Slovak University of Technology in Bratislava
Faculty of Informatics and Information Technologies

FIIT-16768-110867

Matej Pakán

User interface for working with eye-tracker data

Bachelor's thesis

Supervisor: Ing. Miroslav Laco, PhD.

May 2023

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Degree course: Informatics

Field of study: Informatics

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BACHELOR THESIS TOPIC

Student:	**Matej Pakán**
Student's ID:	110867
Study programme:	Informatics
Study field:	Computer Science
Thesis supervisor:	Ing. Miroslav Laco
Head of department:	Ing. Katarína Jelemenská, PhD.

Topic: **User interface for working with data outputs from the eye-tracker**

Language of thesis: English

Specification of Assignment:

Sledovanie pohľadu (angl. eyetracking) je výskumnou metódou pre analýzu ľudskej vizuálnej pozornosti napríklad za účelom medicínskej diagnostiky. Návrh a implementácia používateľského rozhrania pre prácu s dátami zo sledovača pohľadu je komplexnou výzvou z hľadiska návrhu používateľského zážitku. Existujúce riešenia sú často ťažkopádne na použitie a neúmerne finančne nákladné. Otvorenou výzvou je interpretácia a vizualizácia týchto dát špecialistovi prostredníctvom používateľského rozhrania tak, aby bola práca s nimi jednoduchá a zároveň pre lekára príjemná. Analyzujte existujúce aplikácie, ktoré sú používané na prácu s dátami zo sledovača pohľadu. Zamerajte sa tiež na možnosti vyhodnocovania používateľského zážitku v tejto doméne so špecialistom, prípadne s jeho náhradou vo forme laika. Na základe analýzy navrhnite vhodné používateľské rozhranie pre prácu s dátami zo sledovača pohľadu a riešenie implementujte. Vaše riešenie overte štúdiou použiteľnosti so zameraním na vyhodnotenie používateľského zážitku. Dosiahnuté výsledky kriticky zhodnoťte a porovnajte s existujúcimi riešeniami.

Length of thesis: 40

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Assignment of Bachelor thesis approved by:	doc. Ing. Valentino Vranić, PhD. – study programme supervisor

I honestly declare that I prepared this work independently under the guidance of Ing. Miroslav Laco, PhD., based on consultations and using the literature in the bibliography.

In Bratislava, 22.05.2023

Matej Pakán

Acknowledgment

I would like to thank my supervisor Ing. Miroslav Laco, PhD. for his expertise, advice, tolerance and patience, which he very willingly offered me in solving this bachelor's thesis. . . .

Annotation

Slovak University of Technology Bratislava
Faculty of Informatics and Information Technologies
Degree Course: Informatics

Author: Matej Pakán
Bachelor Thesis: User interface for working with eye-tracker data
Supervisor: Ing. Miroslav Laco, PhD.
May 2023

In the field of user experience (UX) design, eye tracking can be used to identify areas of a website or application that are receiving a lot of attention from users, as well as areas that are being ignored or overlooked. This data can be used to inform design choices, such as moving critical parts of the user interface to locations where it is more likely to be viewed or rethinking interface elements that aren't being properly utilized. Research of UX combined with eye-tracking can also be used to test the usability of a website or application and to assess the efficacy of various design layouts. Designers can find and address issues that might be impeding a good user experience by studying how consumers interact with a product.

The goal of the user interface of an application to work with eye-tracking data is to make it easy for researchers to work with large datasets and extract meaningful insights from the data, without the need for specialized technical expertise. The user interface also aims to improve the efficiency and accuracy of data analysis. Overall, the user interface for working with eye-tracking data is an essential tool for researchers in the field of eye-tracking and has the potential to advance the understanding of human visual attention and cognition.

Anotácia

Slovenská technická univerzita v Bratislave
Fakulta informatiky a informačných technológií
Študijný program: Informatika

Autor: Matej Pakán

Bakalárska práca: Používateľské rozhranie pre prácu s dátami zo sledovača pohľadu
Vedúci bakalárskej práce: Ing. Miroslav Laco, PhD.
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V oblasti dizajnu používateľskej skúsenosti (UX) možno sledovanie očí použiť na identifikáciu oblastí webovej stránky alebo aplikácie, ktorým sa venuje veľká pozornosť používateľov, ako aj oblastí, ktoré sú ignorované alebo prehliadané. Tieto údaje sa môžu použiť na identifikáciu možností návrhu, ako je napríklad presun kľúčových údajov na miesta zobrazenia, kde je pravdepodobnejšie, že nebudú prehliadnuté, alebo prehodnotenie prvkov rozhrania, ktoré sú nesprávne využívané. Výskum UX a sledovanie možno použiť aj na testovanie použiteľnosti webovej stránky alebo aplikácie a na posúdenie účinnosti rôznych dizajnových rozložení. Dizajnéri môžu nájsť a riešiť problémy, ktoré by mohli brániť dobrej používateľskej skúsenosti tým, že študujú, ako používatelia interagujú s produktom.

Cieľom používateľského rozhrania aplikácie na prácu s dátami zo sledovača pohľadov je uľahčiť výskumníkom prácu s údajmi a získavať z nich zmysluplné výstupy bez potreby špecializovaných znalostí. Správne implementovanie používateľského rozhrania pre prácu s údajmi zo sledovača očí má potenciál posunúť pochopenie ľudskej vizuálnej pozornosti a vedomia.

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List of abbreviations

UX - User Experience

HCI - Human-Computer Interaction

HCD - Human-Centered Design

GUI - Graphical User Interface

AOI - Area of Interest

SLR - Systematic Literature Review

TOI - Time of Interest

Lo-Fi - Low-Fidelity

Hi-Fi - High-Fidelity

HTML - HyperText Markup Language

CSS - Cascading Style Sheets

SCSS - Sassy Cascading Style Sheets

JS - JavaScript

SUS - System Usability Scale

Chapter 1

Introduction

User experience, commonly referred to as UX, refers to the overall experience of a person using a product or service. It includes the practical, experiential, affective, meaningful, and valuable aspects of human-computer interaction and product ownership. UX design is a field that focuses on creating products that provide a positive and intuitive user experience.

Eye tracking is a technology that allows researchers and designers to measure and understand where and how people look at visual stimuli, such as websites, advertisements, or software applications. By tracking the movement of the eyes, researchers can understand what elements of a design are attracting attention and how long people are looking at them. Eye tracking can be used to identify design elements that are confusing or distracting, and to optimize the layout and content of a design to improve the user experience.

1.1 Motivation

The motivation for creating a software alternative to existing complex and expensive options is driven by the desire to provide users with a more user-friendly and cost-effective solution to work with eye-tracking data. With the increasing reliance on technology in today's society, it is important to have access to tools that are easy to use and affordable, rather than being forced to navigate through complicated interfaces or pay exorbitant fees. By creating a software alternative, we aim to empower individuals and organizations to achieve their goals without the barriers of complexity or cost. By creating a functional prototype, we try to prove the applicability of heuristics in creating a user interface for working with and analyzing eye-tracker data.

1.2 Goals and contribution

The aim of the work is to analyze the current knowledge of user experience, usability and eye-tracking with a connection to human vision and its attention model, to analyze various existing tools for working with eye-tracker data and then in the second part to propose an own design of an interface with the corresponding implementation of an interface for working with eye-tracker data based on previous research.

Thanks to the demonstration of the importance of usability and user experience when working with eye-tracking data, therefore, the correct application of common rules and heuristics, work with eye-trackers and their outputs can be more accessible to the general public or further research. This can be achieved via suitable user testing, iterating above the designs and examining other solutions.

Chapter 2

Introduction to user experience

2.1 Meaning

User experience (UX) encompasses all aspects of the end-users' interaction with the company, its services, and its products. It is an aspect of human interaction with a given system, interface, graphics, and industrial design. [1] In most cases, User Experience Design fully includes the traditional Human-Computer Interaction (HCI) design and expands this team by addressing all aspects of a product or service as perceived by users.

2.2 Importance

UX is important because it tries to fulfil the user's needs. It aims to provide positive experiences that keep users loyal to the product or brand. Additionally, a meaningful user experience allows you to define customer journeys on your website that are most conducive to product and business success.

2.3 Human-Computer Interaction

Human-Computer Interaction (HCI) is a multidisciplinary field of study focusing on the design of computer technology and, in particular, the interaction between humans (the users) and computers.[2]

Interaction designers create connections between interaction in the physical world and the virtual world.

2.4 Usability

Usability is a quality attribute of user experience that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease of use during the design process. Usability is defined by 5 quality components:

- **Learnability**: How easy is it for users to accomplish basic tasks the first time they encounter the design?
- **Efficiency**: Once users have learned the design, how quickly can they perform tasks?
- **Memorability**: When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- **Errors**: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- **Satisfaction**: How pleasant is it to use the design?

[3]

Basically, it is a summary of the acceptability of the design and its functionality.

2.4.1 Heuristics of usability

There are always valid rules or instructions for creating designs and their states. However, these rules are very generally - abstractly written by Jakob Nielsen [9], and it is up to the designer how to apply these rules to reality, either to a prototype or a design.

1. Visibility of system status

   The user should always be informed about the status of his request to the system

2. Match between system and the real world

   Design should communicate in the language its users communicate. It means using phrases, words and concepts that he knows from his life so that the user will feel more comfortable with the design

3. User control and freedom

   Users make many mistakes and make them often, mostly unconsciously. During the entire use of the application, they should have the space to simply leave the application or simply come back. They should be informed about errors in a friendly and matter-of-fact manner

4. Consistency and standards

   Design should use established standards and not reinvent the wheel. The more the design resembles other platforms and conventions, the more the user will understand it.

5. Error prevention

   The user should be informed about what data is entering the application and what is the best step to complete the user scenario. An example can be, for example, filling in contact data when ordering, where we can use placeholders, or colour the field according to whether the given input is acceptable and to what extent.

6. Recognition rather than recall

   The goal is to create designs intuitively so that the first use is straightforward. If the design is memorable, it is also appropriate, but we are limited by human abilities and our memory.

7. Flexibility and efficiency of use

   The use of shortcuts, data already filled in the past and saved templates - all lead to a faster and therefore more pleasant user experience for the advanced user.

   On the other hand, these shortcuts should be hidden from new users, they should be guided through the first processes mainly so that they are in line with the rest of the rules.

8. Aesthetic and minimalist design

   Today, the creation of animations or 3D effects is relatively accessible, but it is necessary to realize that we must eliminate as many distracting elements as possible so that the elements for completing the scenario are always quickly visible, available and usable.

9. Help users recognize, diagnose, and recover from errors

   In general designing and prototyping, we take into account a wide spectrum of the audience, so if the user also makes a mistake, it is necessary to inform him of its context and help him get out of this mistake (for example, by marking the given place of the error and explaining what input the application needs). It is not allowed to display an error code that only the programmer can understand.

10. Help and documentation

    If we are creating a complex system for experts, it is sometimes difficult and counterproductive to make the interface too simple. Then it is necessary to document the created solution or provide the necessary training

2.5 Human-centered design

With the advent of new technologies, people are often confused by the complex use of devices they may work with on a daily basis.

The solution to these problems and people's frustration is human-centred design, which is also one of the specialities of HCI.

It describes ways and fulfilment of human needs so that they are as intuitive as possible based on real-life examples (if possible).

Good design starts with a proper understanding of technology and human psychology. Here you need to realize who the result is aimed at and adapt the design to the user's abilities.

2.5.1 Design thinking process

Design thinking is a non-trivial, non-linear, iterative process. It is a process in which we identify, simulate, find solutions and correct errors.

These rules may vary in different kinds of literature, but we will mention the main five based on Norman's design principles [10].

1. Observation

   Empathy and a good understanding of the characteristics and psychology of users are key to properly understanding their needs and problems. The solution for this phase is to monitor and capture the perceptions and actions of users in their natural environment.

2. Generating ideas

   The input for this step is the result of the previous step. If we already have defined how users behave, you can figure out how to solve user problems in the most effective way. In this phase, we have to define the problems in the HCD way. We can fulfil this step by using UX development practices, such as user scenarios, cart sorting, brainstorming, mind-mapping etc.

3. Prototyping

   If we have precisely defined problems and have analyzed solutions, we can start designing / prototyping, where we will transform the solutions into a usable, clickable interface. Some of the methods are low-fidelity prototyping, wireframing, and high-fidelity prototyping.

4. Testing

   Testing is key to finding mistakes that users can make in the prototype. The output can be a report that summarizes these errors (whether it is qualitative or quantitative data), based on them, we can repeat the whole process until the overall usability improves to a level that is sufficient for the stakeholders.

2.6 Role of eye-tracking in the human-computer interaction

There are various reasons why we need eye-tracking.

- Eye tracking can be used to research how people perceive and interpret visual stimuli as well as how they process and remember information in order to better understand perception and cognition.
- Eye tracking can be used to analyze how people divide their attention among various elements of a visual display, such as a webpage or a photograph. Understanding how people take in information and make judgments can be helped by this.

- Eye tracking can be used to analyze how well certain design components, such as layout, colour, and typography, affect user experience and performance.

  In general, eye tracking is a useful technique for researchers who are interested in learning how individuals perceive and process visual information, as well as how factors like attention, cognition, and emotion may affect these processes.

Chapter 3

Vision

Vision is a highly complex activity with a range of physical and perceptual limitations. The primary source of information for an average human. Memory and vision are closely intertwined, with our ability to remember and recall visual information being critically dependent on the way in which our brains process and encode the visual information we see.

3.1 Processing of visual information

The brain and the eyes work together in a complex and interconnected system to process and interpret visual information. When we see something, light waves from the object enter our eyes and are focused onto the retina, a layer of light-sensitive cells at the back of the eye. The retina converts the light waves into electrical signals, which are then transmitted through the optic nerve to the brain.[4]

In the brain, these electrical signals are processed and interpreted by the visual cortex, a region of the brain dedicated to processing visual information. The visual cortex interprets the signals to create a mental image of the object we are looking at and sends this information to other areas of the brain responsible for higher-level visual processing, such as object recognition and spatial awareness.[6]

As we move our eyes to look at different objects or locations, the brain adjusts the focus of the eyes, using muscles in the eye to change the shape of the lens and bring the image into focus. The brain also coordinates the movements of the eyes to keep them aligned and focused on a single point, enabling us to maintain clear vision and avoid double vision.

Overall, the brain and eyes work together to allow us to see and interpret the world around us, enabling us to navigate our environment and interact with the people and objects in it.

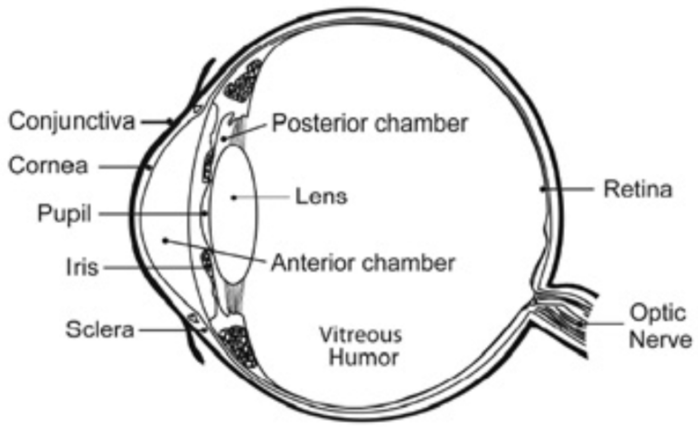


Figure 3.1: Anatomy of human eye
[5]

3.1.1 Memory

Vision plays a critical role in our ability to remember and recall information. When we see something, the visual information is processed and interpreted by the visual cortex in the brain, and this information is then encoded and stored in our memory.

One of the key ways that the brain encodes visual information is through the use of mental images, or "mental representations," of the objects or scenes we see. These mental images are like mental snapshots of the things we see, and they allow us to recall and recognize objects and scenes even when we are not looking at them.[7]

In addition to mental images, the brain also stores other types of information about the things we see, such as their location, size, and colour. This information is stored in different areas of the brain and is used to help us recognize and remember the things we see.

3.1.2 Visual handicaps

Visual handicaps, also known as visual impairments, are any conditions that interfere with a person's ability to see, either partially or completely.

There are many different types of visual handicaps, including conditions such as nearsightedness, farsightedness, and astigmatism, which are caused by abnormalities in the shape of the eye and can be corrected with glasses or contact lenses. Other visual handicaps, such as age-related macular degeneration, glaucoma, and cataracts, are caused by damage or disease to the eye, and cannot be corrected with glasses or contact lenses.[8]

Chapter 4

Visual attention

4.1 Introduction

Attention is an essential human ability. It is an aspect of consciousness that has been evolving for an eternity.

Visual attention is attracted by objects in the surroundings that stand out from the environment. Based on this fact, we can direct visual attention using different methods. We focus on the objects individually, one after the other. Psychologists have distinguished these two models based on observation in natural testing and through experiments.[11]

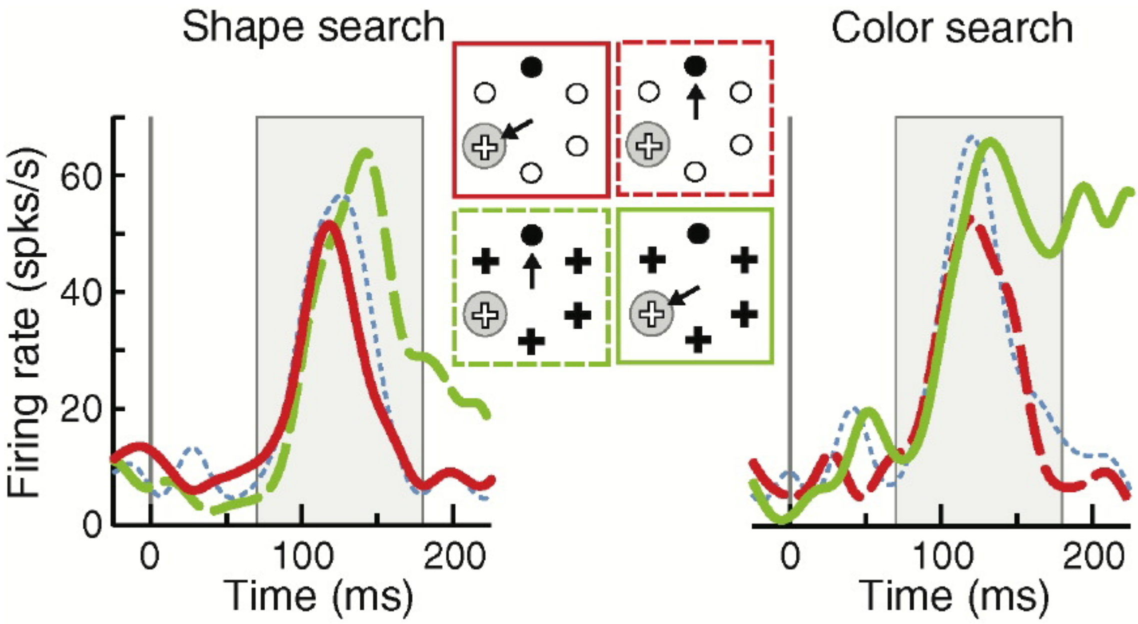


Figure 4.1: Responses of a typical monkey area V4 neuron during the shape search and colour search tasks.

[11]

4.1.1 Bottom-up model

The bottom-up model means that the reflexive part of the vision and the brain is mostly used to observe sensations. Using this model, we perceive quickly and involuntarily based on what could be important. For example, if there is something red in a field of wheat, we pay attention to it because it could be a potential predator represented by its size, colour or direction as it is oriented towards us.

4.1.2 Top-down model

The top-down mechanism takes into account our strategy and experience. If we are hungry, we look for different colours, or if we feel threatened, we try to look for angular objects and quick movements in the surroundings, because they could represent a predator.

4.2 Application in software development

Good usability is key in several directions of software development - whether it is an army fighter pilot who needs to quickly find the right button or information on the screen, or if we are the owner of an e-shop and want users to navigate our website or mobile application simply, intuitively, with the least amount of errors and no sense of frustration.

In the next paragraphs, We will show several examples of how Jakob Nielsen's heuristics [9] are implemented correctly.

4.2.1 The Stroop effect

It says that if the name of the colour is different than the coloured text with the colour name (see Image 4.2), it is very difficult to tell what colour the text is written in.

Figure 4.2: Column 1 displays conflicting colours, while column 2 displays the same colour as written

[12]

If you try to pronounce the colours in which the words are written, you will see that it will be much more difficult for you in the first column.

4.2.2 The F-Shaped Pattern

The F-shaped pattern (see Image 4.3) emerged from the observation of fixations that indicated that users look in the content area first at the top left and proceed vertically or horizontally. It means that we should display the most important content in the first line, or in the first words of the next lines. [13]

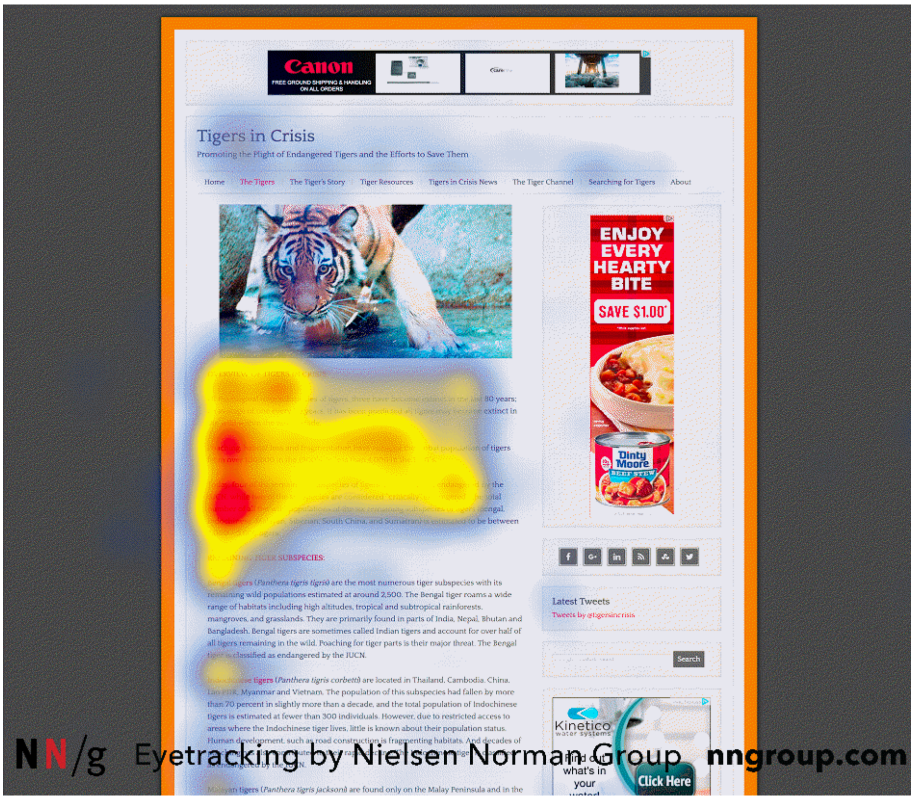


Figure 4.3: Heatmap shows that users focus mostly on the top-left part of the content area

[13]

4.2.3 Nielsen's heuristics

4.2.3.1 Reducing actions to bare minimum

Designers should design interfaces so that there are only minimum actions, that the user needs to do, to complete his task, because if there are more options for users, chances for mistakes are significantly higher.

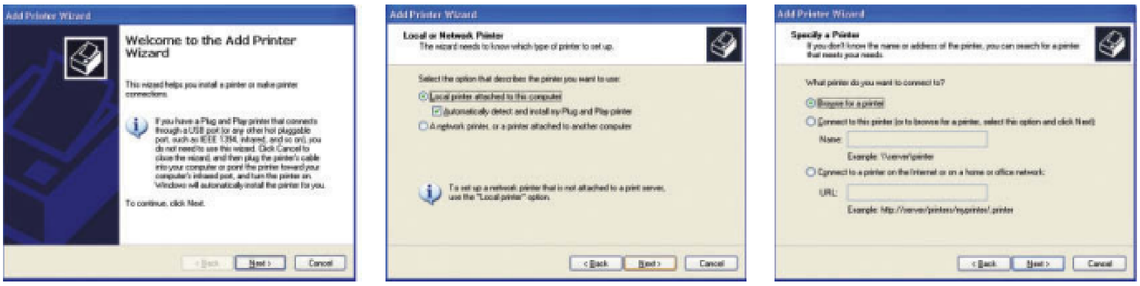


Figure 4.4: User is served only some portion of all information at the same time. All information is obtained after performing all the steps sequentially
[12]

4.2.3.2 Hints and errors

We can also avoid errors if we correctly place the hint for the user, whether it is the expected input format or a required field not filled in at all. We tend to display these errors in red/orange, as these colours are used as indicators of danger or warning - as well as, for example, the colours of traffic lights.

However, these error messages should objectively show how the user can correct the error independently.

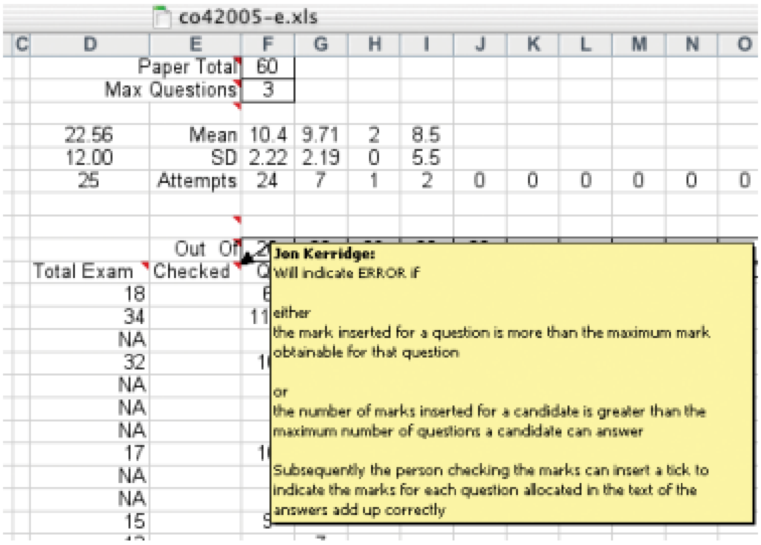


Figure 4.5: User can see documentation, which shows what kind of data should he input into the function. The hint note is also distinguished enough by the yellow colour, which contrasts with the white background.
[12]

Figure 4.6: This is a bad example of when the user is told that something went wrong, but there is not enough information to fix this error.
[12]

4.3 Attention-based practices

4.3.1 Color selection

The content area should be coloured to ensure a contrast between the text/usable elements and the rest of the interface (background, design embellishments). To calculate sufficient contrast, we can use tools such as this one: [14]

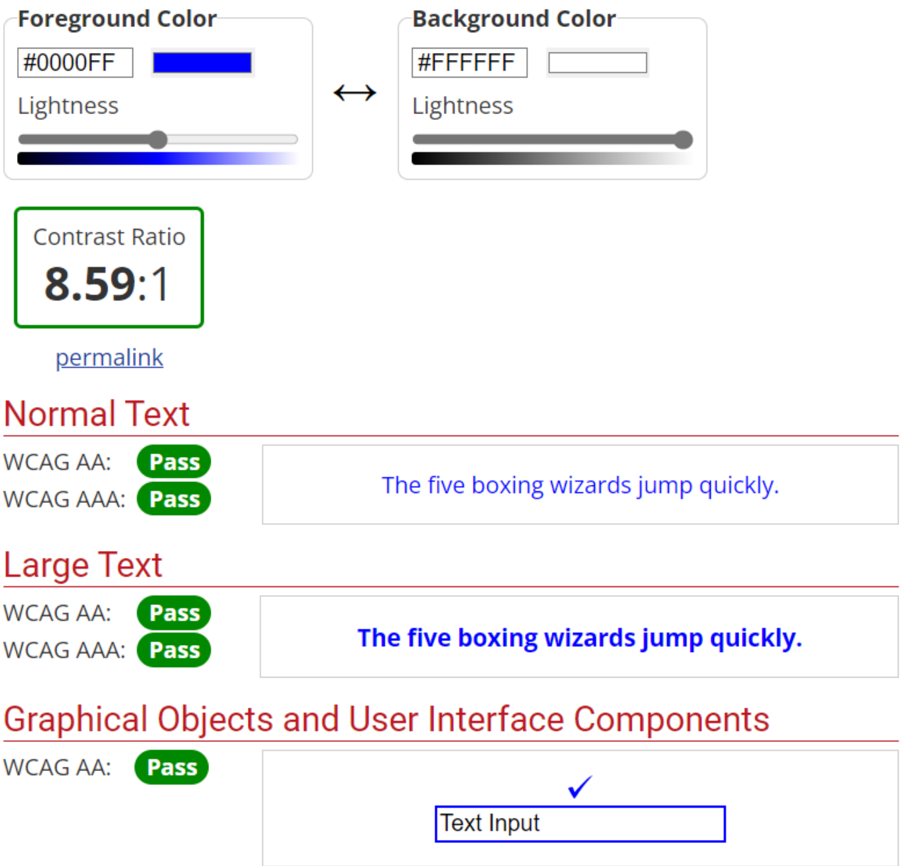


Figure 4.7: Output of contrast checker tells us contrast ratio as well as whether is the text recognizable enough

Contrast checker [15]

4.3.2 Call to action buttons

Call to action (CTA) buttons (see Image 4.8)are buttons that clearly and directly carry factual information and the action that will follow after clicking. The number of such buttons should be one to a maximum of two per screen viewport in order to guarantee a clear flow of the user through the page. This technique is used, for example, to increase sales in an e-shop, when the "BUY" button is clearly highlighted from the rest of the content so that the user is drawn to click on this button.

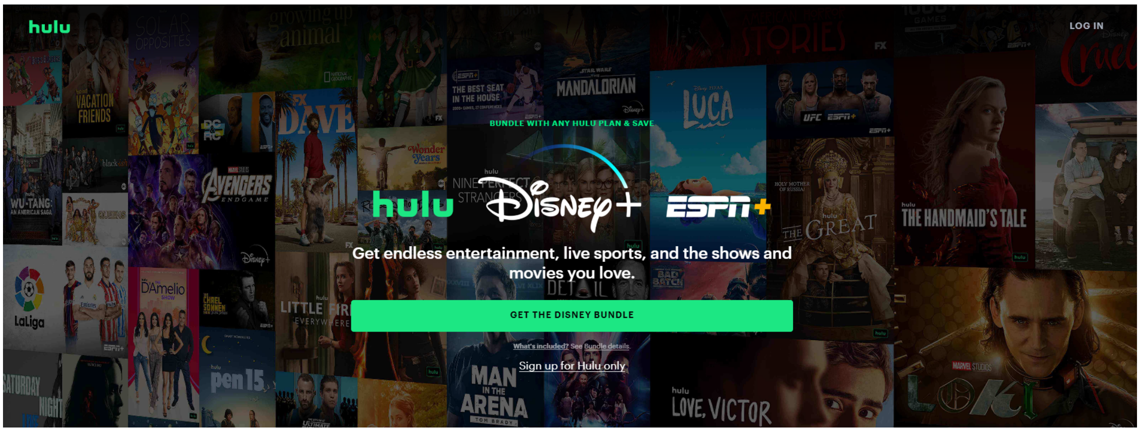


Figure 4.8: In this picture, we can clearly see, that the button green stands out from the other page content

1

4.3.3 Fontsizes

Headings should be large, and well distinguished from the rest of the text (see Image 4.9) so that the user can filter the interface quickly enough and focus only on what interests him. When determining text sizes, we can use some of the commonly used guidelines for sizes.

[1]screenshoted 17. 12. 2022 at www.hulu.com/welcome

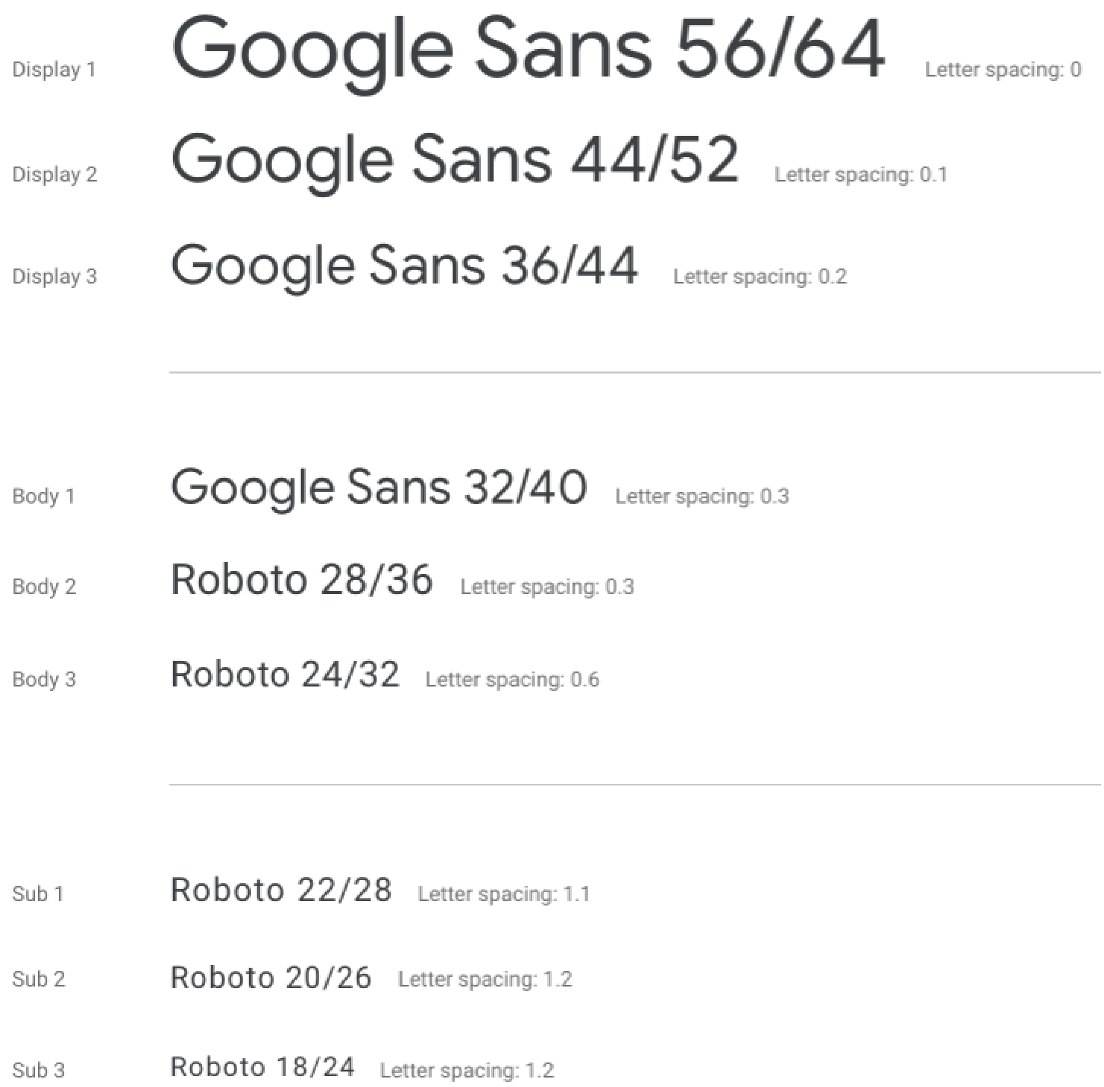


Figure 4.9: Android Auto typographic scale

[2]

[2]screenshoted 17. 12. 2022 at https://developers.google.com/cars/design/android-auto/design-system/typography/

Chapter 5

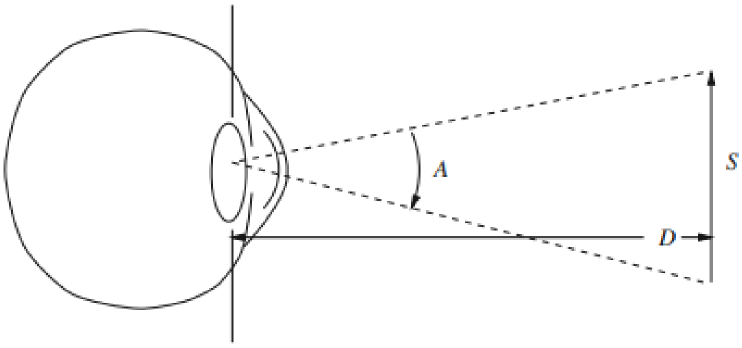
Using eye-tracker devices

Eye-trackers are more accessible than ever, and used by marketing and UX specialists, doctors, psychologists, sports specialists and many more. All of the above are interested in where their users, clients and customers are looking for various reasons.

Our eyes perceive a certain field of view on screens, depending on the size of the screen and the positions of the eyes relative to it (see figure 5.1). If we observe the screen in a standard position, we notice objects on the screen according to certain patterns that we can further investigate.

5.1 Targets of eye-tracker measurements

By using eye-trackers, we can relatively effectively diagnose errors in our application or website, which normal analytical tools cannot identify because they do not work with user perception data. Since the eyes are an organ that directly "works" with the outside world, we can use eye-tracking to analyze them while working with the product under investigation.



$$A = 2\arctan\frac{S}{2D},$$

Object	Distance	Angle subtended
Thumbnail	Arm's length	1.5°–2°
Sun or moon	—	0.5° or 30′ of arc

Figure 5.1: Visual angle. Adapted from Haber and Hershenson (1973), along with common visual angles and their measurement

5.2 Types of eye-trackers

There are several types of eye-trackers and their implementation depends on the way of use (see chapter 5.3). At the same time, technologies evolve and old ones become obsolete.

- Video-Based Combined Pupil/Corneal Reflection
- Lense systems with mirrors
- Scleral Contact Lens/Search Coil
- Photo-OculoGraphy (POG) or Video-OculoGraphy (VOG)
- Electromagnetic coil systems
- Electrooculography
- The Dual Purkinje systems

[16]

Video-Based Combined Pupil/Corneal Reflection eye-tracker is the most used in modern eye-trackers. Near-infrared light directed into the centre of both eyes (pupils) creates a visible reflection on the cornea, and this contrast is recognized and captured by the camera. We use near-infrared light, which the human eye cannot recognize, so there is only little or no interference from the eye-tracker during the measurement.[17]

Type	Duration (ms)	Amplitude	Velocity
Fixation	200-300	-	-
Saccade	30-80	4-20'	30-500°/s
Glissade	10-40	0.5-2'	20-140°/s
Smooth pursuit	-	-	10-30°/s
Microsaccade	10-30	10-40'	15-50°/s
Tremor	-	<1'	20'/s (peak)
Drift	200-1000		6-25'/s

Table 5.1: The most prevalent forms of eye movement actions typically have values in this group. Only a few of these are typically recordable by eye-trackers.

5.3 Interests of measure

- Movement

  Deals with movements between objects and the properties of these movements. [18]

- Positioning

  Examines where the user directs their attention and solves the movement of the eyes within the already focused object.

- Numerosity

  Examines the number of different actions when the eyes move and their frequency

- Latency

  Examines how long it takes for the user to notice / react to a change in the interface and looks for the properties of these spatial distances.

[16]

5.4 Computational representation of the eye-tracking data

After calculating the viewpoints, the raw output is a time series of x,y coordinates, also known as gaze points (see in chapter 5.5.5), representing pixels on the screen with respective width, height where the user pointed the eyes towards.[4]

When evaluating the results from the eye-tracker, the measurement capabilities of the eye-tracker and its settings, for example, frequency, latency, and accuracy, must also be taken into account. Before measuring, the measurement must be adjusted according to the specific needs of the user - for example, glasses or mascara.[18]

5.5 Processing the eye-tracking data

5.5.1 Saccades

These are movements or jumps between fixations in a steady environment. Through saccades, the eyes try to register a new target in order to acquire new data, in high resolution. Due to the high speed of eye movement during a saccade, we see much weaker and out of focus.

Timespans and frequencies:

- From 20 to 120 milliseconds
- Usual duration: 20-40 milliseconds
- Up to 600-700 degrees/second
- Typical frequency: 4 times/second at about 4 Hz rate

[20]

5.5.2 Fixations

Pauses between sets of eye movements during which the eyes acquire information from the external environment. The longer the fixations, the more information they can process. Together with saccades, fixations create a scan path, i.e., the path that a subject's eyes follow.

Timespans and frequencies:

- From 100 to over 600 milliseconds
- Usual duration: 100-300 milliseconds
- Typical frequency: around 3 Hz

[20]

Additionally, eye tracking permits the measurement of:

Time to first fixation (TTFF) – the time between the onset of a stimulus and the fixation within an area of interest (AOI). This provides insight into visual attention.

First fixation duration – total time of first fixation

Fixation count – how many fixations took place inside an AOI

Average fixation duration – the higher the average fixation duration, the more attractive an AOI is for the respondent

Fixation sequences – comprised of fixation location and time of fixation

5.5.3 Smooth pursuit

It is an eye activity when our attention is focused on a moving object. Information processing is present in this case, unlike saccades.

5.5.4 Areas of Interest

(AOI) To assess different fixation metrics, areas of interest (AOIs) are used to select specific regions in a scene.

5.5.5 Gaze points

Gaze point is the estimated point on the screen where the user was looking based on the mapping of the content on the screen and the output from the eye-tracker device (see in Image 5.2). We say it is only an estimate, based on device deviations and the user's ability to focus on the object being tracked. The gaze point is calculated

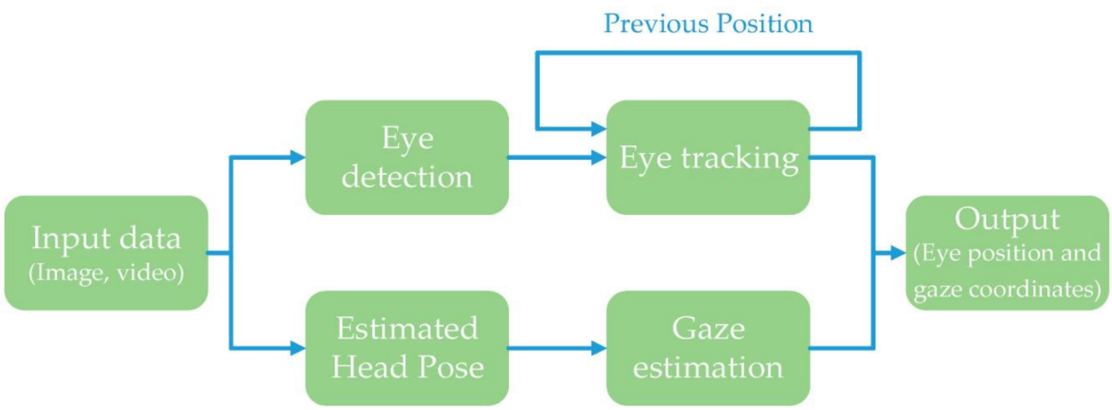


Figure 5.2: The process of tracking eye position and gaze coordinates.

[19]

Gaze plots (see in figure 5.3) on the other hand transform gaze points into scan-paths, which reveals us users' behaviour on the screen.

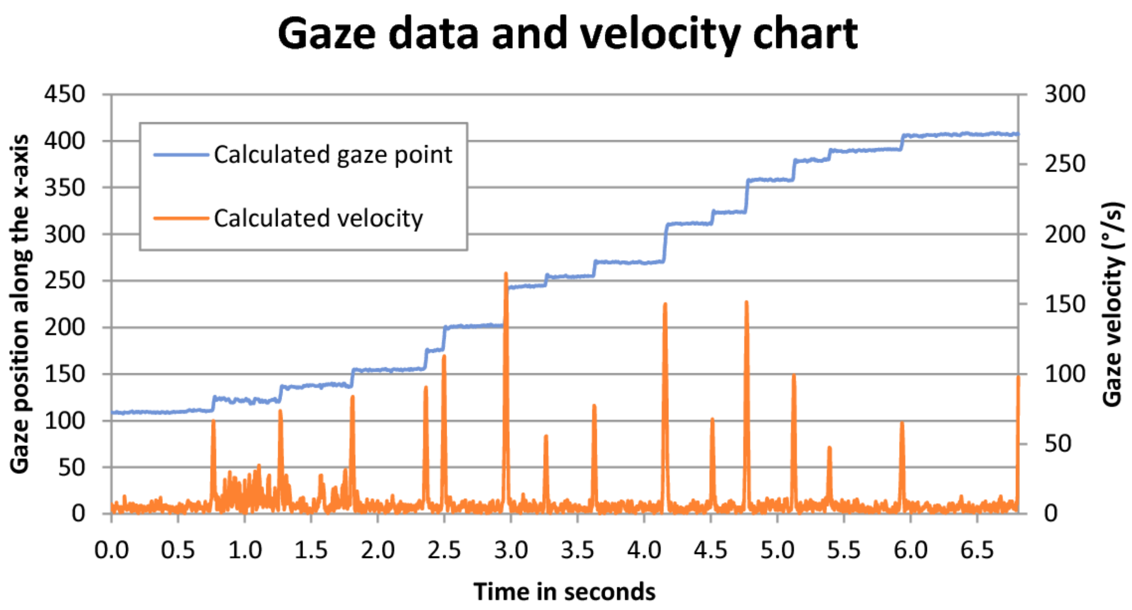


Figure 5.3: Gaze data and velocity chart. Peaks in the calculated velocity can be used to identify saccades between fixations.

[21]

Other valuable measurable variables:

Ratio – the number of participants who fixated on an AOI

Dwell time – how much time was spent viewing an AOI, i.e., duration of observation

Observation count – the number of times a participant revisited an AOI

5.5.6 Heatmaps

It is a visualization technique for displaying the concentration and distribution of gaze points. In the image below, we can see that depending on where and how long the user looks, the given area will be colored in the analysis tool. In this particular example (see figure 5.4), the highest concentration is shown in red. [1]

Figure 5.4: Heatmap sample representing measured eye-tracking data

5.5.7 Focus/opacity maps

They show the same context as heatmaps but in a different sense. Places, where users look the most, are highlighted, while places that have been ignored the most appear darker.[20]

5.6 Fixation classifier

I-VT filter - Velocity threshold identification (I-VT) classification algorithm, which is the most widely used classifier groups consecutive samples, with the same classification, in order to simplify the processed data for the user of the eye-tracking

[1] Colour scales may vary, depending on the application of the visualization technique and its settings.

device. For example, if a sample is taken that is a fixation within the threshold, and the sample immediately before it was also classified as a fixation, then these samples are combined into a total fixation time period.

It also uses eye movement speed to eliminate "smooth pursuit" from the measurements, or to clear data. Thus, using this filter, only fixations and saccades are output.

On the contrary, if the samples are different, a new list of the time period of fixations or saccades is created. Thus, this classification algorithm will remove the gaps from the measurement.[16]

5.7 Eyetracking platforms

Significant changes and evolution in education have been made possible in recent years by dramatically improved sensor design and deployment, edge communication, and computation.

In the following paragraphs, we point out some of the techniques for how data is obtained, in what ways it is analyzed and what are its outputs. Subsequently, in the table (see in figure 5.6) we can see a summary of the software and the range of their capabilities

- Tobii Pro Lab - The user receives a complete multimodal workflow from the combined solutions of Tobii Pro Lab, including a synchronization technique and data fusion tools.

  When recording, Stimulus presentation timing in Tobii Pro Lab is used, which has the task of optimizing the refresh rate of the screen so that the pixels are displayed at an even time. This process will ensure that the image will not tear and the image will be stable. For example, a screen with a standard refresh rate of 60Hz refreshes every 16ms, but it is not guaranteed that the generator (either CPU or GPU) of these images will be able to create 60 frames per second, so we can reduce this refresh rate to 50ms, which will ensure a regular and accurate display new image. [23]

The analysis module mediates recording playback, visualization and recording analysis options such as importing recordings, manual or assisted mapping onto snapshot images, creating areas of interest on images and videos, metrics, plots visualizations and other trivial options. [24]

Analyzes and visualizations are created via detecting event and fixation groups, which that comes onto the fixation classifier (see chapter 5.6) and its result is displayed by the dedicated module of the software that is suitable for creating the classifier´s output based on the type of use.

[2]

- EyeLink Data Viewer - Other eye-tracker data analysis software provides a simpler interface, which is capable of similar results in comparison to Tobii Pro Lab. Among others, it includes a simple evaluation of the first fixation duration as well as regression path duration. It uses a 4-stage data cleaning algorithm (see in figure 5.5), with which we can exclude irrelevant fixations.

  Other mentioning work features is event filtering with which we can eliminate an already classified fixation if the moderator assesses that the observed person may have been significantly distracted during the test. This gap can be completely excluded from the test or connected to another fixation or saccade based on the moment when this event occurred.[25] [3]

[2]Product description: https://www.tobii.com/products/software/behavior-research-software/tobii-pro-lab

[3]EyeLink Data Viewer manual: https://www.hse.ru/mirror/pubs/share/560338929.pdf

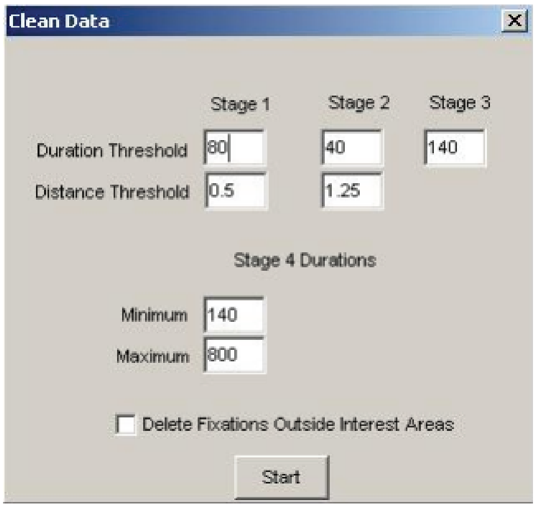


Figure 5.5: Application of 4-stage data cleaning algorithm

- Eyeworks - Among other previous features, it also includes a cognitive workload module that uses The Index of Cognitive Activity [26] - it reacts to the presence and light and changes in the eye muscles that surround the pupil. In this way, we can find out that some part of the tested interface is difficult for the user to process, because the object on the screen is, for example, too small.

  The last feature that we will cover is facekit head and eyelid tracking. It doesn't need any calibration and in case of loss of part of the data from the eye-tracker, we can replace this data with data from this module. We can also measure blink duration and speed of blink movement, which can by used to measure the user's concentration and fatigue. [4]

[4]EyeWorks software further information: https://www.eyetracking.com/eyeworks-software/

Software	Supported Language/ System	Associated Tools/API	Test De-sign	Available eye tracking data						Third Party Support	Warranty and Updates
				Heat Map	Gaze Path	AOIs	Statis-tics	Multi-user	Record ing		
Tobii Core Software [16], [40]	C, C++/ Windows, MacOs, and Linux	Tobii eyeX SDK	✓[1]	✓	✓	✓	✓	✓	✓	Alienware, Preoator,acer,msi	Bundled with the hardware
Tobii Pro Studio for TypeII eye trackers [39]	C, C++, Python, .NET, Matlab/Windows, MacOs, and Linux	Tobii Pro Lab, Tobii Pro SDK	✓[1]	✓	✓	✓	✓	✓	✓	Biometric sensors, GSR	Bundled with the hardware
Gazepoint Analysis [25], [65]	C, C++, C#, Python, Matlab/ Windows	OpenGaze API	✓[1]	✓	✓	✓	✓	✓	✓	N/A[2]	Optional extras
EyeLink Data Viewer [59]	C, C++, Python/ Windows, MacOs, and Linux	SR Research Experiment Builder or EyeLink API	N/A	✓	✓	✓	✓	✓	✓	Matlab, E-Prime, PPT, SPSS	Bundled with the hardware
SR Research Experiment Builder [30]	Drag-and-drop graphical programming /Windows and Mac OS	EyeLink Data Viewer	✓[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Bundled with the hardware
EyeWorks [66]	C++, C sharp, Visual basic / Windows	AppConnect SDK	✓[1]	✓	✓	✓	✓	✓	✓	E-Prime, RED, FaceLAB5, TX300, EyeLink, ViewPoint	Optional extras
Cognitive Workload [16], [66]	C++, C sharp, Visual basic / Windows	EyeWorks Cognitive Workload Module	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FX3/FOVIO, EyeLink, Tobii pro, GP3, SMI RED, Mirametrix	Optional extras
EyeWare [67]	Python/Windows, Linux	Python/Custom API	UNK.[3]	✓	✓	Auto anno-tation	✓	✓	✓	3D cameras(Kinect, Orbbec Astra, Intel RealSense)	Optional extras

[1] Featured with the metrics including frame rate, frame size, FOV, gaze sampling rate, and/ or calibration methods [2] N/A: Not Applicable [3] UNK: Unknown

Figure 5.6: Other commercial software for eye-tracking systems and a summary of their attributes

[22]

5.8 Tobii Pro Lab interface

The Tobii Pro Lab user interface consists of several components:

Analyze panel: This is where the eye tracking data is displayed and analyzed. It includes various plots, graphs, and other visualizations that allow researchers to see how participants looked at different parts of the screen over time.

Participants: This panel displays a list of all the participants in the study, and allows researchers to select and analyze data from individual participants or groups of participants.

Events panel: This panel displays a list of all the events that were recorded during the study, such as button clicks or mouse movements. Researchers can use this panel to analyze how participants interacted with the tasks or stimuli.

Design panel: When creating the measurement scene and the measurement itself, many complex settings are available, which require familiarity with eye tracking and computer skills at a non-trivial level.

After creating the project, we have the project management screen available, where we can see participants and individual measurements or variables that should be used for individual participants.

After the measurement is finished, we have the AOI tool and analytical tools available, as well as the modification of the definitions of the metrics and their visualization. After applying the tools to the project, we can export the project, where during the export we can filter data that is sensitive from the point of view of personal data protection.

Chapter 6

Related Work

6.1 A systematic literature review on the usage of eye-tracking in software engineering

In the work of Zohreh Sharafi et al. [29] they did systematic literature reviews (SLR) project, which compiles all available data from studies and outcomes on a specific subject, which is helpful in the context of Evidence-based Software Engineering. This SLR assesses the state-of-the-art for employing eye-trackers in software engineering and offers support for their use and contributions to empirical studies in the field.

They did an SLR on software engineering eye-tracking studies published between 1990 and 2014. Instead of utilizing manual search, they use Engineering Village to conduct a thorough automated search of all recognized resources. They located 36 pertinent works, including conference papers, workshop papers, and journal papers.

It also analyzes user behaviour, the basic elements of Visual Attention in the context of working with software, as well as strategies for solving problems with eye-trackers, their programming, and working with outputs.

The article visualizes the development of interest in this issue in the academic sphere over the years along with many relevant references divided into semantic categories from which I can further draw valuable information.

It contains detailed sourced metrics that I have already used in previous chapters, along with an explanation of what that represents.

6.2 GlassesViewer: Open-source software for viewing and analyzing data from the Tobii Pro Glasses 2 eye tracker

The article by Diederick C. Niehorster et al. [30] includes an analysis of another tool for working with eye-tracker outputs, as well as described the synchronization, and streaming capabilities of the wearable eye-tracker and software. It focuses on the Tobii Pro Glasses 2 eye-tracker.

The program offers MATLAB-coded features such as a GUI for viewing the Tobii Glasses 2's gaze direction, pupil size, gyroscope and accelerometer time-series data, along with the recorded scene and eye camera videos. A graphical interface for navigating the study- and recording structure produced by the Tobii Glasses 2. Functionality to unpack, parse, and synchronize the various data and video streams comprising a Glasses 2 recording. A fully open-source approach for analyzing Tobii Pro Glasses 2 recordings is made possible by the toolbox's integration with the GazeCode tool developed by Benjamins et al. in 2018.

When describing the functionality of the GlassViewer tool, the functions are compared to the Tobii Pro Lab Analysis module. In the article, this tool is described as flexible and transparent, which can replace most of the functionalities of the Tobii Pro Lab Analysis module after GazeCode implementation.

6.3 Visualization of Eye Tracking Data: A Taxonomy and Survey

In the work T. Blascheck et al. [31] they demonstrate how to use the visualization of eye-tracking data to uncover fresh insights from our persuasive use case involving energy network operators who work in power plants. Then, they go over the findings from interviews with eye-tracking users from various fields, giving the public a deeper knowledge of the system's potential. The findings imply that interactive functions might enhance their investigation of eye-tracking data, such as dynamic AOIs, connected spatial and temporal views, and the classification of saccades.

The study was designed to provide quantitative data to allow to derive insights and recommendations for improvements to the control systems and the operators' workspace. More precisely, they expected to use the eye tracking data to achieve outcomes - distinguishing between sections of the workspace that are frequently used and others that are not, comparing workers' reaction times, to better understand how operators behave both during normal operations and in response to unusual situations. Eye-tracking data in these situations enables us to comprehend operators' varied attention to various display elements over time, for as when operators must repeatedly switch between two programs that may be physically far from one another on the workspace's (big tiled display).

Chapter 7

Observation and generating ideas

It started with a study of work of The impact of education on human perception [33] and [34], from which we selected which scenario from the established hypotheses - Specifically $\mathbf{H}3_0$ - which is the most difficult to implement in Tobii Pro Lab by manually simulating the evaluation of the hypothesis. Accordingly, we agreed, to create a heuristic evaluation for the given scenario, followed by the creation of an optimal information architecture and user flow diagram - according to which prototypes can be made.

7.1 Information architecture

By adjusting the information architecture, we tried to reduce the number of different screens and, above all, display information only in one place, and not share it in different places, so that it does not give the impression that we are overwriting the data we have already written down.

In Image 7.1, we can see the inconsistency in the hierarchy of information, such as the location of Data Selection, Metrics and many settings that are in different

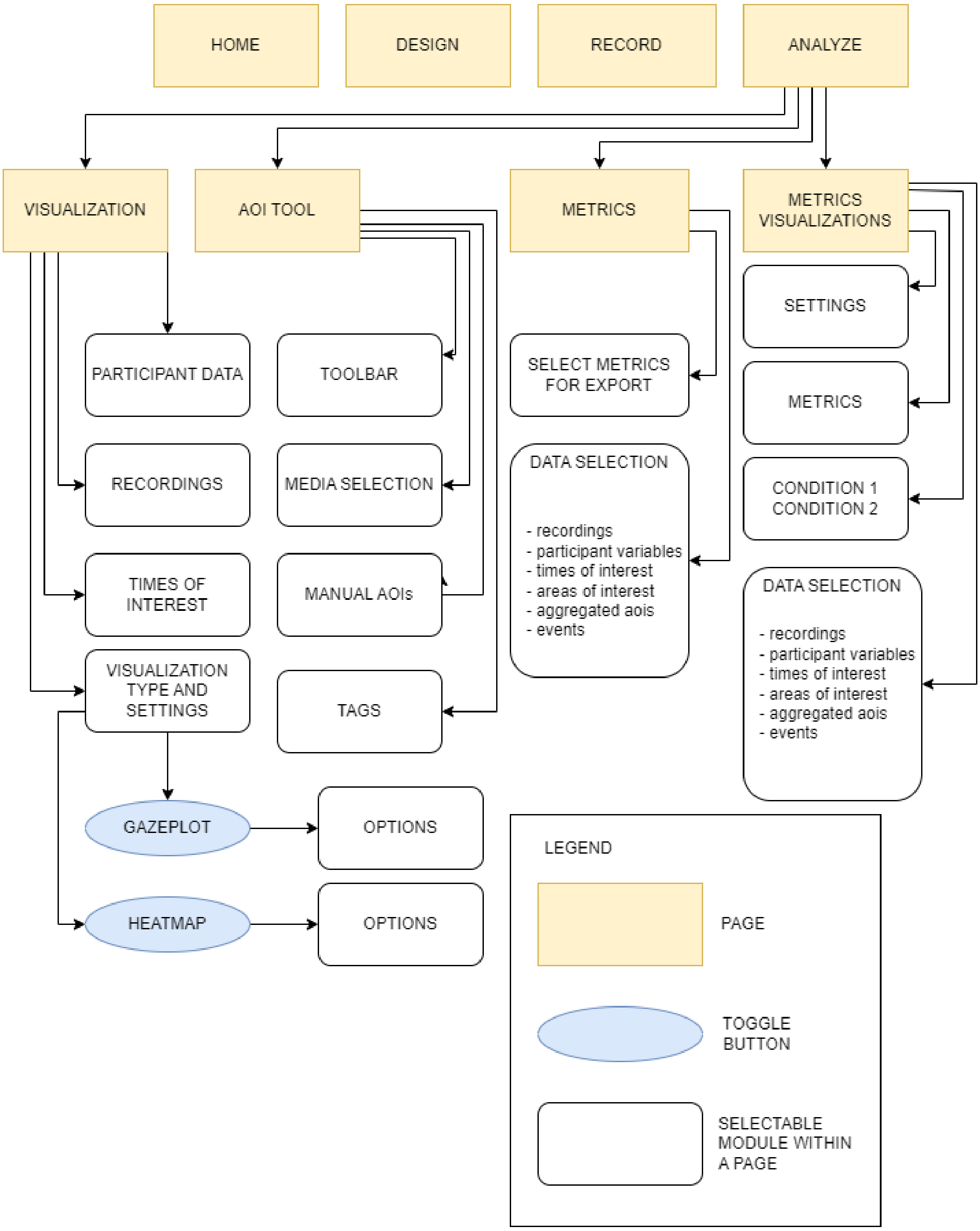


Figure 7.1: Information architecture of Tobii Pro Lab - Focusing on analyze module

places. Even if we take into account the robustness of the program, it can be considered confusing for the user that he may not know which setting and selection override another, which conflicts with the Consistency and standards heuristic [9].

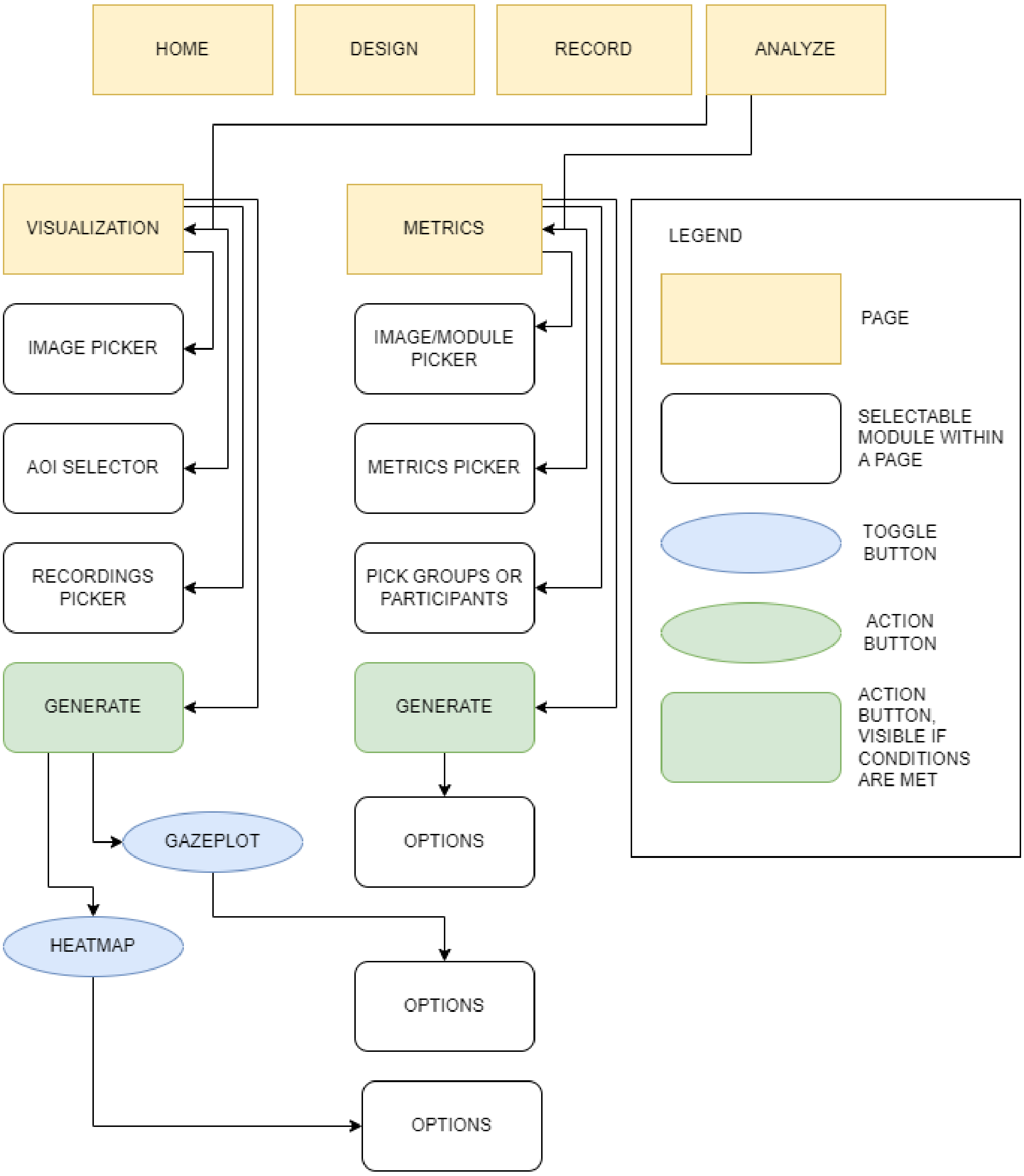


Figure 7.2: Our information structure - Focusing on analyze module

When creating an ideal information structure 7.2, we already thought about the upcoming creation of a user flow diagram, so that the prototype could be as consistent as possible and the same information would not be displayed in different places.

7.2 User flow

When analyzing the Tobii Pro Lab user flow 7.3, we noticed that there is no hint or intuitive procedure to achieve the result of any metric. This result (without a previous study of a user) is achieved only by means of the "trial-error" system. We noticed - as one expert tester also told us during the interview (See Appendix C) - that we have no idea what values we chose on the previous screen, and whether we overwrite this data on the current screen because some options are shared between different screens of the application and it is not clear from the context whether it is affected previous step.

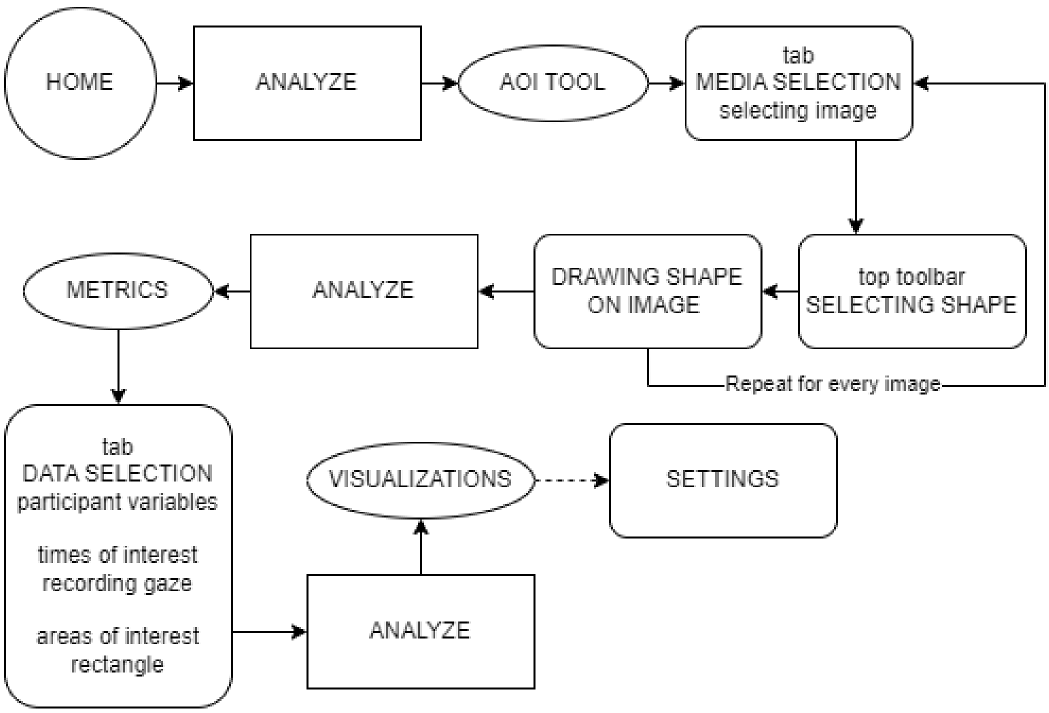


Figure 7.3: User flow diagram - Tobii Pro Lab - Scenario for hypothesis $\mathbf{H}3_0$ [33]and [34]

The user flow we created 7.4 contains clear and semantic steps, as well as their order. At this stage, we already knew that we wanted to implement a stepper, which means that the user will have access to only one single and always the same flow and navigation between the individual parts of the scenario is available using clearly marked "back" and "continue" buttons.

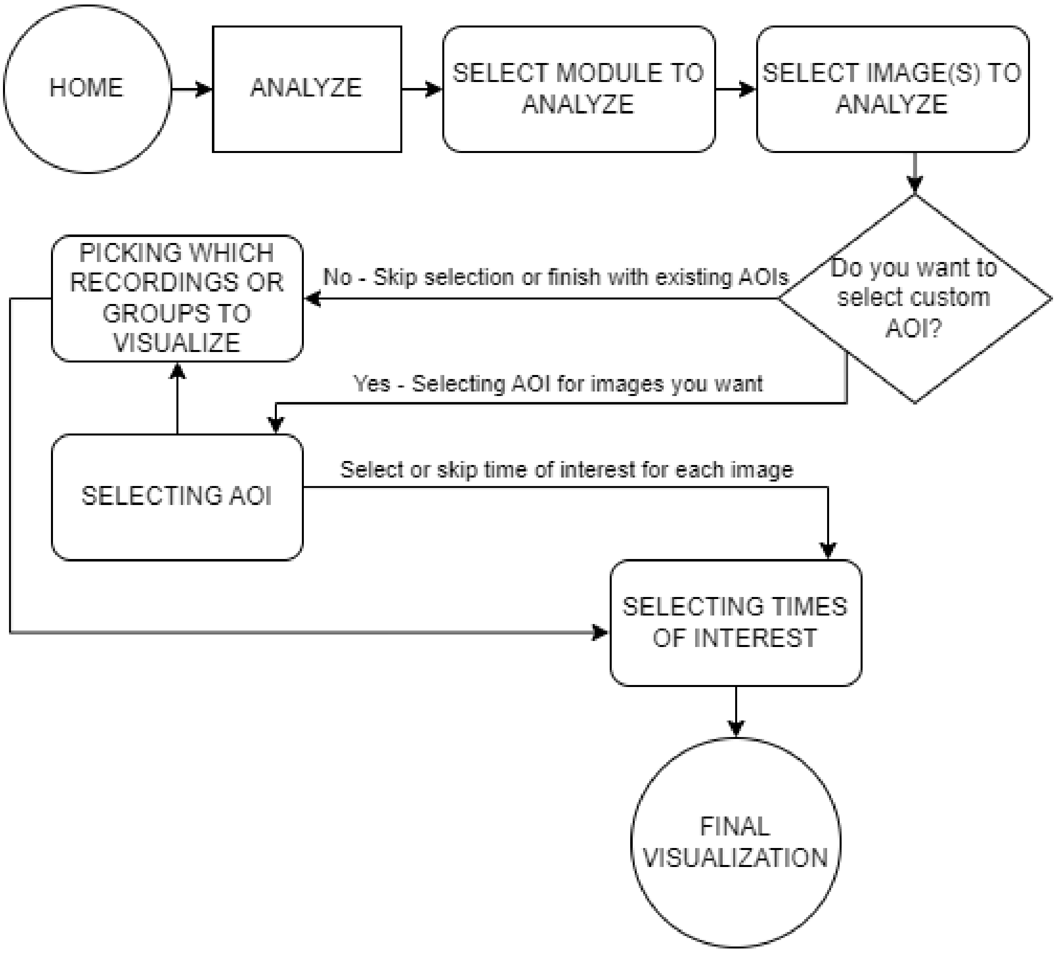


Figure 7.4: Our user flow diagram

7.3 Heuristic evaluation

The heuristic evaluation showed (see Appendix B) that we should focus on a straightforward user flow with return options and on implementing components such as a stepper, CTA buttons, and a simple but effective layout of the application, which is aesthetically and functionally coordinated with the rest of the prototype or screens.

The whole heuristic evaluation can be found within Appendix B - Heuristic evaluation

7.4 Prototyping

After the evaluation of the heuristic evaluation and the subsequent creation of the information architecture and user flow diagram for solving the given scenario, a low-fidelity prototype began to be made, which had 2 iterations, and then another 2 iterations of the high-fidelity prototype began to be made in the Figma tool. This tool was preferred over Axure, due to greater familiarity with the program.

7.4.1 Low-fidelity prototype

In the first iteration of the Lo-Fi prototypes, we found that the stepper will definitely be a useful thing, and that if the navigation and individual screens are sufficiently simple, it will not be necessary to implement the undo/redo functionality, so we did not introduce this function in the next iterations.

In the second iteration, the prototype was truncated with functions/screens that are not relevant to this scenario, therefore we do not even mention the first iteration.

In this prototype, it is already possible to see the elements shared by the entire application for consistency. Each screen has a clear title describing what can be done on that screen. Among the common elements, we will also mention the footer, which contains a stepper and navigation buttons, i.e. a step forward and a step back.

On the first screen "Selecting modules/images" (top-left corner of Image 7.5) the user selects images or entire image modules that it wants to process further.

On the second screen "Selecting AOI" (top-right corner of Image 7.5) we define the areas of interest that interest us in the given images. This screen is repeated for each image, with the option to skip selecting areas of interest. (We will modify this approach later during high-fidelity prototyping).

In the third screen "Recordings" (bottom-left corner of Image 7.5) we see the same pattern as in the screen "Selecting modules/images", that is, the selection of total groups of participants or the selection of individual recordings within the selected group. On the right side of the screen, there is the Times of Interest adjustment, but in the high-fidelity prototype, we moved it to the "Selecting AOI" screen.

On the last "Visualizations" (top-right corner of Image 7.5) screen, we can see an already finished visualization with options for selecting variables, metrics and functions in the left and right panels, which have not yet been further defined at this stage.

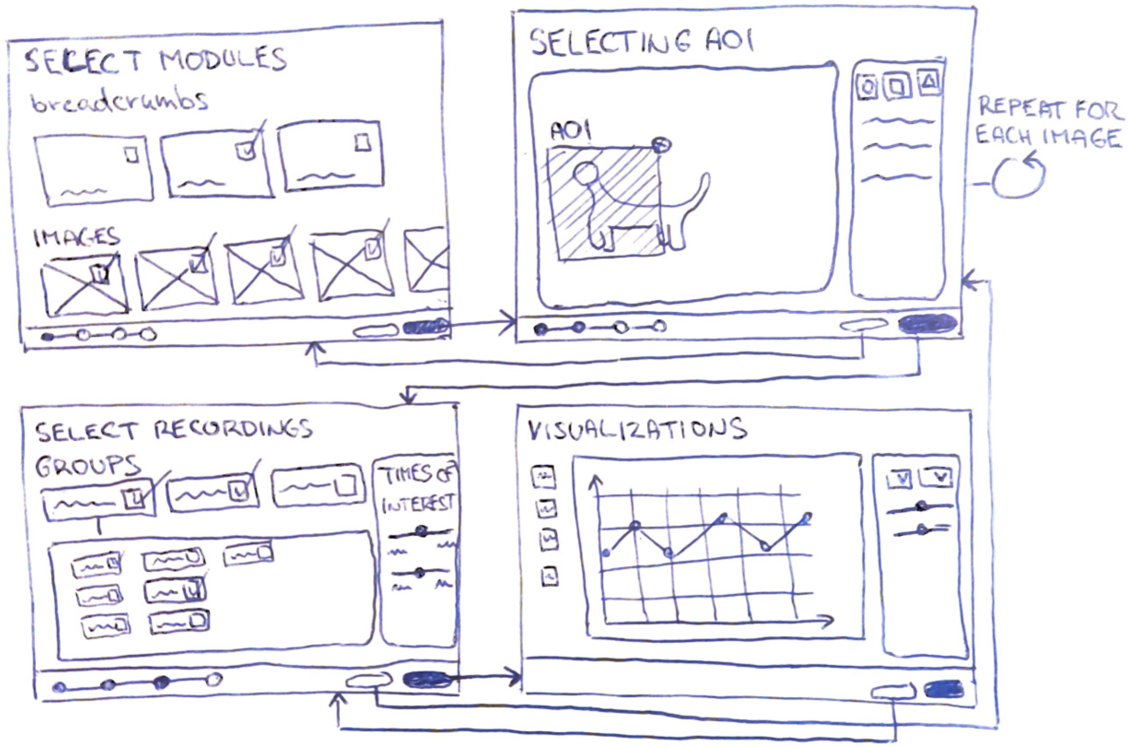


Figure 7.5: Low-fidelity prototype - 2. iteration

7.4.2 High-fidelity prototype

We increased the fidelity of the prototype making it look like a real application with a realistic design and content.

In the high-fidelity prototype, a new header section was created, where the stepper was moved, in order to better recognize which step the user is currently in to fulfil the scenario.

In the first screen (Image 7.6), the selected images and modules are colour-coded, as well as the number of nested images that will be used in the analysis.

On the second screen (Image 7.7), AOIs are defined. Compared to the low-fidelity prototype, there are 2 main differences:

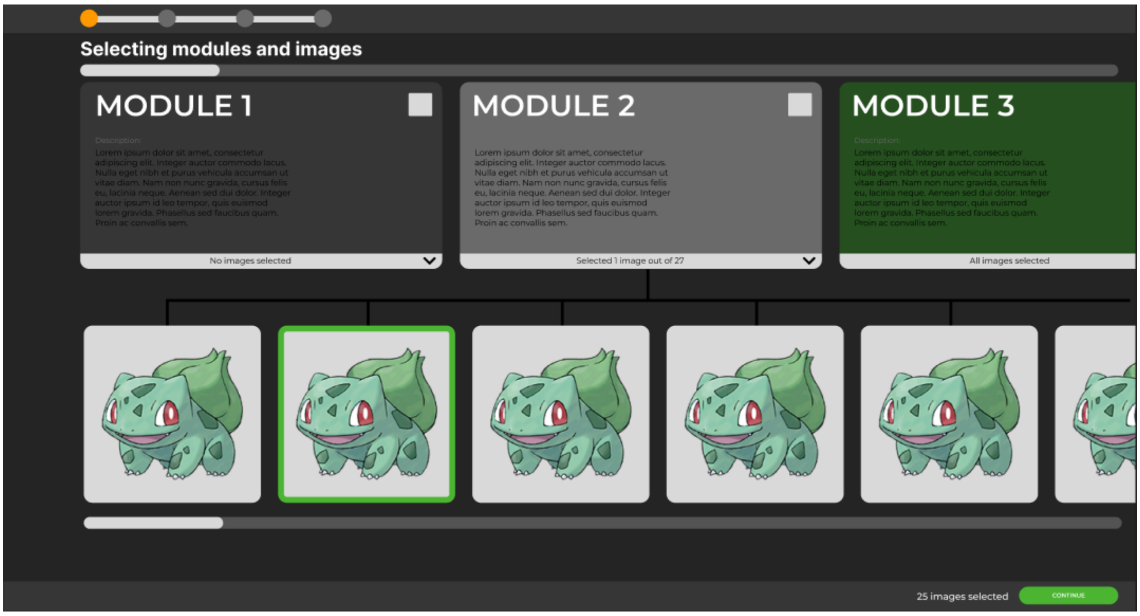


Figure 7.6: High-Fidelity prototype - Modules/images screen

1. Area of interest is by default selected as the entire image. It is up to the user to define it by selecting a module from the left panel and then selecting an image from the bottom slider.

2. The time of interests panel was moved from the "Recordings" screen here, for better semantics and user flow, so the current idea is that the time of interest can be defined globally, but at the same time it can be overridden by the settings for a certain module and at the same time it can be also overwritten only the given image to which the AOI is currently assigned.

In the third screen "Recordings" (Image 7.8) there are no changes compared to the low-fidelity prototype, except for the mentioned move of the time of interest panel.

In the last screen of the visualizations (Image 7.9), the layout was simplified, that is, it consists of an informative panel on the left about which modules, images

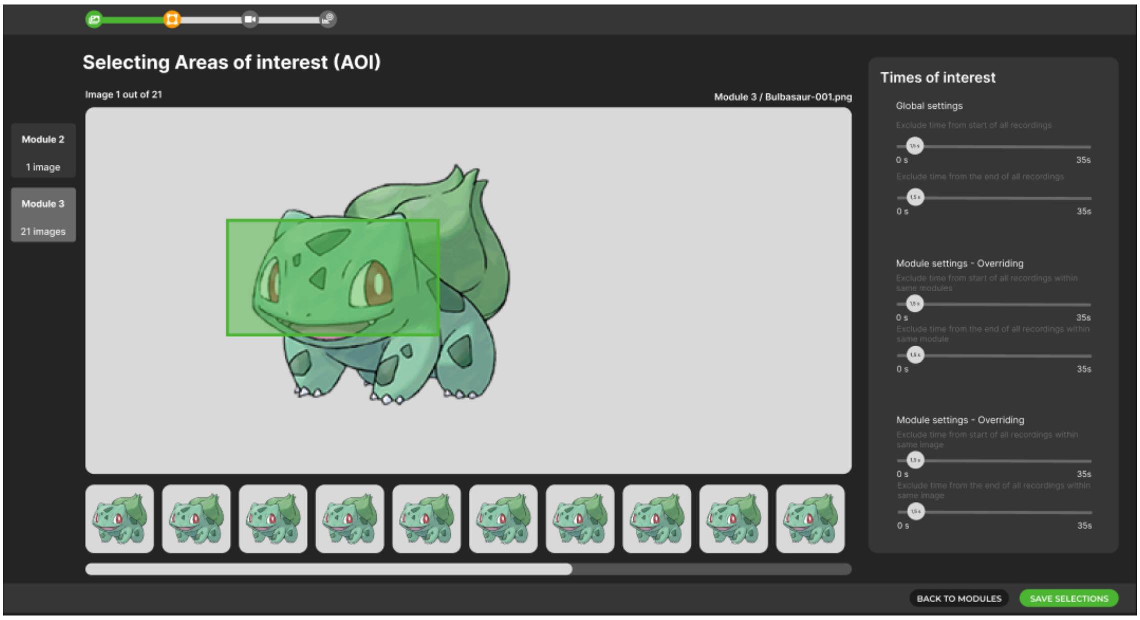


Figure 7.7: High-Fidelity prototype - Selecting AOI screen

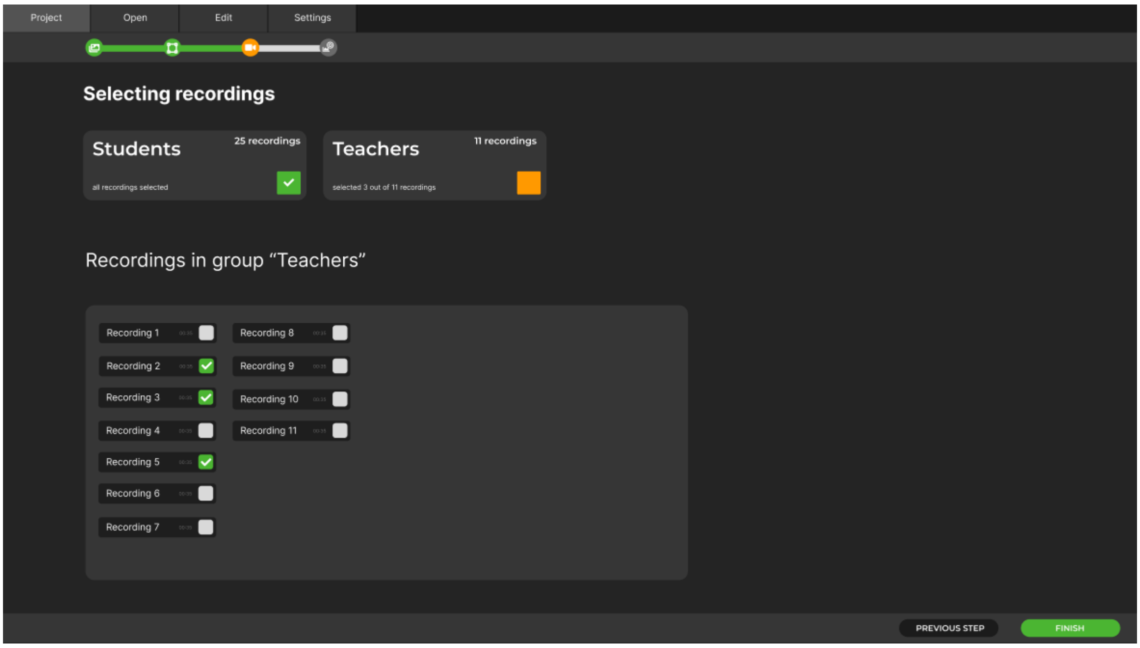


Figure 7.8: High-Fidelity prototype - Recording screen

or areas of interest concern and the left panel contains metrics and groups for comparison.

Figure 7.9: High-Fidelity prototype - Visualizations screen

7.4.3 Final interactive prototype

The final and interactive prototype was programmed - making it interactive in order to match the user scenario. First, the templates were created using HTML and SCSS, and then the interactivity was programmed mostly using jQuery. This approach was chosen because of the highest approximation to a real application. When working with programs like Figma or Axure, we were limited in data persistence, which we replaced with Node.js + Express.js server, which stored the data of exactly one project for exactly one scenario. This data was stored in JSON database format. For further documentation of this implementation see technical documentation in appendix E.

Below are screenshots of the "Selecting AOI" (Image 7.10) and "Visualizations" (Image 7.11) screens, because only these screens had some changes compared to the prototype in Figma, which was described in the subsection above.

Changes on the "Selecting AOI" screen (Image 7.10) are on the right panel, where there are darkened parts that inherit the time of interest of the global settings. These settings can be adjusted using the "Override" button, where the time of interest change will be reflected in the desired object, whether the module or the image itself.

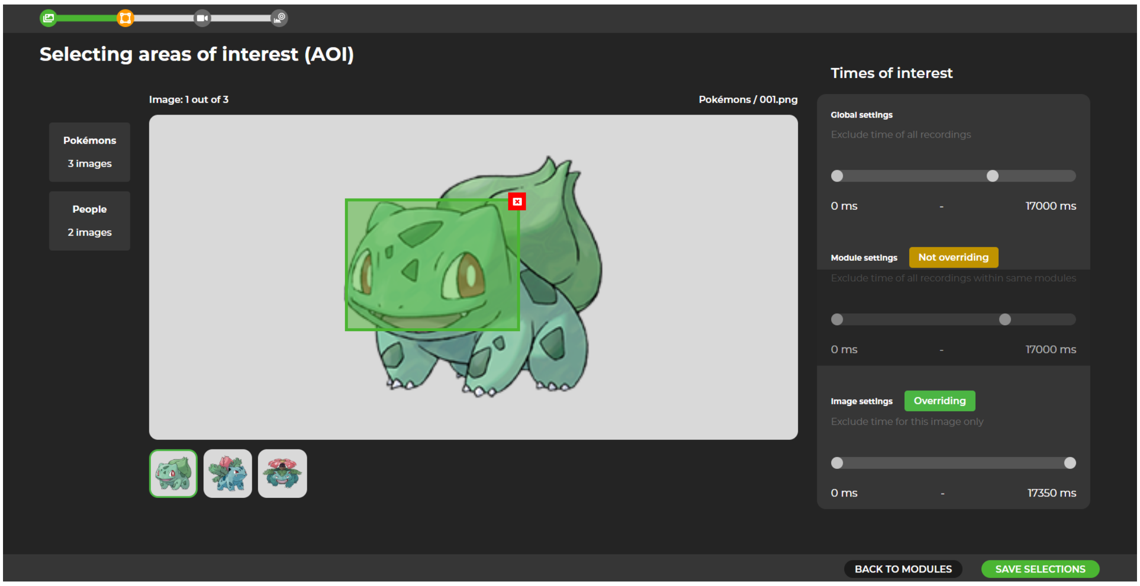


Figure 7.10: Final interactive prototype - Selecting AOI screen

On the "Graph visualization" (Image 7.11) screen, changes are also made to the right panel, where 2 different groups of participants can be compared instead of choosing which module/image should be compared against which one.

Figure 7.11: Final interactive prototype - Visualizations screen

Chapter 8

User testing

This section includes several key subsections. Testing preparation involves planning and defining objectives, selecting metrics, and setting up the testing environment. The testing process includes the actual user testing sessions, where participants perform specific tasks or scenarios while their interactions and feedback are observed and recorded. Evaluation involves analyzing the data collected during testing to identify patterns, insights, and areas for improvement. Lastly, Comparison with existing solution summarizes comparing the implemented software against an existing solution, highlighting strengths, weaknesses, and opportunities for enhancement.

8.1 Testing preparation

When preparing the testing, we had to create the right conditions for the most relevant results. These conditions were the testers, the test environment - both physical and virtual, i.e. recording, server, browser, the programs themselves, the data on which the test was performed and the correct test scenario.

8.1.1 Defining persona

Our user is a researcher, expert, or at least a more proficient computer user who has collected data from previous eye-tracking measurements with different users and is now trying to evaluate and analyze this data.

Testers consisted of 2 groups - experts and users that are not familiar with eye-tracking at all.

The group of experts are senior students who are the authors of the work "The impact of education on human perception" that defined the hypothesis $\mathbf{H}3_0$[33] and [34] on the basis of which the user scenario that was created and has practical experience with the entire interface of the Tobii Pro Lab application, including the analysis of eye-tracking data.

The other testers are proficient users of computers and various programs but have no experience in analyzing eye-tracking data.

8.1.2 Creating user scenario

The creation of the user scenario was based on hypothesis $\mathbf{H}3_0$ [33] and [34]. This script has been modified in that we are not looking for the distribution of fixations - and thus a heatmap or gaze plot, but we have modified the final step to show the difference metric "time to first fixation" between 2 groups, namely students and teachers.

The test scenario (see Table 8.2) was slightly modified for Tobii Pro lab (see Table 8.1) and our solution, mainly due to different interfaces and information architecture, but the tasks of the scenario represented the same idea.

The test was mapped to use all the functions of our implementation and this scenario was replicated for the scenario that was supposed to achieve finding a solution for the mentioned solution of hypothesis $\mathbf{H}3_0$.

User scenarios are defined in Table 8.1 and 8.2.

8.1.3 Metrics and goals

When choosing the metrics and goals, I was based on the literature "Measuring the User Experience - Collecting, Analyzing and Presenting User Experience" [36], where the following metrics were selected after assessing the time requirement and effectiveness:

- Task completion rate - The most important metric that tells whether the given scenario has been fulfilled - suitable for testing complex programs
- Time to complete the task - This metric turned out to be less relevant, due to too big difference between the programs and their interfaces
- Subjective satisfaction - The combination of qualitative data (from the interview) and quantitative data (from the questionnaire) discusses the overall impression of the users. Based on this metric, problems and their solutions were also defined. This metric can be also referred as System Usability Scale [35]

The goal of the test was to go through the entire application completely, and the tasks are described in Table 8.1 and 8.2

8.2 Testing process

The applicants were familiarized with the purpose of the testing, the persona they were to assume and the meaning of the testing was presented to them. There was only one user in the room at any time, along with the testing facilitator.

Task	Description	Prerequisities	Compl. Criteria	Max. Time	Possible Solution
1	[Impressions] Please visit the program and spend 2 minutes looking around.	Tobii Pro Lab with opened project is displayed on the users's screen	User indicated they have finished looking around or the time has elapsed.	2 minutes	The user managed to find and go through analyze module
2	Select a rectangle over Bicycle image using AOI tool	User is currently at page called "Analyze"	User picked desired images and now is on Selecting AOI screen	1 minute	User went to the correct screen (tool), selected bicycle from media selection panel, selected draw tool rectangle and draw rectangle over bicycle image
3	Select Time to First fixation only	User is currently at page called "Metrics"	User found correct metric within list of metrics and unselected all other metrics	1 minute	Quickest solution was to unselect all metrics and find Time to first fixaiton in AOI metric
4	Create custom time of interest, select offset 2 seconds from start and 2 seconds from the end	User is currently at page called "Metrics visualizations"	User found where custom times of interest is located, and create custom time of interest	2 minutes	User clicked on "+" button on the up-right panel, switched toggle buttons and inserted correct offset
5	Select that it should use only RP10 and RP11, as well as area of interest Bicycle	User is currently at page called "Metrics visualizations"	User managed to found where participants are located and checked correct participants and AOI	1 minute	Either going into each group and selecting by each image or selecting via checkbox located in the group header and suddenly deleting unwanted images

Table 8.1: User scenario in Tobii Pro Lab

Task	Description	Prerequisities	Compl. Criteria	Max. Time	Possible Solution
1	[Impressions] Please visit the program and spend 2 minutes looking around.	Web browser is opened at localhost, where the website is running	User indicates they have finished looking around or time has elapsed.	1 minute	The user clicked through max 2. screens, and stopped so he couldn't see whole application
2	Pick all images from group Pokémons. Also pick first and last image from People module. After that, go to next step	User is currently at page called "Modules"	User picked desired images and now is on Selecting AOI screen. On the next screen, user can see Pokémons and People as well as image count, that he selected within those modules	1 minute	Either going into each module and selecting by each image or selecting via checkbox located in the module header and suddenly deleting unwanted images
3	Within last image of People's module, select area of interest that user likes about image the most and override images' times of interest to 0-10000 without changing Global or Module settings.	User is currently at page called "Selecting areas of interest"	User marked second image of People and is now visible in green color. He had overriden image's time of interest.	1 minute	Clicking onto People module and then in the slider on second image. User creates AOI points on the image and then override time on right panel.
4	Select all students but remove students 7 and 8, then click CONTINUE	User is currently at page called "Selecting recordings"	Group "Students" is marked green, and group "Teachers" is marked orange, with Teacher 7 and Teacher 8 unselected	30 seconds	Either going into each group and selecting by each image or selecting via checkbox located in the group header and suddenly deleting unwanted images
5	You want to compare "People" group against "Teachers" group, you are also interested in "Time to first fixation"	User is currently at page called "Graph visualization"	User has selected "People" and "Teachers" within dropdowns, as well as Y axis metric "Time to first fixation"	30 seconds	Selecting 3 dropdowns, order is not important

Table 8.2: User scenario in bachelor's thesis implementation

Before the actual testing, the scenario itself was tested by a pilot user, who only checked whether the given tasks made sense. But this pilot tester did not continue, through those tasks.

The testing occurred in the UX laboratory at the Faculty of Informatics and Information Technology of the STU in Bratislava. In the case of Tobii Pro Lab testing, the user's screen, audio and camera were recorded. Eye tracking was also used when testing our implementation. The screen on which the testing took place had a resolution of 1920x1080.

8.3 Evaluation

When evaluating, we start from Appendix C - Usability test report, where all measurements are recorded in a wider context.

8.3.1 Evaluation of metrics

Metrics were recorded using a stopwatch or a questionnaire (listed next to the metric). These metrics were then entered into a predefined user testing template and if the metrics were numerical, the mean and standard deviation were calculated.

	Tobii Pro Lab					Bachelors's thesis implementation				
	Task 1	Task 2	Task 3	Task 4	Task 5	Task 1	Task 2	Task 3	Task 4	Task 5
TP1	1	1	1	1	0.5	1	1	1	1	1
TP2	1	1	1	0.5	1	1	1	1	1	1
TP3	1	0.5	1	1	1	1	0.5	1	1	1
TP4	1	1	1	1	1	1	1	1	1	1
TP5	1	1	1	0	1	1	1	1	1	1
Avg	1	0.9	1	0.7	0.9	1	0.9	1	1	1
Std	1	0.2	1	0.4	0.2	1	0.2	1	1	1

Table 8.3: Task completion rate

8.3.1.1 Task completion rates

Task completion rate is a binary measure, where 0 indicates failure, 1 indicates success and 0.5 indicates success but with the help of the facilitator.

Based on this metric and referring to Table 8.3 we can evaluate that our software includes a more intuitive and user-friendly interface, clearer instructions and fewer usability errors. Users are able to navigate independently and there are no difficulties and errors.

	Tobii Pro Lab					Bachelors's thesis implementation				
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**
TP1	120	43	28	95	21	60	25	45	16	19
TP2	120	63	31	120	23	60	45	51	14	23
TP3	85	35	23	65	28	60	43	36	11	18
TP4	83	40	26	52	26	60	38	33	8	22
TP5	120	55	31	120	31	60	25	55	12	35
Avg	105.60	47.20	27.80	90.40	25.80	60	35.20	44	12.20	23.40
Std	17.75	10.28	3.06	27.90	3.54	0	8.63	8.44	2.71	6.09

Table 8.4: Time to complete tasks

8.3.1.2 Time to complete tasks

This metric was not well established as authoritative for this solution, due to too much variation between software. Nevertheless, we can see in 8.4 that our solution was much more acceptable for tasks 2 and 4. A weaker result was achieved in task 3, which may be conditioned by the fact that in the scenario in our interface, the task is relatively extensive. The time to complete tasks was measured in seconds.

				TP1	TP2	TP3	TP4	TP5	Mean	Std. dev
1.	Completely	10 - 1	Not at all	8	6	8	4	6	6.4	1.5
2.	Completely	10 - 1	Not at all	2	2	6	6	7	4.6	2.15
3.	Completely	10 - 1	Not at all	4	8	7	8	6	6.6	1.50
4.	Completely	10 - 1	Not at all	10	4	6	10	7	7.4	2.33
5.	Completely	10 - 1	Not at all	4	8	8	8	8	7.2	1.60
6.	Completely	10 - 1	Not at all	2	4	2	4	2	2.8	0.98

Table 8.5: Summary of user ratings from the feedback questionnaire on Tobii Pro Lab solution

				TP1	TP2	TP3	TP4	TP5	Mean	Std. dev
1.	Completely	10 - 1	Not at all	8	8	10	8	9	8.6	0.80
2.	Completely	10 - 1	Not at all	2	4	4	4	3	3.4	0.80
3.	Completely	10 - 1	Not at all	2	4	2	4	4	3.2	0.97
4.	Completely	10 - 1	Not at all	2	4	2	4	2	2.8	0.98
5.	Completely	10 - 1	Not at all	10	7	10	8	10	9	1.26
6.	Completely	10 - 1	Not at all	4	5	5	4	4	4.4	0.49

Table 8.6: Summary of user ratings from the feedback questionnaire on bachelor's thesis solution

8.3.1.3 Subjective satisfaction

From the values from the feedback questionnaire, we evaluated that we were most successful with the learnability heuristic for the question "Do you think that you would need more time to learn how to use this system?", where a total improvement of 4.4 points out of 10 was achieved and for the question "Do you find this system hard to use?" was a total improvement of 3.4 points.

We achieved a less significant improvement in the overall intuitiveness of the program, where the question "Was the system intuitive?" an improvement of 2.2 points was achieved out of the total range of 10 points and for the question "Did you find the layout of the screen to be visually appealing and easy to use?" an improvement of 1.8 points was achieved.

For the other questions, an improvement of 1.2 - 1.6 points was also achieved.

Problem	User scenario	Participant	Severity (1 - 5)
Swiper/carousel was not intuitive on the slide "Selecting modules and images"	2	TP2, TP3, TP4, TP5	4
Drawing AOI over image is by default "Click and move" and not "Click and drag",which have lead to confusion	3	TP1, TP2, TP3, TP5	4
It's hard to input precise time of interest	3	TP3, TP4	3
Stepper is not clickable	1, 2, 3, 4, 5	TP3	2
Confusion when selecting metric of interest when creating visualization	5	TP2, TP5	2

Table 8.7: List of problems

8.3.2 List of problems and recommendations

A list of problems that occurred during testing bachelor's thesis implementation is shown in Table 8.7.

The first problem with severity 4 showed that the swiper is not intuitive on a desktop device, but after a while users found a solution to the given task.

The second problem with severity 4 showed an inconsistency against Tobii Pro Lab, where users could select an area of interest in a click-and-drag style, which did not work in our implementation.

The other issues did not turn out to be too significant to compromise the completeness of the user scenario.

Recommendations to solve problems

1. Add pagination, arrows or draggable scrollbar, so user can use sliders as carousels instead of swipers.

2. Make creating AOIs by implementing "Click and drag", so that when users do "mouseup" event, the AOI will be created, instead of clicking 2 times at different places.

3. Implement custom typed time of interest instead of forcing to use a slider, so that user can input exact value he wants - Simple solution may be double-clicking over value, and that value would change onto the input element.

4. Make already completed steps marked as links, so that the user can get back quicker. However, there should be also some alerts implemented because all data after the step will be lost when there will be changes on the previous slide.

5. Use more common labels, when creating a chart via dropdown options.

8.3.3 Comparison with existing solution

As a result of testing qualitative and quantitative metrics, it was evaluated that our solution is mainly easy to learn and intuitive.

Tobii Pro Lab program is a robust and functional solution that is able to solve the complex problems of eye-tracking analysis, although more user experience is needed. But the program is not stable, which was proven in the testing, where the loading times were high and in one case it was not even possible to complete the scenario, due to the overflow of the computer's memory, because the program was evaluating a completely irrelevant graph in the background.

Testers commented on this program that it is chaotic, it is difficult to find information in it, however, they marked it as more professional and capable of solving tasks.

As for our implementation, the use of a shared layout across the application proved to be appropriate when evaluating eye-tracker data. Users appreciated the easy navigation across the app and the uniform layouts, but this could be due to the fact that the app only addressed one user scenario.

If we were a stakeholder of the Tobii Pro Lab program, we would certainly try to implement solutions to simplify the user flow, or create predefined user flows to solve different scenarios.

Chapter 9

Conclusion

As a result of this work, we evaluated the current state of UX, and eye-tracking and tried to define the right heuristics, metrics and best practices that could be used to create an interface for working with eye-tracker data. It was found that Nielsen's heuristics are applicable and should also be used when working with eye-tracker data. The right information architecture and user flow have proven to be key to solving this problem. At the same time, it was found from the user testing that it is crucial to analyze the data from the eye-tracker in individual steps and thus not show the user options that are irrelevant or unnecessary for him at that moment, which also contributes to a lower error rate and lower overall time to complete the user's goal. We think that by applying the right tools, heuristics and enough iterations and testing, it is possible to create a simpler application with similar functions that will be more accessible even for a more demanding user. The progress of this work could be the implementation of additional functions and thus the possibility of additional user scenarios.

Chapter 10

Resumé

10.1 Úvod

Definícia používateľskej skúsenosti a sledovača pohľadov

10.1.1 Motivácia

Zmysel tejto práce

10.1.2 Ciele a prínos

Ciele a prínos práce a jej prínos spoločnosti

10.2 Úvod do používateľskej skúsenosti

Základné vysvetlenie používateľskej skúsenosti a jej aplikácie

10.2.1 Význam

Bližšia definícia používateľskej skúsenosti

10.2.2 Prínos

Prínos, podstata a dôležitosť toho, čo nám používateľská skúsenosť prináša

10.2.3 Interakcia človek-počítač

Definícia interakcie človek-počítač

10.2.4 Použiteľnosť

Definícia použiteľnosti a kvalitatívne komponenty, z ktorých sa skladá

10.2.4.1 Heuristiky použiteľnosti

Definícia a zoznam heuristík použiteľnosti podľa Jakoba Nielsena

10.2.5 Dizajn zameraný na človeka

Definícia a cieľ dizajnu zamenaného na človeka

10.2.5.1 Proces dizajnérskeho myslenia

Opis a pravidlá dizajnérskeho myslenia

10.2.6 Zmysel sledovača pohľadov pri interakcii človek-počítač

Dôvody, prečo používať sledovač pohľadov pri skúmaní interakcie človek-počítač

10.3 Zrak

Opis zraku ako aktivity

10.3.1 Spracovanie vizuálnych informácií

Opis spracovania vizuálnych informácií človekom

10.3.1.1 Pamäť

Opis ako funguje pamäť v kontexte vizuálnych informácií

10.3.1.2 Vizuálne hendikepy

Hendipeky ovplyvňujúce zrak

10.4 Vizuálna pozornosť

Čo to je vizuálna pozornosť a jej vlastnosti

10.4.1 Úvod

Definícia vizuálnej pozornosti

10.4.1.1 Model zdola nahor

Opis modelu/mechanizmu pozornosti zdola nahor (bottom-up)

10.4.1.2 Model zhora nadol

Opis modelu/mechanizmu pozornosti zhora nadol (top-down)

10.4.2 Aplikovanie vo vývoji softvéru

Príklady aplikovania modelov pri vývoji softvéru.

10.4.2.1 Stroopov efekt

Opisuje, že je náročné prečítať názov farby ak text napísaný inou farbou ako názov

10.4.2.2 Vzor v tvare F

Opisuje, že ľudia sa na objekty pozerajú v tvare F

10.4.2.3 Nielsenove heuristiky

Vybrané Nielsenove heuristiky použiteľnosti

1. Obmedzenie akcií na úplné minimum - Dáva používateľovi málo možností aby sa nemohol zmiasť
2. Nápovedy a chyby - Kde zobrazovať nápovedy a ako zobrazovať chyby

10.4.3 Postupy založené na pozornosti

Príklady použitia v praxi

10.4.3.1 Výber farieb

Výber farebnej škály v kontexte kontrastu.

10.4.3.2 Tlačidlá výzvy na akciu

Definícia a využitie tlačidiel na akciu (CTA)

10.4.3.3 Veľkosti písma

Využitie a zmysel veľkosti písma resp. nadpisov

10.5 Využívanie sledovača pohľadov

Používateľia sledovačov pohľadov a použitie pri obrazovkách

10.5.1 Ciele meraní pomocou sledovača pohladov

Výhody oproti iným analytickým nástrojov

10.5.2 Typy sledovačov pohľadov

Typy sledovačov pohľadov a opis aktuálne najpoužívanejšieho typu

10.5.3 Metriky merania

Metriky, ktoré vieme merať pomocou sledovača pohľadov

10.5.4 Počítačová reprezentácia dát zo sledovača pohľadov

Konverzia dát zo sledovača pohľadov do počítača aby boli mohli byť ďalej spracované

10.5.4.1 Sakády

Definícia sakád, ich časové rozsahy a frekvencie

10.5.4.2 Fixácie

Definícia fixácií, ich časové rozsahy a frekvencie

10.5.4.3 Sledovanie objektu

Pohyb očí za účelom sledovania pohybujúceho sa objektu

10.5.4.4 Oblasti záujmu

Zmysel využitia oblastí záujmu (AOI)

10.5.4.5 Body pohľadu

Aproximácia bodov pohľadu, využitie na pohľadovú cestu (Gaze path)

10.5.4.6 Tepelné mapy

Definícia tepelnej mapy a ich využitie

10.5.4.7 Mapy zamerania / priehľadnosti

Typ vizualizácie podobný tepelnej mape, opísaný je rozdiel

10.5.5 Klasifikátor fixácií

Klasifikácia fixácií pomocou klasifikačného filtra

10.5.5.1 Platformy sledovačov pohľadov

Existujúce platformy sledovačov pohľadov, hlavné vlastnosti a funkcie

10.5.5.2 Rozhranie Tobii Pro Lab

Opis rozhrania Tobii Pro Lab

10.6 Podobné práce

Popis podobných prác a jej relevancia k našej

10.7 Pozorovanie a generovanie nápadov

Začiatok praktickej časti - prístup pri riešení

10.7.1 Informačná architektúra

Informačná architektúra Tobii Pro Lab a návrh vlastnej informačnej architektúry

10.7.2 Používateľský tok

Používateľský tok Tobii Pro Lab a návrh vlastného používateľského toku

10.7.3 Heuristická evaluácia

Výsledky heuristickej evaluácie a podnety spracovanie v prototypoch

10.7.4 Prototypovanie

Opísaný proces prototypovania a iterácií nad prototypmi

10.7.4.1 Prototyp s nízkou vierohodnosťou

Vytváranie prototypu s nízkou vierohodnosťou - rozloženia a komponenty

10.7.4.2 Prototyp s vysokou vierohodnosťou

Vytváranie prototypu s vysokou vierohodnosťou - takmer finálny prototyp

10.7.4.3 Finálny interaktívny prototyp

Vytváranie finálneho finálneho a interaktívneho prototypu formou webovej stránky

10.8 Používateľské testovanie

Úvod a ciele testovania

10.8.1 Príprava testovania

10.8.1.1 Definícia persón

Zadefinovanie používateľov aplikácie

10.8.1.2 Vytvorenie používateľského scenára

Vytvorenie používateľského scenára podľa hypotézy zo súvisiacej práce

10.8.1.3 Sledované metriky

Výber metrík na sledovanie

10.8.2 Priebeh testovania

Ako, kde a na akých zariadeniach testovanie prebiehalo

10.8.3 Evaluácia

Vyhodnotenie testovania

10.8.3.1 Evaluácia metrík

Vyhodnotenie sledovaných metrík na základe testovania

1. Miera dokončenia úloh - Vyhodnotenie metriky miery dokončenia úloh
2. Čas dokončenia úloh - Vyhodnotenie metriky času potrebného na dokončenie úloh
3. Subjektívna spokojnosť - Výsledky z dotazníka a podnety získané bezprostredne po testovaní

10.8.4 Zoznam problémov a odporúčania

Zoznam nájdených problémov v našej implementácií a spôsoby ich riešení

10.8.5 Porovnanie s existujúcim riešením

Silné a slabé stránky oboch testovaných riešení

10.9 Záver

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Appendix A

Work summary

Work summary of winter semester

1.-2. week	Creation of document structure
3.-4. week	Section introduction to user experience
5.-6. week	Section visual attention
7.-8. week	Section using eye-trackers
9. week	Checking up on references and its formatting
10.-11. week	Section introduction and vision
12.-13. week	Section related work
14.-15. week	Chapter eye-tracking platforms and finishing based on supervisor's feedback

Work summary of summer semester

0.-2. week	Discover Tobii project and explore paper
2.-3. week	User scenarios
2.-3. week	User flows in Tobii
2.-4. week	User problems and heuristic evaluation
3.-4. week	Information architecture for US3
3.-4. week	User Flow diagram for US3
4.-5. week	Prototyping Lo-Fi
5.-7. week	Prototyping Hi-Fi
7.-9. week	Implementation
10. week	Usability Testing
11. week	Usability Testing: Evaluation
11.-13. week	Final document
13. week	Document revision and proofreading

Appendix B

Heuristic evaluation

BP2 – Appendix B

Heuristic Evaluation

Bachelor's thesis: User interface for working with eye-tracker data
Heuristics used: Usability Heuristics by Jakob Nielsen

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetics and minimalistic design
9. Help users with errors
10. Help and documentation

Severity rating:

0) I don't agree this is a usability problem at all
1) Cosmetic problem only: need not be fixed unless extra time is available on project
2) Minor usability problem: fixing this should be given low priority
3) Major usability problem: important to fix, so should be given high priority
4) Usability catastrophe: imperative to fix this before product can be released

	Severity	Strengths	Problems	Recommendations
1	4		User doesn't know in what state of an analysis he is. Loading takes a lot of time sometimes	Implementing stepper / progress bar Implementing percentage progress
2	3		It is not intuitive at all, The user cannot map the situation from the real world, including that, adding to this the fact that he does not have a clearly defined flow	Create simple yet effective userflow, that always stays the same

3	4	Project is saved throughout each operation and user can jump to other actions every time he wants to	There are so many ways to get lost by just going through application User doesn't know how many actions until the end of process If the user opens a graph that contains a lot of data, on low-performance computers the program will start to crash and nothing can be done	Implementing stepper, so user can simply go back by clicking on certain step implementing undo/redo. Reducing amount of data and frequency of rerendering existing data
4	3		The process of analyzing visualizations and metrics is very different, and doesn't contain same steps that should be found on same places	Create better informational architecture and simplify userflow
5	3		We don't know why certain functions/variables are not available Highlight modules metrics/variables that are mostly used	Recommend next actions, recommend most used functions and variables. Display anavailable metrics as "disabled", give user a tooltip why is it disabled.
6	3		Only expert user may remember, what action will lead to desired outcome	Create better informational architecture and simplify userflow
7	1	There are many available saves, so we do not have to do everything again when closing a project	Flexibility and efficiency is provided only to expert users, however, loading times may be still high	
8	3		The design is complex, there are many ways for users to get lost	Create better informational architecture and simplify userflows.
9	3		We don't know why certain functions/variables are	Recommend next actions, recommend going back to certain

			not available	step
10	2	Tobii Pro Lab’s documentation is well writen	There are moments, when user don’t what he should to achieve his goal without looking further into documentation	Implement tooltips to give user a hint, what should be his next step

Appendix C

Usability test report

BP2 – Appendix C

Usability Test Report

Name of tested web/application – Bachelor’s thesis prototype implementation

UX Lab, FIIT 3.29, Bratislava – 3. May 2023

1. Summary

These are recommendations that should be implemented into our prototype implementation based on list of problems from Table 10:

1. Add pagination, arrows or draggable scrollbar, so user can use sliders as carousels, instead of swipers.
2. Make creating AOIs by implementing “Click and drag”, so that when users do “mouse up” event, the AOI will be created, instead of clicking 2 times at different places.
3. Implement custom typed time of interest instead of forcing user to use slider, so that he can input exact value he wants – Simple solution may be double-clicking over value, and that value would change onto input element.
4. Make already completed steps marked as links, so that user can get back quicker. However, there should be also some alert implemented because all data after that step will be lost when there will be changes on previous slide.
5. Use more common labels, when creating chart via dropdown options.

2. Test Procedure Description

User Profiles

Our user is a researcher, expert, or at least a more proficient computer user who has collected data from previous eye tracking measurements with different users and is now trying to evaluate and analyze this data.

Test Users

Test User	**TP0 (Pilot)**	**TP1**	**TP2**	**TP3**	**TP4**	**TP5**
Alias	Filip	Adam	Lucia	Expert-1	Expert-2	Matej
Date of Test	3.5.2023	3.5.2023	3.5.2023	3.5.2023	3.5.2023	3.5.2023
Time of Test	13:00	15:45	18:15	17:15	17:45	16:45
Language of Test	Slovak	Slovak	Slovak	Slovak	Slovak	Slovak
General Information						

Test User	TP0 (Pilot)	TP1	TP2	TP3	TP4	TP5
Sex	M	M	F	F	M	M
Age	22	22	23	23	24	23
Education	IT	IT	IT	IT	IT	IT
Sight Impairment						
Sight Aid			Glasses	Glasses		
Colour Blindness?						
Education						
Education level	Undergrad	Undergrad	Bachelor	Bachelor	Bachelor	Bachelor

Table 1: Overview of the test users.

Two expert users were familiar of eye-tracking tools and the Tobii Pro Lab tool specifically, and the other three had never used the tool but were familiar with eye--tracking technology and what could be achieved with this technology.

Test Environment

Equipment	
Device	Desktop PC
Operating System	Windows 10
Web Browser	Tobii Pro Lab / Google Chrome
Internet Connection	Stable / Ethernet
Screen Resolution	1920x1080
Screen Size	19’

Table 2: Environment used for the thinking aloud test.

Recording equipment

In the case of Tobii Pro Lab testing, the user's screen, audio, and camera were recorded. Eye tracking was also used when testing our implementation. Specifically, XY devices.

The screen on which the testing took place had a resolution of 1920x1080 and the screen size was XY"

Tasks

The internal task list used by the test team is shown in the Table 3 below**.** The **description** is given as a task command to the test participant**.**

TOBII PRO LAB

Task No.	Description	Prerequisites	Completion Criteria	Max. Time	Possible Solution Path
1	Impressions] Please visit the program and spend 2 minutes looking around	Tobii Pro Lab with opened project is displayed on the users's screen	User indicated they have finished looking around or the time has elapsed.	2 minutes	The user managed to find and go through analyze module
2	Select a rectangle over Bicycle image using AOI tool	User is currently at page called "Analyze"	User picked desired images and now is on Selecting AOI screen	1 minute	User went to the correct screen (tool), selected bicycle from media selection panel, selected draw tool rectangle and draw rectangle over bicycle image
3	Select Time to First fixation only	User is currently at page called "Metrics"	User found correct metric within list of metrics and unselected all other metrics	1 minute	Quickest solution was to unselect all metrics and find Time to first fixaiton in AOI metric
4	Create custom time of interest, select offset 2 seconds from start and 2 seconds from the end	User is currently at page called "Metrics visualizations"	User found where custom times of interest is located, and create custom time of interest	2 minutes	User clicked on "+" button on the up-right panel, switched toggle buttons and inserted correct offset
5	Select that it should use only RP10 and RP11, as well as area of interest Bicycle	User is currently at page called "Metrics visualizations"	User managed to found where participants are located and checked correct participants and AOI	1 minute	Either going into each group and selecting by each image or selecting via checkbox located in the group header and suddenly deleting unwanted images

Table 3: The internal task list used by the test team to test Tobii Pro Lab interface.

Tasks

The internal task list used by the test team is shown in the Table 4 below**.** The **description** is given as a task command to the test participant**.**

Bachelor's thesis implementation

Task No.	**Description**	**Prerequisites**	**Completion Criteria**	**Max. Time**	**Possible Solution Path**
1	Impressions] Please visit the program and spend 1 minutes looking around	Web browser is opened at localhost, where the website is running	User indicates they have finished looking around or time has elapsed.	1 minutes.	The user clicked through max 2. screens, and stopped so he couldn't see whole application
2	Pick all images from group Pokémons. Also pick first and last image from People module. After that, go to next step	User is currently at page called "Modules"	User picked desired images and now is on Selecting AOI screen. On the next screen, user can see Pokémons and People as well as image count, that he selected within those modules	1 minute	Either going into each module and selecting by each image or selecting via checkbox located in the module header and suddenly deleting unwanted images
3	Within last image of People's module, select area of interest that user likes about image the most and override images' times of interest to 0-10000 without changing Global or Module settings	User is currently at page called "Selecting areas of interest"	User marked second image of People and is now visible in green color. He had overriden image's time of interest	1 minute	Clicking onto People module and then in the slider on second image. User creates AOI points on the image and then override time on right panel
4	Select all students but remove students 7 and 8, then click CONTINUE	User is currently at page called "Selecting recordings"	Group "Students" is marked green, and group "Teachers" is marked orange, with Teacher 7 and Teacher 8 unselected	30 seconds	Either going into each group and selecting by each image or selecting via checkbox located in the group header and suddenly deleting unwanted images

Task No.	Description	Prerequisites	Completion Criteria	Max. Time	Possible Solution Path
5	You want to compare "People" group against "Teachers" group, you are also interested in "Time to first fixation"	User is currently at page called "Graph visualization"	User has selected "People" and "Teachers" within dropdowns, as well as Y axis metric "Time to first fixation"	30 seconds	Selecting 3 dropdowns, order is not important

Table 4: The internal task list used by the test team to test Tobii Pro Lab interface.

Interview Questions

Feedback Questionnaires for both Tobii Pro Lab and bachelor's thesis solution

1.	Was the system intuitive?	Completely	10 9 8 7 6 5 4 3 2 1	Not at all
2.	I had not any troubles completing the tasks?	Completely	10 9 8 7 6 5 4 3 2 1	Not at all
3.	Do you find this system hard to use?	Completely	10 9 8 7 6 5 4 3 2 1	Not at all
4.	Do you think that you would need more time to learn how to use this system?	Completely	10 9 8 7 6 5 4 3 2 1	Not at all
5.	Did you find the layout of the screen to be visually appealing and easy to use?	Completely	10 9 8 7 6 5 4 3 2 1	Not at all
6.	Were there any moments where you felt frustrated or overwhelmed with the task or the design?	Completely	10 9 8 7 6 5 4 3 2 1	Not at all

Table 5: Summary of possible user ratings from the feedback questionnaire.

Metrics

- *Time to complete the task*
- *Task completion rate*
- *Subjective satisfaction*

Task completion rate is often a binary measure, whereby 0 indicates failure, 1 indicates success and 0.5 indicates success with the help of the facilitator:

	Tobii Pro Lab					**Bachelors's thesis implementation**				
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**
TP1	1	1	1	1	0.5	1	1	1	1	1
TP2	1	1	1	0.5	1	1	1	1	1	1
TP3	1	0.5	1	1	1	1	0.5	1	1	1
TP4	1	1	1	1	1	1	1	1	1	1
TP5	1	1	1	0	1	1	1	1	1	1
Avg	1	0.9	1	0.7	0.9	1	0.9	1	1	1
Std	1	0.2	1	0.4	0.2	1	0.2	1	1	1

Table 6: Task completion rates (0 - not completed, 1- completed, 0.5 - assistance was given)

Task completion time measured in seconds:

	Tobii Pro Lab					Bachelors's thesis implementation				
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**
TP1	120	43	28	95	21	60	25	45	16	19
TP2	120	63	31	120	23	60	45	51	14	23
TP3	85	35	23	65	28	60	43	36	11	18
TP4	83	40	26	52	26	60	38	33	8	22
TP5	120	55	31	120	31	60	25	55	12	35
Avg	105.60	47.20	27.80	90.40	25.80	60	35.20	44	12.20	23.40
Std	17.75	10.28	3.06	27.90	3.54	0	8.63	8.44	2.71	6.09

Table 7: Task completion time

Feedback Questionnaires - answers to the facilitator – Tobii Pro Lab solution

Table 8 and **Table** shows a summary of the ratings given by users in the feedback questionnaire at the end of the test. The neutral scale in the original feedback questionnaire has been mapped to a weighted scale between 10 (best) and 0 (worst)

				TP1	TP2	TP3	TP4	TP5	Mean	Std. Dev
1.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	8	6	8	4	6	6.4	1.50
2.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	2	2	6	6	7	4.6	2.15
3.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	4	8	7	8	6	6.6	1.50
4.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	10	4	6	10	7	7.4	2.33
5.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	4	8	8	8	8	7.2	1.60
6.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	2	4	2	4	2	2.8	0.98

Table 8: Summary of user ratings from the feedback questionnaire on Tobii Pro Lab Solution

Feedback Questionnaires - answers to the facilitator – Bachelor's thesis solution

				TP1	TP2	TP3	TP4	TP5	Mean	Std. Dev
1.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	8	8	10	8	9	8.6	0.80
2.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	2	4	4	4	3	3.4	0.80

				TP1	TP2	TP3	TP4	TP5	Mean	Std. Dev
3.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	2	4	2	4	4	3.2	0.97
4.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	2	4	2	4	2	2.8	0.98
5.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	10	7	10	8	10	9	1.26
6.	Completely	10 9 8 7 6 5 4 3 2 1	Not at all	4	5	5	4	4	4.4	0.49

Table 9: Summary of user ratings from the feedback questionnaire on bachelor's thesis solution

Interview transcripts

What do you think about Tobii Pro Lab solution?

1. user - "It seemed more professional but confusing - too much information. Graph's axis is also labeled better."

2. user - "Very unintuitive, but professional"

3. user - "More possibilities of what to do in the program, but it was more complex and chaotic."

4. user - "Bad distribution of information, bad information structure, better statistics, more features (probably unnecessary), more AOI tools like ellipse or polygon"

5. user - "The problem is that the program was slow, I didn't know what was going on sometimes."

What was better about our solution?

1. user - "There was no cognitive load, less difficult words to understand, easier orientation."

2. user - "Sliders were fine, but there should be some kind of pagination or arrows to navigate more intuitively."

3. user - "Fewer options, clear interface, times of interest is better solution is better. Inserting time of interest could be input as well."

4. user - "Flow and times of interest were better; I was missing information about TOI in image list slider though."

5. user - "Clearer interface, maybe because there were not so many features."

List of problems

List of problems that occurred during testing bachelor's thesis implementation

Problem	User scenario	Participant	Severity (1-5)
Swiper / carousel was not intuitive on the slide "Selecting modules and images"	2	TP2, TP3, TP4, TP5	4
Drawing AOI over image is by default "Click and move" and move "Click and drag", which have lead to confusion	3	TP1, TP2, TP3, TP5	4
It's hard to input precise time of interest	3	TP3, TP4	3
Stepper is not clickable	1, 2, 3, 4, 5	TP3	2
Confusion when selecting metric of interest when creating visualization	5	TP2, TP5	2

Table 10: List of problems

Recommendations to solve problems

1. Add pagination, arrows or dragable scrollbar, so user can use sliders as carousels, instead of swipers.
2. Make creating AOIs by creating implementing "Click and drag", so that when users do "mouseup" event, the AOI will be created, instead of clicking 2 times at different places.
3. Implement custom typed time of interest instead of forcing user to use slider, so that he can input exact value he wants – Simple solution may be double-clicking over value, and that value would change onto input element.

4. Make already completed steps marked as links, so that user can get back quicker. However, there should be also some alert implemented because all data after that step will be lost when there will be changes on previous slide.
5. Use more common labels, when creating chart via dropdown options.

Appendix D

User guide to starting the implementation

Downloading project

The first step to run the application is to clone/download the project from the public repository, which is available online here: https://github.com/Matt1s/BP-public

Installing Node.js

In order to download dependencies that are needed for implementation functioning, it is required to install Node.js (preferably version 18.12.1), so that we will be able to use the command "npm" (Node package manager).

Installers are free to download and install here:

https://nodejs.org/en/blog/release/v18.12.1. Please make sure that you download the proper installer for your operating system.

For further Node.js documentation you can visit the official

Node.js website: https://nodejs.org/en

Starting the backend

To start Node.js server, open the command prompt in the project directory - for example, "D:/downloads/BP-public" and type in

```
npm install
```

Node package manager will now install dependencies, after that, please run

```
node ./server/server.js
```

You will be informed on which host and port server is listening to.

Starting the frontend

In order to run frontend code, just open the index.html file and follow the user scenario, which is defined in either Appendix C - usability test report or Appendix D - technical documentation.

Appendix E

Technical documentation

Running the project

In order to run the project, please follow the tutorial in Appendix D - User Guide to start the implementation or see readme.md at https://github.com/Matt1s/BP-public

Project structure

The whole project structure can be seen in Figure 1.

Database

The project uses JSON databases - one for saving images and another for saving participants' recordings. These data are editable only via editing the ./assets/data/*.json files manually. By completing user scenarios, the user is just editing the state of images/participants - whether they are displayed in green and usable in the AOI selection screen.

Server

Changing the state of JSON database files is handled by the Node.js/Express.js server, which implements endpoints, that are triggered from the frontend by the user. When a certain endpoint is used, an informational message is logged to the server console about what data is being handled, along with errors if they occur.

List of endpoints:

- /save - type POST - saves properties of all images within modules
- /load - type GET - loads all modules and images as well as their properties
- /loadChecked - type GET - loads all images within modules, that have property "checked" equal to true
- /loadParticipants - type GET - loads all participants as well as their properties
- /saveParticipants - type POST - saves all participants as well as their properties
- /saveAOI - type POST - edits "aoi" object within images, where the area of interest is being edited

Frontend

Frontend uses simple HTML files. Every HTML file is linked to the same main.css file which contains shared properties like layout, buttons, colours, fonts, header and footer.

Every HTML is linked to another CSS file that is file specific and is not shared through the rest of the application. CSS files were compiled via VS Code extension Live SASS Compiler.

In HTML files, there is also inline JavaScript code within script tags, or external JS files, which are linked either in the head of certain HTML files or at the end of its body, depending on the usage.

When a user goes to the next screen within the user scenario, data are sent to the server via built-in javascript function fetch.

Example fetch function for getting images

```
fetch(‘http://localhost:3000/load‘)
    .then(response => response.json())
    .then(data => {
        dataGlobal = data;
    })
```

If data are fetched correctly, they are suddenly put into a DOM via document.querySelector() function.

Example fetch function for saving images

```
await fetch(‘http://localhost:3000/save‘, {
    method: ’POST’,
    headers: {
        ’Content-Type’: ’application/json’
    },
    body: JSON.stringify(dataGlobal)
    })
```

```
.then(response => response.json())
.then(data => console.log(data))
.then(() => {
    console.log("Data saved")
    window.location.href = "./aoi.html";
})
.catch(error => console.error(error));
```

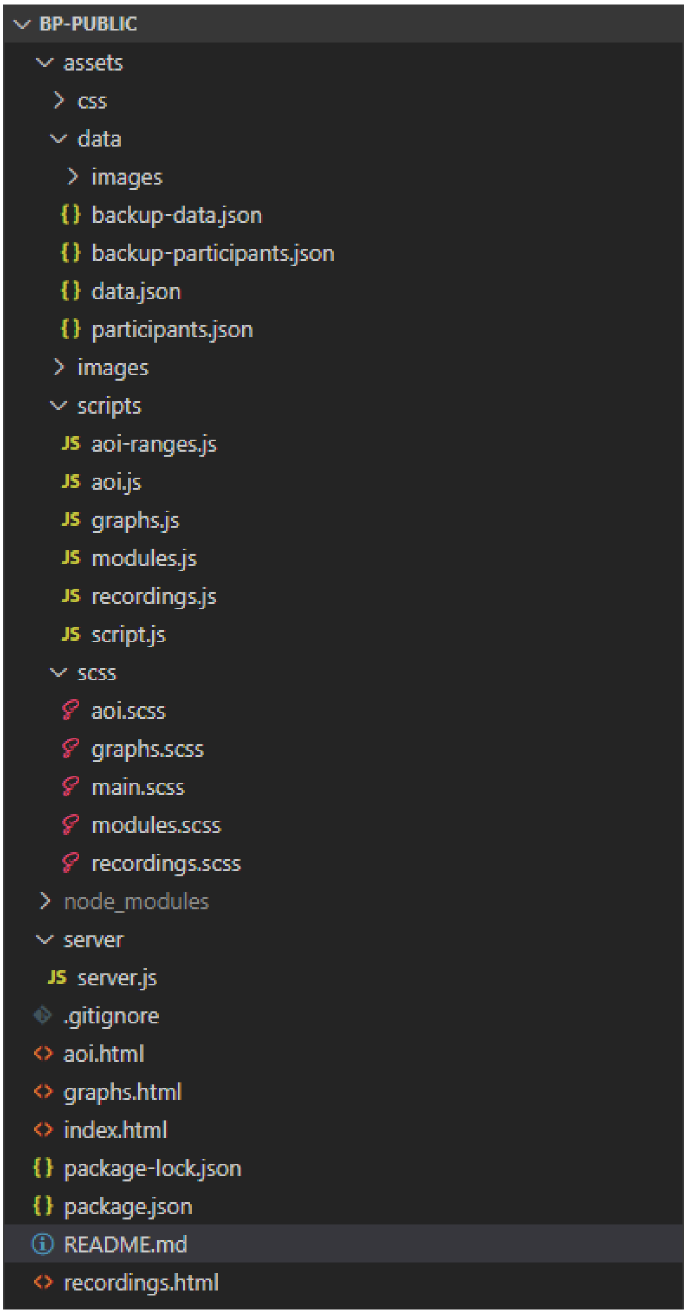

Figure E.1: Project structure

User scenario

The user scenario is attached as a video in the repository - https://github.com/Matt1s/BP-public as "UC-VIDEO.mp4", due to the fact that screenshots from the application would not be visible enough in this document.

Appendix F

Content of electronic media

- assets
  - CSS
    - `*.min.css` .... Generated automatically via Live Sass Compiler extension
    - `*.min.css.map` ...... Generated automatically via Live Sass Compiler extension
  - data
    - images
      - `*.png` .... Images that are used in the application
      - `*.jpg` .... Images that are used in the application
    - `backup-data.json` . Data set that contains paths to image with unset properties
    - `backup-participants.json` Data set that contains participants' data with unset properties
    - `data.json` ...... Data set that contains paths to image current/saved properties
    - `participants.json` ... Data set that contains participants' data with current/saved properties
  - images
    - icons
      - `*.svg` .... Icons that are used thorough application
  - scripts
    - `aoi-ranges.js` . Handling times of interest sliders on AOI screen
    - `aoi.js` .... Handling interactivity on AOI screen

- graphs.js .... Handling interactivity on graphs screen
- modules.js ... Handling interactivity on modules/images screen
- recordings.js ..... Handling interactivity on recordings screen
- scss
  - aoi.scss ....Styling for AOI screen
  - graphs.scss .... Styling for Graphs screen
  - main.scss ....Styling for layout, components, colours, fonts for whole application
  - modules.scss ....Styling for Modules/images screen
  - recordings.scss .... Styling for Recordings screen
- node_modules
  - * ....Dependencies Generated automatically via npm install
- server
  - server.js .... Server file with endpoints
- .git_ignore
- aoi.html .... AOI layout
- BP_MatejPakan.pdf ....Final bachelor's thesis
- graphs.html .... Graphs/visualizations layout
- index.html .... First screen - Module/images screen
- package-lock.json ....Dependencies Generated automatically via npm install
- package.json ....File with information about the project and runnable scripts
- readme.MD ....Guide to download and install application
- recordings.html ....Graphs/visualizations layout
- UC-VIDEO.mp4 ....Video of fulfilling user scenario