspire to do research that uses eye-tracking technology and tracks the person's gaze for a dog image or video to understand if looking at a certain area improves the understanding of the dog's behavior. In this research, we aim to explore the feasibility of developing a system capable of identifying a dog's emotions through analysis of its movements and facial expressions. Leveraging advancements in image technology and deep learning, this project can provide crucial milestones for the future development of such a system, facilitating thorough preparation and planning of the process.

# 1.Introduction

Animals, and dogs in particular, employ facial expressions and body language to aid in maintaining their social structure with humans [Bloom & Friedman, 2013]. Those facial expressions of emotion offer important visual indicators for understanding others' emotional states and intentions [Guo & Shaw, 2015]. Being able to identify and comprehend a dog’s emotions through areas in their faces or bodies is crucial, since it can improve human communication with them [Eretová et al., 2024].

Dogs play various roles in human life, including companions, rescue, therapy, and medical. Therefore, they have shown remarkable abilities in interpreting human gestures and cues, but understanding dogs' emotions through human-directed visual communication remains limited. Lack of knowledge about breed-specific traits or common dog behaviors can make it difficult to meet a dog's needs effectively.

Previous studies have delved into the emotional facial expressions of dogs, shedding light on their behavior and communication cues [Eretová et al., 2024; Correia‐Caeiro et al., 2023; Bloom & Friedman, 2013]. Moreover, research conducted by Correia-Caeiro et al. 2023 demonstrated that emotional expressions of dogs impact the duration of gaze directed towards particular facial regions in both children and adult humans, as evidenced in their previous study in 2020 [Correia-Caeiro et al., 2023; Correia-Caeiro et al., 2020]. Continuing this trajectory, our aim is to investigate whether individuals' focus on specific regions of a dog's face and/or body helps in comprehending its emotions. Given the challenge of precisely determining which part of the dog's body a person is observing and for how long, we intend to utilize gaze tracking technology for our research in order to understand if looking at a certain area improves the understanding of the dog's behavior. We are aiming to answer the following research question: How can eye-tracking technology contribute to a deeper understanding of dogs and strengthen the connection between humans and dogs?

Our plan involves developing a system equipped with an eye-tracker. This system will present videos and images featuring various breeds of dogs and ascertain the specific body/face areas the observer focuses on, along with the duration of their gaze. We will also explore whether individuals' proficiency in interpreting these signals is influenced by their experience with different dog breeds. The system will present observation results in diverse visual formats to enhance comprehension of the findings.

# 2. Background and Related Work

This section is organized as follows. We first provide a general introduction to the breed-specific differences in dogs. Next, dealing with understanding a dog's emotions, we first review works related to this issue. Since our work examines the contribution of eye-tracking technology to a deeper understanding of dogs and their emotions, we then review relevant earlier work in area of facial reenactment using eye-tracking technology, specifically focusing on humans (since there is no research, that we are aware of, regarding dogs’ facial reenactment).

## 2.1. Breed-Specific Changes Observed in Dogs

Evolutionary changes in facial muscles may enhance affectionate expressions. Modern dog breeds have extreme morphological changes, such as brachycephaly (‘shortened head’ dogs, the appearance of their head looks as if the skull is very compressed from front to back, therefore they appear flat with short noses[[1]](#footnote-1), for example, see Fig. 1) which has negative consequences for dog welfare and health. Brachycephalic dogs may struggle with communication with humans due to their small tails, limited facial expressions, and difficulty in breathing. However, evidence on dog ownership status and the impact of age on recognizing canine cues is limited [Eretová et al., 2024].

  
 **Fig. 1:** Brachycephalic dog. **Fig. 2:** Non-brachycephalic dog.

In the context of brachycephalic dogs, research has specifically examined how their facial structure influences their visual signals and how humans interpret these cues, encompassing both facial expressions and body language. However, it's important to note certain limitations within the existing literature [Eretová et al., 2024]. For instance, some studies may have varied participant demographics in terms of gender and age, potentially impacting the generalizability of the findings. Additionally, certain investigations may not have concentrated on a specific demographic or population subset, and sometimes, people do not report accurately or erroneously about the things they looked at, due to a variety of factors such as subconscious memory or external influences. All these could affect the depth of understanding in this area.

## 2.2. Dog’s Facial Reenactment

**A study provided by [Bloom & Friedman, 2013]** asserted that humans could ascertain emotions in other animals via both their facial and body expressions, using illustrations of a dog to demonstrate this claim.

How they examine:

1. First of all, they examined whether three experts in dog behavior displayed significant concordance when ranking photographs of a dog's face taken under seven behaviorally defined conditions.
2. Secondly, they examined if non-experts could judge these expected emotional states of that dog and identify the emotion under which the photographs were taken.
3. Third, they examined the differences between two groups of humans who had big experience with dogs and those who had little experience with dogs.

For the emotionality ratings, they presented a response sheet listing each basic emotion (i.e., Happy, Sad, Surprise, Disgusted, Angry, and Fearful) accompanied by a Likert-type scale (ranging from 0 indicating “None of this emotion present” to 4 indicating “As much of this emotion as possible is being displayed”). The interviewer asked them to select the correct situation for each of the 21 photographs, given the situations described on the response sheet.

Results:

They stated the expected emotion and the behavioral situation. humans were able to accurately, but not perfectly, identify at least one dog's facial expressions. For example, data from both groups indicated that happiness was easily identifiable by all the human participants (Experienced 92%; Inexperienced 84%) integrated 88%. Percentages and accuracies of correctly categorized situations means that the situation selected by the participant matches the situation the dog was experiencing.

**A study provided by [Eretová et al., 2024]** the study suggests that canine visual signals convey contextual and affective information to humans. However, the development of extreme features through artificial selection, such as brachycephaly, could hinder the efficacy of dogs’ visual signals. The researchers hypothesized that the shortened muzzle region of brachycephalic dogs may affect how human observers decipher a brachycephalic dog’s facial expressions.

What the study examines:

The study examined the ability of humans to interpret the visual signals and facial expressions of extremely brachycephalic (flat-faced) dogs, specifically Boston Terriers, and compared it with a normocephalic breed, Jack Russell Terriers.

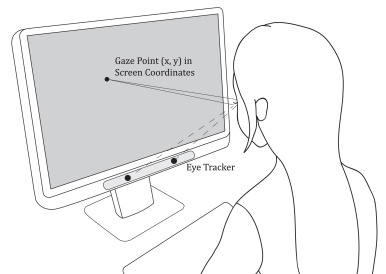
Results:

The study found that accuracy of contextual recognition depended on the type of source. Participants were generally more successful in recognizing ‘positive’ contexts (“Called by name”, “Play”) in the case of Boston Terriers, while ‘negative’ contexts (“Separation”, “Threatened by stranger”) were more likely recognized in the case of Jack Russell Terriers. When comparing the valence of assigned contextual signals, Boston Terriers were more often assigned with ‘positive’ contexts based on video clips than on still pictures. No such difference was found in the Jack Russells. While evaluating the videos and pictures, participants more likely based their decision on the face and tail in case of the Jack Russells, but preferred to use the torso of the Boston Terriers for contextual information.

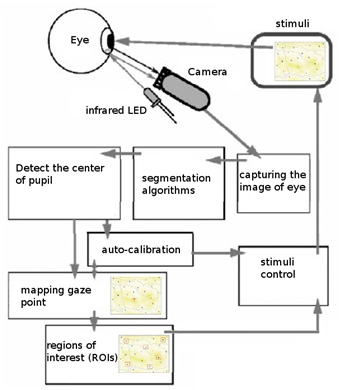
## 2.3. Eye Tracking Technology

Eye tracking technology is a sophisticated research tool that records and analyzes human eye movements, providing valuable insights into facial expressions, communication, and body perception. It is widely used in fields like psychology, neurology, and human-computer interaction, as well as human factors research and marketing. Eye tracking solutions include screen-based methods and wearable devices. However, effective use requires acquiring practical and methodological skills. Overall, eye tracking is a powerful tool for understanding human visual behavior [Majaranta & Bulling, 2014]. For our project, we'll use Tobii Pro Spark[[2]](#footnote-2) using eye-tracking metrics and imaging to gain deeper insights into participants' behavior and visual experiences (for example, see Fig. 3).

The eye-tracking methodology employed an integrated hardware and software approach, comprising an infrared camera to capture eye images, segmentation algorithms to detect the center of the pupil, auto-calibration procedures to map gaze points accurately, and stimulus control to identify regions of interest on the displayed map stimuli (for example, see Fig. 4).



**Fig. 3:** How does the screen-based eye-tracking work [Liu et al., 2021].



**Fig. 4:** Eye-tracking technology architecture.

## 2.4. Facial Reenactment Using Eye-Tracking Technology

We review some existing studies that tested the ability to identify facial expressions:

**A study provided by [Hickson et al., 2019]** describes the challenges of social interaction in VR, where VR masks hide a large part of the face and limit non-verbal communication. The authors present an algorithm that makes it possible to distinguish facial expressions by analyzing images of the user’s eyes, taken using the eye-tracking camera inside the VR mask. The authors also introduce an innovative method for collecting data and improving the CNN accuracy through customization.

The parameters tested in the study are:

1. Fixations - prolonged views on specific areas of the face, such as the eyes, mouth, etc. Check the location, duration and frequency of the fixations.
2. Saccades - the rapid movements of the eye between fixation points. Check the trajectories of the saccades, their speed and accuracy.
3. Scan paths - the total paths of the eye movements across the face during the viewing of the expression. Check the scan path sequences and scan strategies.
4. AOIs - defined areas on the face such as the eyes, mouth, forehead. Check the order of visit, length of stay and return to the same AOIs.
5. Dwell Times - The total amount of time the gaze stayed on different areas of the face.
6. Visit Counts - the number of times the gaze visited different areas of the face.

Results:

The results show an average accuracy of 74% between 5 emotional expressions and an average of 70% between 10 different internal action units.

**A study provided by [Rabadan et al., 2022]** conducted to examine the effect of a face mask on the reaction of the eye and the pupil. The research focused on understanding the effect of the mask on neurological and neurophysiological behavior, such as eye exploration and pupil response.

The parameters tested in the study are:

1. AOIs.
2. The time spent on AOIs.
3. fixation: The article found that the face masks interfered with the ability to perform stable fixation during eye movement tasks. This may affect many processes that require fixation, such as reading.
4. saccades: The findings showed that masks caused disruption and lengthening of the reaction times of saccades between different POI in the environment. The disruption to natural scanning patterns of saccades may affect the ability to scan and track visual stimuli in the environment.
5. Accuracy in eye movements: the article found that the face masks impaired the accuracy of the ability to make saccades to precise visual targets. The results showed undershoot or overshoot of the target with face masks.

Results:

The study reveals that masked faces show different eye exploration than unmasked faces, masked faces had little effect on pupillary response and less exploration of masked areas, but still showed sensitivity to emotion, even with an accessory on the face.

**A study provided by [Ludyga et al., 2023]** examined the effect of aerobic physical activity on facial recognition in children with autism spectrum disorders and found that the disorder caused by facial identification practice is due to the interaction between the physiological state and the learning effect commonly seen for facial structural coding. The study involved 29 participants who completed a 20-minute round of cycling at moderate intensity on an ergometer and control mode.

The parameters tested in the study are:

1. Time of response to the cognitive task of facial recognition.
2. The positive strength of N170 (which is a component of the potential corresponding to the event and pupil size, is measured using electroencephalography).
3. The size of the pupil, measured by eye tracking.

Results:

The results suggest that aerobic physical activity may cause a decrease in the ability to recognize faces in children with autism spectrum disorder, and the results showed an increase in response time and a decline in the positive strength of the N170 component. This indicates that physiological status and facial recognition may collide, which may affect the learning effect for facial structural coding. Eye Tracking tests have demonstrated that autistic children are characterized by a constriction of pupil size in reaction to faces and objects, while non-autistic peers show the opposite effect.

**A study provided by [Iwauchi et al., 2023]** describes a method that utilizes the FEIT eye movements to identify neurodevelopmental disorders.

The parameters tested in the study are:

1. Fixations: Average fixation duration – participants with developmental disorders showed longer fixations, especially on irrelevant areas of the face, Frequency of fixations - Lower rate fixations in disorder groups, Distribution on the inside areas – less focus on key areas such as the eyes and mouth.
2. Saccades: Fewer saccades in the disorder groups, for no distinct differences, the horizontal and vertical saccade are more common in the critical group.
3. Scan path length: The disorder groups showed shorter scan-paths, indicating more restricted eye mobility.
4. AOIs: Looking time – Spend less time on critical areas such as the eyes and mouth, fewer visits to important AOIs, Order of Visits - Different patterns in order of visits in different AOIs.
5. Proportion of viewing time: A smaller portion of the viewing time was devoted to the key areas.
6. Visit count: Fewer “visits” are repeated to key areas among disorder groups.

Results:

Participant groups with developmental disorders exhibited different patterns of eye movements than those of the review group, including longer fixations on less relevant areas, relative ignorance of key areas and a more limited scan of facial expressions. These parameters allowed accurate identification and prediction of the disturbances.

**A study provided by [Bruckert et al., 2023]** Investigates the use of gaze and mouse tracking technology in the context of facial expression recognition. The research focuses on how a person's attention is directed when performing a facial expression recognition task.

The Methodology:

Eye movement data is collected through eye-tracking. Data on mouse movements such as location and clicks were collected. Participants classified their expressions into one of seven categories: anger, disgust, fear, joy, sadness, surprise, and neutral.

Stock includes: files that show the location and timing of eye and mouse movements. Files with participants' answers data on the expressions.

The parameters tested in the study are:

1. Types of fixations that was checked:
   1. duration of fixation - the average continuity of fixations on different areas inside the face (eyes, mouth, etc.) for every expression.
   2. Counting fixations - Count the number of fixations on AOIs such as eyes and mouth, for different expressions.
   3. Distribution fixations – The spatial distribution of the fixations on the face was tested to identify areas that attracted more/less attention to each expression.
2. Types of saccades:
   1. Amplitude saccades - Think of the distances of the saccades between the AOIs to learn about scanning patterns.
   2. Saccades direction - the proportions of horizontal, vertical and diagonal saccades between the expressions were compared.
   3. Speed saccades - tested the speed of the saccades between the different features of the face.
3. Facial features and AOIs:

The study segmented images into AOIs based on six facial features using semantic segmentation models. The distribution of gaze fixations showed significant differences, with eyebrow fixations higher in anger or surprise images.

Results:

The database provides a rich source of data for the study of human behavior and computer vision in the context of facial expressions. It enables the development of methods for analyzing patterns of eye/mouse movements for the identification of expressions.

The study offers an innovative approach to combining eye and mouse movement data for facial expression learning. Significant differences were found in parameters such as the average length of view, the number of clicks and the mouse positions between the different expressions.

**A study provided by [Iwauchi et al., 2023]** used Tobii Pro Fusion and Tobii Pro Lab to analyze eye movements during tasks. Participants sat 65cm from the display, with AOIs set to eyes, mouth, and face for FEIT images. It analyzed eye-movement features, including fixations and saccades, to understand facial emotions.

The parameters tested in the study are:

1. Fixation: It was found that people with higher autistic traits tended to have a shorter fixation on relevant areas of the face. They had more difficulty focusing their gaze for a long time on important points.
2. Saccades: Individuals with autistic traits were different, with fewer saccades to central AOIs and greater deviations from relevant points.
3. Accuracy: The study also found impaired accuracy of eye movements in people with higher levels of autism. They showed more overshoot and undershoot in making saccades to targets and less accurate fixation on important regions of interest.
4. The eye movement path (Scan path): people with higher autistic traits presented different and less efficient scanning paths across the different visual stimuli.
5. Time to AOIs: for people with higher autism, a longer time was needed for the initial arrival of important areas on the face or in the scene.
6. Number of visits to AOIs: people with high autistic traits visited areas critical to performing the tasks less often.
7. Dwell time in AOIs: there was a shorter time of prolonged stay in important areas.

Results:

The study demonstrates that using eye movement during VPT alongside facial emotion identification can enhance the prediction accuracy of autistic traits, suggesting multidimensional evaluation of cognitive activities.

## 2.5. Summary

Although the literature review revealed many studies on different applications of eye-tracking technology and different parameters that were tested, most of them were concerned with human emotion recognition. Hence, there is a need for research focusing on the use of eye-tracking technology to identify the emotions of animals and dogs in particular. This can contribute to a better understanding of the human-dog relationship and improve the human experience with the behavior of dogs.

# 3. Research Process

Our work process on the project began by getting to know the research field "animal-computer interaction" and learning about the relationship between animals and people. As part of the learning process, we participated in an international workshop "New Methods in Dog Behavior"[[3]](#footnote-3) held at the University of Haifa. This international workshop provided opportunities for researchers and practitioners working on dog behavior, cognition and welfare to meet and exchange ideas.

Following the meeting and brainstorming session with Prof. Anna Zamansky, Head of "Tech4Animals"[[4]](#footnote-4) Lab at University of Haifa, we decided to focus on investigating How eye-tracking technology can contribute to a deeper understanding of dogs, and strengthen the connection between humans and dogs? Prof. Anna Zamansky introduced us with the research provided by Czech University of Life Sciences in Prague [Eretová et al., 2024], and then we decided to reproduce their experiment with the addition of the eye tracker technology.

As we delved into the realm of eye-tracking technology, we uncovered a number of works dealing with face and emotion recognition of humans. Next, we checked if there were similar research done in the field of face and emotion recognition of animals in general and dogs in particular. As a result of our learning, we progressed in understanding the dynamics of human-animal interaction, and we began delving into the mechanics of eye tracking systems, such as software applications like Tobii Pro Spark and Tobii Pro Lab, to understand their functionality and potential applications. Next, we defined the methodology we are going to use for our research: a controlled experiment. Consequently, we defined the experiment, including the data set based on the Czech experiment and the gaze tracking technology.

Going forward, we are going to develop a system equipped with an eye-tracker. This system will present videos and images featuring various breeds of dogs and ascertain the specific body/face areas the observer focuses on, along with the duration of their gaze. We will also explore whether individuals' proficiency in interpreting these signals is influenced by their experience with different dog breeds. The system will present observation results in diverse visual formats to enhance comprehension of the findings.

As part of the experimental procedure we will provide a questionnaire, based on previous study from which we draw inspiration. However, the questionnaire needs to be adapted to our needs of using eye-tracking technology. In addition, the questionnaire will need to be translated (to Hebrew (.

Finally, we will analyze the results and examine the conclusions. In order to ensure reliable and accurate results, potential limitations, such as environmental conditions, must be considered and resolved as much as possible. Also, attention should be paid to planning the stages of the experiment, performing them in a planned order using a scientific method, and working on developing protocols and precise instructions for the participants in the experiment.

# 4. Research Methodology

In our research, we plan to duplicate the experiment with the effect of brachycephaly on visual signals in dogs [Eretová et al., 2024] with the addition of eye-tracking technology that will record the participants' eye movements for a dog image. We aim to understand if looking at a certain area improves the understanding of the dog's behavior. Participants (40 Braude College of Engineering students, in an evenly distributed age range, as well as in terms of participants' gender) will be given videos and photographs of brachycephalic and normocephalic dogs in various contexts, with the expectation that these dogs will display behaviors and facial expressions related to their inner states.

## 4.1. Dataset

Our dataset is divided into two sets of pictures and videos from the Eretová et al. [2024] experiment that recorded 23 dog behaviors, with the Boston Terrier representing brachycephalic dogs and the Jack Russell Terrier representing normocephalic dogs.

Dogs were divided into two groups: (1) the initially tested group of 16 Boston Terriers (10 females, 6 males, age range 1.25-6 years, average 3.17 years, standard deviation 1.64); and (2) the second group of 7 Jack Russell Terriers (2 males, 5 females; age range 2-4 years, average 2.75 years, standard deviation 0.96).

The study will produce video clips ranging from 5 to 10 seconds long, showcasing typical dog behaviors in four situations. The images will be altered and cropped to display only the dog's detailed face. The final dataset will be composed of a set of 8 photos and 8 videos, each breed having 4 photos and 4 videos (photo and video for every situation).

Photos of the dog’s face and videos of the whole body include these dogs in one of these four situations:

1. **Situation 1 - Called the dog by his name:** Experimenter 1 called a dog by its name, recorded using a tripod camera, while Experimenter 2 recorded the dog's responses using a hand-held camera.
2. **Situation 2 - Play:** The dog was tasked to play with a tennis ball on a leash, with Experimenter 1 presenting the ball without giving it. Responses were recorded using a tripod and hand-held cameras, ensuring the ball and Experimenter 1 were hidden.
3. **Situation 3 - Separation:** The owners left a dog in an experimental room for a minute examination, with Experimenter 1 present and the dog on a leash, maintaining a minimum distance of 2 meters.
4. **Situation 4 - Threatened by a stranger**: Experimenter 2 threatened the dog, crouching, taking wide steps, and maintaining eye contact. Experimenter 1 captured the photo, keeping Experimenter 2 out, while Experimenter 2 remained silent.

## 4.2. Hypothesis

Here are the hypotheses we want to check based on hypotheses from [Eretová et al., 2024]:

**H1:** People will increasingly rely on different body parts when interpreting the context of interactions with dogs with less informative facial areas.

**H2:** Owners of brachycephalic dogs are more likely to recognize visual cues compared to those of normocephalic dogs due to their experience with such dogs.

**H3:** People will understand normal dogs more compared to brachycephalic dogs.

**H4:** Participants were expected to rate brachycephalic dogs more positively than normocephalic dogs.

**H5:** As participants' age increases, their ability to accurately identify presented situations and assign positive evaluations to samples decreases.

**H6:** Boston Terriers' flat, baby-like faces, particularly their large eyes, would offer a more appealing and informative source of information to viewers.

**Here are our hypotheses for the study**:

**H7:** Participants will spend more time examining brachycephalic dog pictures due to their difficulty in understanding, and less time focusing on areas not understood than on more suggestive ones.

**H8:** Participants will spend more time watching videos of brachycephalic dogs due to difficulty understanding them, with less focus on ununderstood areas and more on suggestive areas.

**H9:** Understanding dogs is expected to be compromised due to factors such as their limited ability to make facial expressions or facial structure distortion, particularly in brachycephalic dogs.

**H10:** It can be expected that high-quality eye-tracking system will provide more accurate and unbiased results compared to self-reported alone. However, integrating both approaches can give a more comprehensive understanding of the subject.

## 4.3. Experimental Parameters

The parameters we want to examine in our experiment, which will assist us in our research, are:

* AOI of photographs [Sæther et al., 2009], including number of visits to AOIs.
* Fixation [Guo & Shaw, 2015; Sæther et al., 2009], including duration of fixation [Guo & Shaw, 2015] and number of fixations.
* Saccades: amplitude saccades (describes the distance the eye moves from point to point), including saccades direction [Sæther et al., 2009].
* Scan paths.
* Proportions of fixations are directed at a specific area of the dog [Sæther et al., 2009] (this gives an indication if focusing on a specific AOI provides a more accurate answer [Eretová et al., 2024]).
* TOI meaning for how long did they look? [Guo & Shaw, 2015].

The selection of the parameters for this study was based on a comprehensive review of previous studies and relevant articles in the field. Special emphasis was placed on locating the most common and accepted indices for examining eye movements and visual coding processes, as these are expected to provide the most reliable and significant data for the needs of the current study. At the same time, it was decided not to include parameters that have been identified as less relevant to the research question and the hypotheses that have been put forward in order to focus efforts on the indicators that are expected to yield the most significant results.

## 4.4. Procedure

The experiments will be conducted in a quiet room, one participant at a time. The participants will be seated in front of a 24-inch screen using a full HD resolution of 1920x1080, about 65 cm from the display. We will use the Tobii Pro Spark with a sampling rate of 120 Hz to show the tasks (for example, see Fig. 3). After a welcome and a brief introduction to the purpose of the study, a short questionnaire containing personal information questions will be administered. Afterwards, the participants will proceed to the next part of the questionnaire, which includes viewing pictures and videos of dogs. They will have to answer for each picture or video in what situation they think the dog is in (called by its name, play, being separated from their owners, or being threatened by a stranger). Furthermore, participants will be required to indicate which areas of the dog's body or face they focused on to discern the dog's emotions and current state. During the viewing, eye analysis of the participants will be conducted using eye tracking technology, which will record eye movements and collect the data that will be utilized to algorithmically estimate a sequence of (x, y) participants gaze point placements on the computer screen [Liu et al., 2021]. Once all the analyses are completed, the results will be saved for each video and image separately.

## 4.5. Results

Eye tracking experiments often use heat maps, a technique for analyzing spatio-temporal data (for example, see Fig. 5). These representations, aggregated over time and based on density, highlight areas of increased participant focus as well as those that received less attention. However, heat maps lack information about the sequential order of visited AOIs or POIs. Despite this, heat maps are still used in eye tracking experiments, even though they don't provide information about the order of fixations [Raschke et al., 2014], because it enables researchers to visually analyze participant gaze patterns and areas in images or videos that receive the most significant visual attention.

We are going to use eye tracker technology in our research because we can receive, automatically comprehensively understand, and analyze more accurate and detailed insights about the eye activity of the participant watching the pictures or videos that we will show them in the questionnaire. Using this technology allows us to use a more efficient and accurate method of investigation.

A screenshot of a computer

Description automatically generated

**Fig. 5:** Image of a heat map as an output for an eye tracker.

# 5. Future Work

Based on the elements of our research and our hypotheses, there's potential to develop a future system that will efficiently and accurately identify the emotions and moods of dogs:

1. Hypotheses as a Source for Building: Hypotheses based on research can serve as a source of inspiration and guidelines for the planning and construction of the system. According to these hypotheses, we can develop algorithms and data processing procedures necessary for identifying the emotions and mood of the dog.

2. Influence on System Construction: Hypotheses can influence the design of the system and the selection of technologies and programming options. For example, if the hypotheses encourage training based on concise data, it is possible that we will choose to use machine learning algorithms to tailor the system to these data.

3. Analysis of Results: The results obtained from the research can serve as a starting point for further analysis of the data and future development of the system. These results can provide new ideas for improving and advancing the system.

4. Learning from Data (Machine Learning): The parameters collected in the research can be used as input for machine learning algorithms. Based on these data, it is possible to develop learning models that can identify and analyze the emotions of the dog using classification processes.

5. Considering the Whole Body: To ensure that the system accurately identifies the emotions and mood of the dog, it is necessary to consider the entire body and not just its face. Thus, we can use additional data, such as movements, gestures, and general behaviors of the dog, to identify its emotional state.

This system would generate outputs based on the four different scenarios discussed in our research.

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