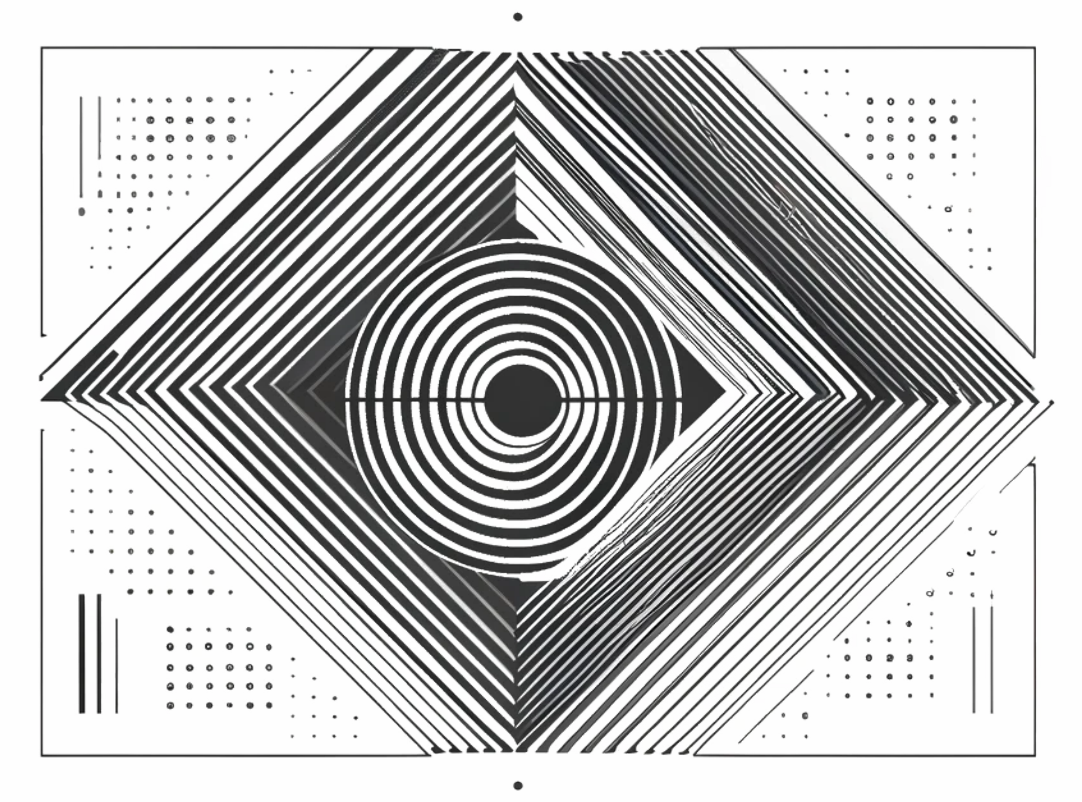
# Usability of the vario-scale approach in interactive and dynamic mapping

## MSc. Geomatics Graduation Thesis Proposal



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# 1 Introduction

In the quiet realm of parchment and ink, where ancient mariners and explorers charted their journeys, the art of cartography reveals its stories. Since ancient times, this craft has not only involved the making of maps but also the blending of reality with the threads of imagination and knowledge. Cartography, derived from the Ancient Greek words χάρτης (chartēs), meaning 'papyrus, sheet of paper, map', and γράφειν (graphein), meaning 'to write', stands as a testament to humanity's enduring quest to understand and delineate the contours of Earth (**AntiqueMapsDavid2007**; "Cartography", 2024). It is a discipline that fuses art, science, and technology, a triad that navigates the vast seas of geographic mysteries and truths. In every line drawn and every feature symbolised, cartographers from ages past to the present day engage in an act of creation that is both scientific and profoundly artistic.

As we delve into the modern era, where digital realms and virtual landscapes begin to dominate, the essence of cartography evolves yet remains anchored in its foundational principles. My thesis, set against the backdrop of this rich history, explores the usability of vario-scale maps through the lens of modern technology, particularly eye-tracking.

The concept of 'variable-scale' or vario-scale maps, as introduced by Van Oosterom and Meijers, allows for a seamless and smooth digital presentation of geographic data across multiple scales (Huerta et al., 2014; Oosterom, 2005; P. van Oosterom and Meijers, 2011). This is achieved through the innovative tGAP data structure, which minimises redundancy and supports progressive map generalisation. Such technology permits the dynamic simplification of map features, prioritising them based on their importance, which could significantly alter the user's engagement with and understanding of spatial data (See Figure 1).

Addressing the usability of these vario-scale maps involves examining how users interact with and experience these dynamic representations compared to traditional multi-scale maps. Utilising methodologies from the realm of eye-tracking provides critical insights into this interaction. Eye-tracking not only records where users look but also interprets these gazes as direct indicators of cognitive processing, thus connecting vision, attention, and action (Fairbairn and Hepburn, 2023; Henderson and Ferreira, 2004). The fixation and saccades data gathered during these sessions reveal the elements of the map that hold the user's attention the longest, providing invaluable feedback on map design and usability.

This thesis employs a mixed-method approach, integrating both qualitative and quantitative research methods such as observations, the think-aloud protocol, and structured questionnaires (Fairbairn and Hepburn, 2023). These methods are complemented by technological analyses such as mouse tracking, which assess user interaction with digital interfaces. Such comprehensive methodology ensures a holistic view of the user experience, capturing the nuanced ways users navigate and understand vario-scale maps over their multi-scale counterparts.

Ultimately, this study aims to suggest refined vario-scale mapping techniques by focusing on user satisfaction concerning map navigation settings, the saliency of labels, and overall map content density and presentation. This effort will hopefully contribute to the broader discourse on how digital maps can better serve our understanding of and interaction with the geographical landscapes they represent.

Figure 1: An example of a vario-scale map of the Netherlands at different zoom levels.

## 1.1 Scientific Relevance

The scientific relevance of this thesis lies in its comprehensive examination of the use of the vario-scale mapping approach, particularly through the innovative application of eye-tracking technology. By integrating eye-tracking into the usability study, this research provides a granular understanding of user interactions and cognitive processes offering insights that complement existing usability metrics. Eye-tracking offers precise data on how users navigate and interpret vario-scale maps, revealing patterns of visual attention and areas of difficulty. This method allows for a more nuanced analysis of usability, going beyond traditional metrics to capture real-time user engagement.

By comparing vario-scale maps with multi-scale maps, this study not only evaluates the effectiveness of vario-scale maps but also advances the broader field of interactive digital mapping. The insights gained from this research can inform the design of more intuitive and user-friendly mapping interfaces, ultimately enhancing the utility and accessibility of vario-scale maps. Therefore, this thesis, represents contribution to both cartographic science and the development of advanced geospatial technologies.

## 1.2 Social Relevance

Given that billions of people worldwide use digital, interactive maps for navigation every month ("Blog", 2019), a small improvement in user experience, such as the smoother interactions and less confusion when changing scale, provided by vario-scale maps, can significantly enhance the quality of life for a large number of users.

For instance, commuters using navigation apps could benefit from more intuitive zooming and panning using the vario-scale technology, reducing cognitive load and making route planning more efficient. This improvement not only makes commuting smoother but also encourages greater use of public transit, reducing traffic congestion and environmental impact. Consequently, enhanced public transit can boost urban residents' mental well-being and quality of life by alleviating daily commuting stress.

Additionally, emergency responders could navigate complex urban environments more swiftly, potentially improving their response times. Tourists exploring unfamiliar cities could find it easier to navigate and discover points of interest, enhancing their travel experience.

Moreover, in educational settings, students and researchers could benefit from more engaging and accurate geographical tools, fostering a deeper understanding of spatial relationships and geographic concepts. Generally, it can be claimed that vario-scale technology enhances the functionality and usability of maps for every application it is used for, due to its profound capabilities.

By examining ways of enhancing the usability of digital maps through vario-scale technology, this research has the potential to contribute to improved societal efficiency, environmental sustainability, safety, and knowledge dissemination.

# 2 Related Work

## 2.1 Vario-scale Maps

Vario-scale maps represent a significant advancement in the field of cartography, particularly in the realm of digital map visualisation and usability. These maps are designed to provide users with a seamless zooming experience, avoiding the common disruptions encountered with multi-scale maps. Central to this technology are the sophisticated data structures that enable continuous generalisation of map features, crucial for a smooth transition across different scales.

The concept of vario-scale maps was fundamentally advanced by Van Oosterom and Meijers, who introduced the tGAP (topological Generalised Area Partition) and SSC (Space Scale Cube) structures. These innovations represent a leap in handling continuous map generalisation, allowing maps to dynamically adjust detail and complexity according to user interaction (P. van Oosterom et al., 2014). The tGAP model is particularly effective in minimising data redundancy while ensuring that both detailed and generalised versions of map features are readily accessible. This is achieved through a strategy where less important features are incrementally simplified based on a global criterion, and all changes are recorded in a database that supports scalable data retrieval (Oosterom, 2005; P. van Oosterom and Meijers, 2011).

Moreover, the SSC as a translation of tGAP in a 3D structure (2D+scale), conceptualises each terrain feature as a polyhedron within a volumetric space. This spatial arrangement allows for effective slicing at various altitudes to produce horizontal map slices that correspond to different levels of detail. By adjusting the slicing plane within the SSC, a smooth zoom effect is created, which simulates a continuous zooming capability (Suba et al., 2016).

## 2.2 Eye-tracking in Usability Research

In recent studies, eye tracking technology has increasingly demonstrated its robust capacity for enhancing our understanding of human-computer interaction and usability research, particularly in the context of map usability studies. Eye tracking systems meticulously record eye movements, capturing crucial metrics such as saccades and fixations that indicate cognitive processing and visual attention (Strandvall, 2009). Rayner's work further underscores the importance of fixations in interpreting visual stimuli, providing a scientific basis for observing user behavior through eye movements (Rayner, 1998).

The integration of eye tracking (See Figure 2) in usability testing, particularly using think aloud methods, has revealed varied applications depending on the task characteristics and interactivity required (Røsand, 2012). Pernice highlights the additional dimension that eye tracking brings to traditional usability studies, allowing for a deeper, more intuitive understanding of user engagement and preventing common errors such as premature interruption during testing (Pernice and Nielsen, 2009).

Moreover, Just and Carpenter's exploration into the cognitive implications of eye fixations reveals the potential to dissect the processing stages within trials, enhancing the granularity of usability assessments (Just and Carpenter, 1976). In cartographic research, the use of eye tracking is pivotal in studying how users interact with maps and geospatial displays. Fairbairn discusses the evolution of methodologies within this domain, emphasizing the role of eye tracking in understanding user interactions with maps, the selection of appropriate eye-tracking equipment, and the analysis of output data (Fairbairn and Hepburn, 2023).

Krassanakis et al. highlight the value of eye tracking for investigating visual perception and search in cartography, underscoring the need to analyse cognitive processes triggered by map elements during map reading tasks (Krassanakis, 2011). This approach is complemented by Wenclik's exploration of saliency models that predict initial gaze behavior in response to salient

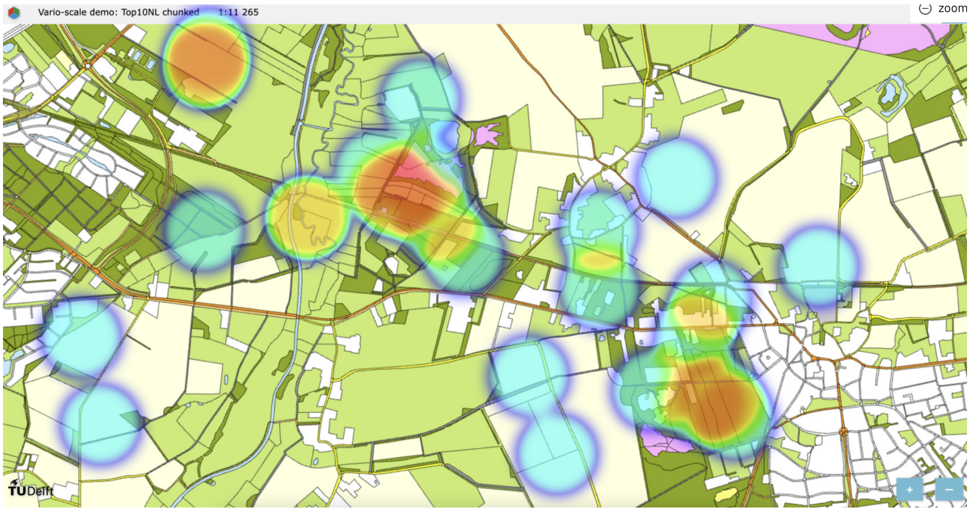


Figure 2: A screen-capture of a heatmap generated using RealEye. The heatmap shows the areas of the vario-scale map that attracted the most attention.

map objects, suggesting a direction for future research into the visual attributes that attract attention (Wenclik and Touya, 2024).

In summary, the convergence of eye tracking technology with usability testing methodologies offers a profound toolset for enhancing the effectiveness and efficiency of map usability studies. This blend not only enriches our understanding of user interactions with complex visual stimuli but also refines the process of interface design, ensuring that maps effectively meet their intended usability goals. The ongoing development and application of mixed-method approaches in this field, as suggested by Fairbairn, ensure a comprehensive assessment of usability by integrating diverse data sources and analytical techniques (Fairbairn and Hepburn, 2023).

It is clear that in the context of usability research, eye-tracking technology offers a precise method for assessing how users interact with various interfaces, providing insights into their visual attention and cognitive processes. This technique involves defining specific tasks that users must perform, which are then analysed to evaluate both the quality and speed of task execution. These tasks are carefully designed to simulate real-world usage scenarios, allowing researchers to gather data on performance efficiency and the effectiveness of design elements in facilitating user goals. User satisfaction is gauged through post-task questionnaires, capturing subjective responses to the interface's usability. For data analysis, sophisticated tools such as heat maps, gaze plots, and fixation metrics are employed. These tools help identify patterns in eye movement and attention allocation, which are crucial for interpreting user interaction dynamics and refining interface design to enhance overall user experience.

### 2.3 Dynamic Labeling

The dynamic labeling of interactive maps is a pivotal aspect in enhancing user experience. Recent advancements underscore the importance of an effective labeling scheme that accommodates both areas and points of interest across varying scales (Krumpe, 2020). Krumpe et al. highlight the challenges associated with naive label reduction strategies during map zooming, which often result in uneven label distribution across densely versus sparsely populated regions. This issue is addressed by adopting a 'relative importance' strategy to ensure that essential labels in less populated areas are retained, thus maintaining a balanced informational perspective across the map.

Further exploring the cognitive aspects of map navigation, Couclelis discusses the anchor-point hypothesis, which assumes that certain geographical features serve as cognitive anchors in mental maps, facilitating spatial orientation and regional structuring (Couclelis et al., 1987). This theory complements the dynamic labeling process by suggesting that certain labels could act as anchor points, enhancing the memorability and navigational ease of maps.

Krassanakis et al. extend this idea into the realm of topographic maps, emphasising the need for salient locations that capture user attention and contribute to effective map design (Krassanakis et al., 2013). The concept of pan-scalar anchors, as discussed by Grugeon in his methodological inquiry, further enriches this perspective by illustrating how certain cartographic elements remain salient across various zoom levels, aiding in self-localisation during map navigation (Gruget et al., 2024).

Dynamic label placement is another critical component discussed by Schwartges and Been, who argue for the need to maintain label consistency across different scales and interactive map manipulations (Been et al., 2006; Schwartges, 2015). They emphasise the importance of avoiding label flickering and jumping during transitions, which can disrupt user orientation and degrade the usability of the map. Their approach involves sophisticated algorithms that prioritise labels based on their importance and manage their visibility across scale transitions smoothly.

Gemsa's work on sliding labels for dynamic point labeling adds another layer to this discussion by addressing the technical challenges associated with maintaining label size and visibility during map zooming (Gemsa et al., 2011). This approach ensures that labels do not overlap or clutter as the map scale changes, thereby preserving the user's cognitive load and facilitating easier interpretation of the map's contents.

## 2.4 Cartographic Map Usability Studies

The domain of usability studies in map applications has seen a variety of approaches aiming to enhance user interaction through optimised map zoom and pan functions. These functions are crucial as they determine how users magnify, reduce, or shift the view of a map without altering its scale, which has a direct impact on user experience (You et al., 2007). The development of vario-scale maps addresses some of these user interaction challenges by providing smoother transitions between various scales, thereby maintaining user orientation and reducing cognitive load during navigation (**subaDesign_development_system_for_varioscale_maps**).

User profiling is a critical initial step in usability studies, ensuring that research encompasses a broad spectrum of user backgrounds, as highlighted by Suba et al., who emphasise the importance of accommodating a diverse range of users to better understand the universal applicability of map interfaces (**subaDesign_development_system_for_varioscale_maps**). Furthermore, the evaluation methodologies, such as field usability tests, highlight the significance of maintaining a 'mental link' between map displays during navigation tasks (Van Elzakker et al., 2008).

Additionally, the research on public usability testing of web-based systems by Van Oosterom provides a framework for assessing the effectiveness, efficiency, and satisfaction, which are crucial metrics in the ISO standards for usability (International Organization for Standardization (ISO), 2018; P. J. M. van Oosterom et al., 2019). These metrics are essential for evaluating whether users can achieve their navigation goals effectively and with minimal effort, which is particularly relevant in the context of dynamic, interactive map applications.

The concept of vario-scale maps is further explored in usability tests where the smoothness of zoom operations and the ability to maintain spatial orientation significantly enhance user satisfaction and reduce navigation errors (Suba et al., 2016). These studies collectively highlight the need for interfaces that allow seamless navigation through different map scales, ultimately aiding users in building a better mental model of the geographical space.

# 3 Research Objectives

## 3.1 Objectives

**Main Research Question**
To what extent do vario-scale maps improve user interaction and satisfaction compared to multi-scale map interfaces?

**Sub-questions**

1. How can cartographic principles be applied to develop effective vario-scale map prototypes?
2. What features, functionalities and settings (e.g. zooming and panning speed) are most critical to include in these prototypes to enhance user interaction?
3. How can the features and functionalities of vario-scale maps be optimised to improve user satisfaction and usability?
4. How does the vario-scale approach affect user performance and satisfaction in map-use tasks compared to multi-scale maps?

## 3.2 Scope of Research

The primary scope of this thesis is to conduct a comprehensive usability study of the vario-scale mapping approach. This involves modifying prototypes based on cartographic principles and evaluating their usability through realistic map-use tasks performed by participants. Using advanced tools such as eye-tracking and screen-logging software, the study aims to capture detailed user interaction and cognitive processes, focusing on ease of use, user satisfaction, and interaction effectiveness. Additionally, the research aims to compare vario-scale maps with other dynamic mapping technologies, specifically the multi-scale approach, to assess their relative advantages and disadvantages. This broader investigation will provide valuable insights into the performance of vario-scale maps in relation to other interactive mapping solutions, ultimately contributing to the evolution of dynamic digital vario-scale mapping.

While this thesis investigates the usability of vario-scale maps, it does not encompass the development of new vario-scale algorithms or technical advancements in map generation. It will not focus on the technical implementation details of the vario-scale data structure beyond what is necessary for usability testing. Additionally, the study will not explore other forms of dynamic mapping technologies in-depth, such as multi-scale maps, except for the purpose of comparative usability analysis. Furthermore, the thesis will not delve into extensive field tests or long-term studies of vario-scale map usage in real-world applications beyond the controlled environment of the lab. Thus, it will not include testing how vario-scale maps perform in outdoor navigation scenarios. It will also not involve longitudinal studies to observe how users adapt to vario-scale maps over weeks or months, nor will it assess the maps' effectiveness in diverse environmental conditions. The focus remains on controlled usability testing within the lab setting, where immediate feedback and detailed interaction data can be collected and analysed.

# 4 Methodology

## 4.1 Exploration Phase

This thesis aims to explore the usability of vario-scale maps through a structured methodology (See Figure 3) that leverages eye-tracking technology and comprehensive user interaction techniques.

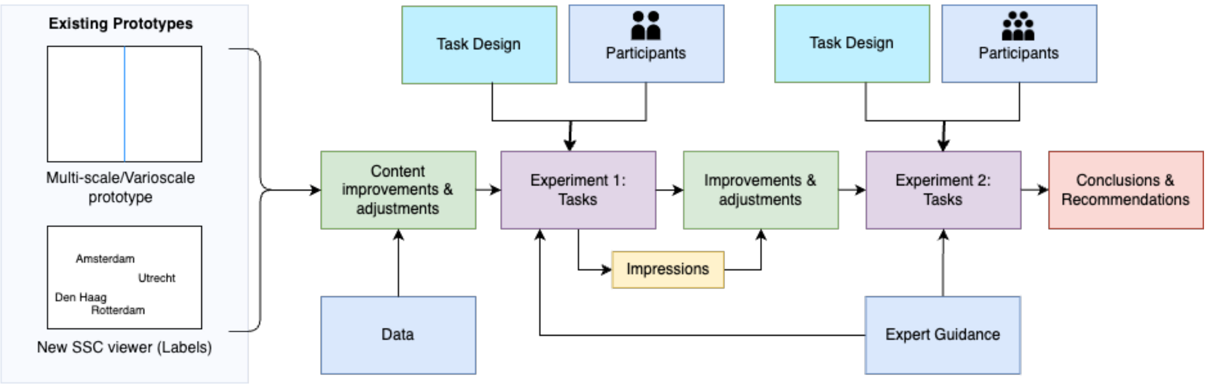


Figure 3: Workflow of the research methodology.

The methodology begins with setting the selection criteria for the eye-tracking device that will be used, based on the price, specifications and the models available in the market, and ends with finalising the ongoing research process of an appropriate eye-tracking device, which is critical for capturing precise user engagement data.

Prior to the main study, an amount of time will be devoted to getting a grip of the operation of the eye-tracking device and its associated software. This process includes a learning curve as the study conductor becomes familiar with using both the device and its accompanying software. Alternatively, in the case that professional commercial software will not be used, the respective code will be developed, in combination with existing scripts and libraries, setting up the necessary software for mouse/keyboard logging and data capturing.

Additionally, becoming further familiar with the development tools for the vario-scale maps, such as Node.js, npm, HTML, CSS, and JavaScript, will require a significant amount of time. This phase is essential for effectively implementing and testing the modifications to the map prototypes.

Finally, from a technological perspective, simultaneously executing vario-scale rendering, screen recording, and capturing all user inputs on a single computer could potentially strain system resources. It is considered crucial to assess the computational capacity of the computer during this phase to ensure it can adequately handle these concurrent processes. Should the laptop prove insufficient for these demands, efforts will be made to secure a more powerful computer, such as a desktop.

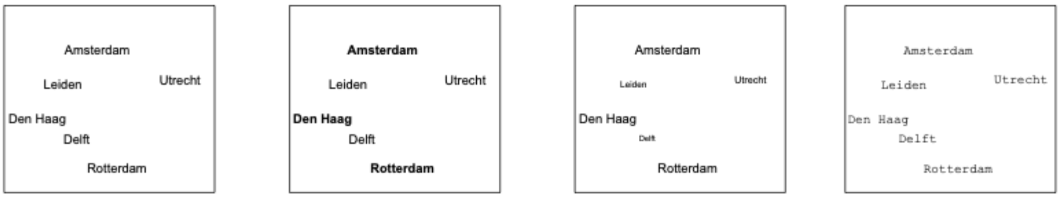
## 4.2 Setting Up Map Prototypes

The initial phase of the methodology involves modifying existing vario-scale map prototypes. For the pilot study phase-as introduced in the next sections-the prototype that is chosen to be used as a basemap, where all the necessary modifications will be implemented, is the map of Drenthe. Intentionally this map will not be the same as the one used in the next phase to avoid the inevitable familiarity of the user with the map that could seriously influence the results. The aim is to test the same map with both the vario-scale and multi-scale approaches.

For the final experiment, we have chosen to test the map developed using Top10NL data, which covers the entirety of the Netherlands and will serve as a good basemap for the panning and zooming tasks. Given the fact that it incorporates embedded interaction settings and gives the opportunity for various implementations, this prototype is considered the most suitable for the study. This same prototype will also be used as a basemap to test the multi-scale approach, but with zoom implemented in a multi-scale manner.

Adjustments to labels, styles, and the addition of landmarks and symbols will be made to enhance visual clarity and user interaction. Label modifications will be implemented using data retrieved from sources such as Open Street Maps (OSM).

Different panning and zooming settings will be tested to determine optimal user settings. The comparison of vario-scale maps and multi-scale maps will aim to assess user preferences and the effectiveness of real-time navigation and map readability.



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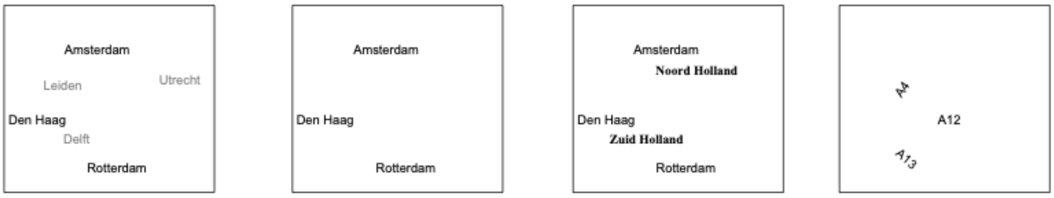


Font color Label density Administrative hierarchy Rotation

Background Color Case Contrast Point symbols

Figure 4: Labels potential modifications.

### 4.3 Initial Pilot Study

Prior to employing the eye-tracking device, an initial pilot study without eye-tracking technology will be conducted. This study will gather preliminary data on user preferences regarding panning, zooming, and map content density both for multi-scale and vario-scale maps. To standardise the experience of all test participants, they are asked to sequentially perform a predetermined set of tasks. These tasks will be performed with varying settings for panning and zooming speed and duration. The tasks are intentionally designed so that the participant will have to perform an extensive combination of zooming and panning to complete them.

Their experience performing these tasks in both vario-scale and multi-scale environments will be gathered through a questionnaire created and distributed in an online form. The questionnaire focuses both on panning and zooming specific aspects, and general map preferences including labelling. The insights from this pilot study about users' preferences regarding the different panning, zooming and general content features will inform further adjustments to the map prototypes to better suit user needs. Subsequently, these insights will set the basis for the task design of the following final experiment.

The necessity of approval from the Human Research Ethics Committee (HREC) (See Appendix A) of TU Delft, will be examined before conducting the pilot study, as it involves privacy-sensitive data obtained from Human Research Subjects.

## 4.4 Final Public Experiment

Following the pilot study, a larger-scale public experiment will be conducted, involving as many participants as possible from diverse backgrounds. Approval for this experiment will be obtained from the Human Research Ethics Committee (HREC) (See Appendix A) of TU Delft, since it involves privacy-sensitive data obtained from Human Research Subjects. The study will involve a diverse group of participants, including individuals of different ages, backgrounds, ethnicities, genders, and individuals with colour vision differences to ensure a broad range of perspectives and experiences. As everyday users of maps are typically non-geomatics, testing with a variety of people will help replicate real-world conditions.

### 4.4.1 Experiment Setup and Execution

The experiment will take place in a pre-determined, preferably quiet location, chosen based on its suitability for conducting eye-tracking and usability studies. Another critical factor in determining the location for the experiment will be the availability of the eye-tracking device. Should professional devices not be available, using a webcam for eye-tracking provides a flexible alternative, allowing the study to be conducted in a broader range of environments, but the faculty will be preferred for reasons of familiarity and engagement.

Before the experiment, each of the participants will be asked to fill out an HREC-approved consent form before participating.

Then, the eye-tracking device will be calibrated for each participant to ensure accuracy. They will be individually introduced to the study. Sufficient time will be given to familiarise themselves with the setup and the environment to minimise any potential discomfort or confusion. This approach ensures that participants feel comfortable and informed, which is crucial for obtaining reliable and accurate data during the usability testing.

During the experiment, participants will interact with the maps displayed on a monitor that has been set up to show either vario-scale or multi-scale prototypes. The original hypothesis is that each participant should test both vario-scale and multi-scale map prototypes to ensure comparability. Special care must be taken in the design of the study to prevent experience gained on one of the two map types that will influence the results when testing the other. Both insights from scientific literature and expert guidance will be deployed to prevent this. Another tactic would be to have participants only test one map type during the whole study, but this would come with challenges for ensuring comparability of the results of both map types. Also, it could cause underrepresentation of certain types of participants for either map type.

The prototypes, developed using cartographic software principles, will incorporate various elements such as labels (See Figure 4), symbols, designed to facilitate user interaction and information retrieval. Additionally, feedback from users regarding the density of map information, including the clarity and placement of labels, as well as the overall ease of navigation on the map will be solicited. By gathering detailed user input, the aspects of the map that are most effective and the ones needing improvement can be identified.

Tasks will include:

1. Distance estimation: The ability of the participant to estimate travelled distances.
2. Orientation: The ability of the participant to return to a previously visited location.
3. Searching: The ability of the participant to locate a specific feature on the map.

Each of the tasks will require the user to perform panning, zooming, and/or label and symbol inspection. The tasks will be designed to be challenging enough to require a combination of these actions, but not so difficult that they end-up causing frustration. The tasks will also aim to be designed to be completed within a reasonable time frame, ensuring that the participants do not become fatigued or lose interest.

The description of the tasks that participants need to complete will not be written on paper to ensure they remain focused solely on the screen, to preserve the eye-tracking integrity. Instead, the conductor of the study will verbally describe the tasks and will be present to address any arising questions in case the participant fails to memorise efficiently. Therefore, it is crucial for the tasks to be clearly defined to prevent any confusion among participants.

### 4.4.2 Data Collection and Analysis

As participants engage with the maps, their interactions will be recorded via the eye-tracking device, and they will be encouraged to verbalise their thoughts using the think-aloud method. This qualitative data will be supplemented with quantitative data from the eye-tracking analysis. After completing their tasks, participants will be asked to fill out a detailed questionnaire. The questionnaire will be distributed to the participants on paper. The purpose of the questionnaire is to assess aspects such as task difficulty, clarity of scale changes, navigation ease, and overall satisfaction with the map interface through targeted questions. Additionally, for the purposes of clarification in instances where participant behaviour is ambiguous or unclear.

## 4.5 Study Aimed Outcomes

The data collected from these sessions will be thoroughly analysed to assess the effectiveness of vario-scale maps compared to multi-scale maps. The sources "Eye-tracking in map use, map user and map usability research: what are we looking for?" (Fairbairn and Hepburn, 2023) and "How to Conduct Eyetracking Studies" (Pernice and Nielsen, 2009) will serve as guiding references to ensure scientific backing for the results. Furthermore, consultation with experts in the field of eye-tracking usability studies will be sought to enrich the research methodology and enhance data interpretation. The conclusions drawn from this analysis will inform recommendations for improvements in the design and functionality of vario-scale maps, aiming to enhance their usability and effectiveness for various user groups. Additionally, the study results allow to quantitivaly and qualitatively assess user satisfaction and task performance differences when using vario-scale maps compared to multi-scale maps.

This detailed methodology aims to pursue a rigorous examination of vario-scale maps, leveraging both technological tools and user-centred research approaches to provide deep insights into user behaviour and preferences.

# 5 Time Planning

Table 1: Time allocation.

| Start | End | Activity |
|---|---|---|
| | June 14 | **P2 - Graduation Plan - Formal Assessment** |
| June 15 | July 14 | Prepare Experimental Usability Study |
| July 15 | July 15 | Conduct Experimental Usability Study |
| July 16 | July 26 | Analysis and Conclusions |
| | TBD | **P3 - Midterm Progress Meeting** |
| July 27 | August 31 | Prepare Final Usability Study |
| September 1 | September 7 | Conduct Final Usability Study |
| September 8 | September 24 | Analysis and Conclusions |
| September 25 | October 6 | **P4 - Formal Assessment** |
| October 7 | October 29 | Finalise thesis |
| October 7 | October 29 | Prepare Final Presentation |
| October 30 | November 10 | **P5 - Public Presentation and Final Assessment** |

## 5.1 Schedule

Table 2: Graduation calendar.

| Event | Date |
|---|---|
| P1 | April 19 |
| P2 | June 14 |
| P3 | To be determined |
| P4 | September 25 - October 6 |
| P5 | October 30 - November 10 |

## 5.2 Meetings and Communicaton

During the initial phases of the thesis, meetings with the supervisors are held weekly. As the project progresses, these meetings shift to a biweekly schedule. The main goal is to ensure the continuous progress of the thesis, make key decisions, address technical challenges, and engage in fruitful brainstorming. Valuable guidance and feedback are being provided in these sessions to keep the research on track.

In addition to regular meetings with my supervisors, I am in contact with several key individuals and departments to support my research. Hans Hoogenboom from the VR department of the Faculty of Architecture at TU Delft is an example of a key-contact. We have reached out to him, and we are in ongoing discussions about obtaining the eye-tracking device.

Furthermore, I have contacted Prof. Dr. Mark Neerincx, from the Human-Centered Computing of TU Delft, who has extensive experience in fundamental and applied research on human-computer interaction. His expertise, particularly in enhancing social, cognitive, and affective processes in human-automation teams, could be of great value to my research. I have reached out to him for potential advice and feedback, given his previous use of eye trackers and usability studies.

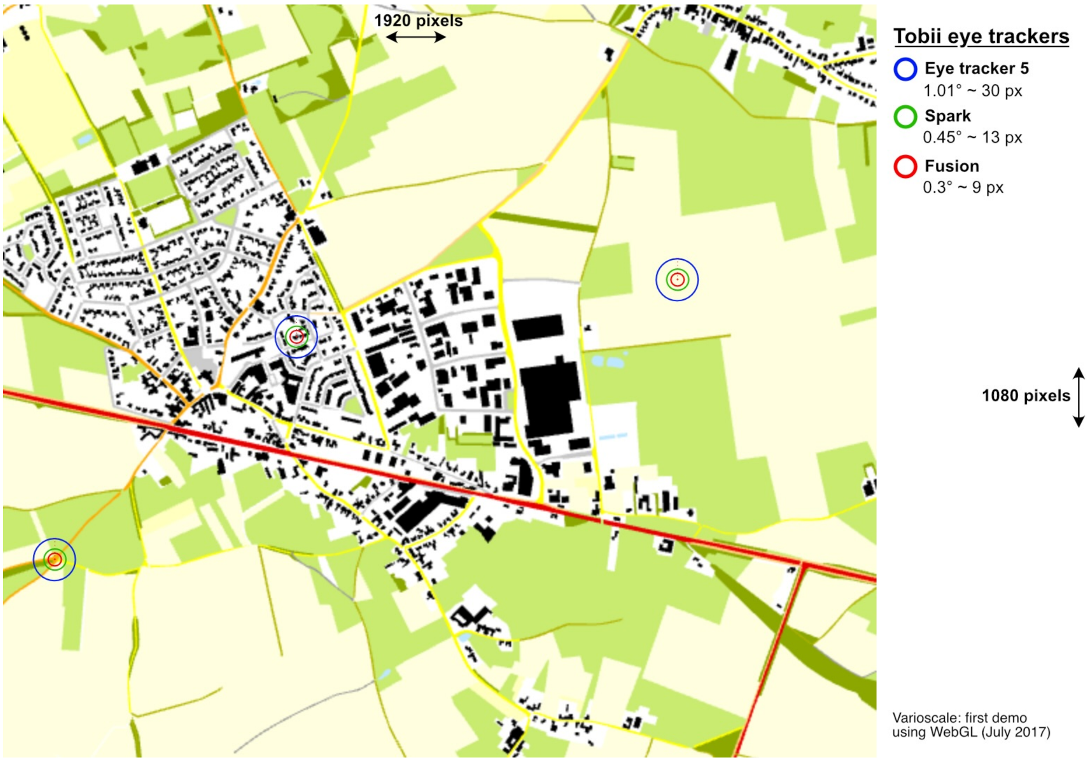
SOLO and the LUCL lab at Leiden University have also been contacted. These experts would hopefully provide significant expertise, not only in terms of advice regarding usability studies but also with their experience in using eye-tracking devices and software. However, they are not yet confirmed as collaborators.

The co-reader for the thesis has not yet been decided.

# 6 Tools and Data

## 6.1 Tools

The usability study will utilise a variety of tools to collect comprehensive data on user interactions with vario-scale and multiscale maps. A critical and unique component of this study is the screen-based eye-tracking device, for which research (See Figure 5) has been conducted on the specifications of 11 different models (See Appendix B). These specifications include model, price, screen compatibility, sampling rate, operating distance, precision, accuracy, pros & cons, and associated software for data analysis.



Varioscale: first demo using WebGL (July 2017)

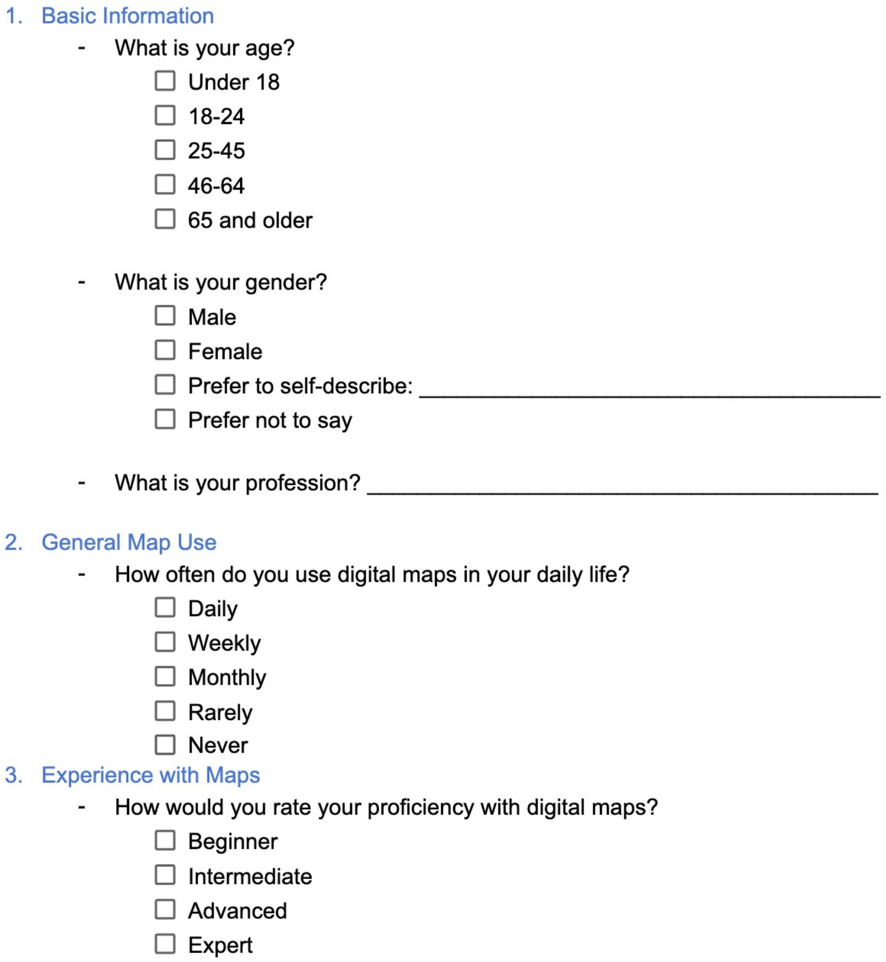
Figure 5: Comparing Tobii devices accuracy.

Our primary objective is to employ a professional eye-tracking device due to its enhanced accuracy and precision. TU Delft is the preferred location for conducting the study as it provides access to geomatics students as participants with previous cartographic experience. We are exploring collaboration possibilities with Leiden University due to its proximity. If collaboration with Leiden University is not feasible, the University of Twente remains an alternative, offering both professional equipment and participants with diverse backgrounds in cartography. We are currently awaiting a response from Leiden University regarding collaboration. Both Leiden University and the University of Twente would utilise Tobii Pro Lab software for the eye-tracking study, which supports the design, recording, and analysis of visual stimuli.

Additionally, we are in communication with a researcher from TU Delft experienced in eye-tracking, who may facilitate access to the necessary equipment. Should these options prove unviable, we will resort to using a webcam-based eye-tracking approach, ensuring that data collection can still proceed for the thesis. The selected eye-tracking device will be complemented by a suite of recording and analytical tools to ensure comprehensive data collection during usability tasks.

A crucial aspect of utilising multiple recording methods is ensuring they are synchronised in time. If the ongoing process of acquiring professional eye-tracking equipment with its accompanying software is successful, this software is capable of synchronisation. In the alternative case of using separate equipment and software for the different recordings, special care will be taken to synchronise their timestamps, and to cross-validate this, "anchor" events will be performed. In these events, an action is performed that is captured on all recordings so it can be ensured that time is indeed synchronised.

Voice recording will be conducted on the study computer, while video documentation will be carried out with either a mobile phone or a DSLR camera. Mouse/keyboard movements will be tracked through either custom-developed code or existing software. Additionally, the x and y position along with the current map scale will be recorded, in order to keep track of the part of the map that is visible over time and at what scale. The questionnaire of the final experiment (See Figure 6) will be designed to collect subjective feedback on the usability of the multi-scale and vario-scale maps.



1. Basic Information
   - What is your age?
     - ☐ Under 18
     - ☐ 18-24
     - ☐ 25-45
     - ☐ 46-64
     - ☐ 65 and older
   - What is your gender?
     - ☐ Male
     - ☐ Female
     - ☐ Prefer to self-describe: ________________________________
     - ☐ Prefer not to say
   - What is your profession? ________________________________
2. General Map Use
   - How often do you use digital maps in your daily life?
     - ☐ Daily
     - ☐ Weekly
     - ☐ Monthly
     - ☐ Rarely
     - ☐ Never
3. Experience with Maps
   - How would you rate your proficiency with digital maps?
     - ☐ Beginner
     - ☐ Intermediate
     - ☐ Advanced
     - ☐ Expert

Figure 6: Questionnaire draft design.

Furthermore, the think-aloud method will be integrated into the study protocol to analyse cognitive processes, providing deeper insights into how users interact with and process information from the two map types.

The study will utilise a monitor, the size of which will be determined by the specifications of the chosen eye-tracking device to ensure optimal compatibility.

This combination of tools and methods is designed to deliver a deep understanding of user behaviour, essential for refining the design and functionality of vario-scale cartographic products.

## 6.2 Data

The data collected from this study will be multifaceted, providing a comprehensive understanding of user interactions with vario-scale maps. From the questionnaires, we will gather subjective feedback on various aspects of usability, including task difficulty, clarity of scale changes, satisfaction with information, ease of navigation, and suggestions for improvements. The mouse/keyboard tracking logs will offer detailed insights into user behaviour, capturing scrolling, clicking, and navigation patterns on the screen. Heatmaps generated from eye-tracking data will visually represent areas of high and low user attention, helping to identify focal points and potential problem areas on the maps, at different scales. Additionally, the eye-tracking software will provide precise metrics such as gaze duration, fixation points, and saccades, which will be useful for understanding how users engage with different map elements and actions, such as panning and zooming. Data from the professional or developed software will include detailing on how users interact with the map over time.

Finally, the data put on the map such as labels, and topographic information, will be analysed to see how effectively users can interpret and navigate the information provided. These diverse data sets will enable a thorough evaluation of the vario-scale maps and guide the development of enhancements to improve their usability.

# References

Been, K., Daiches, E., & Yap, C. (2006). Dynamic Map Labeling. *IEEE Transactions on Visualization and Computer Graphics*, *12*(5), 773–780. https://doi.org/10.1109/TVCG.2006.136

Blog: 9 things to know about Google's maps data: Beyond the Map. (2019, September).

Cartography. (2024). *Wikipedia*
Page Version ID: 1223272473.

Couclelis, H., Golledge, R., Gale, N., & Tobler, W. (1987). Exploring the anchor-point hypothesis of spatial cognition. *Journal of Environmental Psychology*, *7*(2), 99–122. https://doi.org/10.1016/S0272-4944(87)80020-8

Fairbairn, D., & Hepburn, J. (2023). Eye-tracking in map use, map user and map usability research: What are we looking for? *International Journal of Cartography*, *9*(2), 231–254. https://doi.org/10.1080/23729333.2023.2189064

Gemsa, A., Nollenburg, M., & Rutter, I. (2011). Sliding labels for dynamic point labeling.

Gruget, M., Touya, G., Potié, Q., & Muehlenhaus, I. (2024). A methodological inquiry for anchoring pan-scalar maps. *AGILE: GIScience Series*, *5*, 1–6. https://doi.org/10.5194/agile-giss-5-27-2024

Henderson, J. M., & Ferreira, F. (Eds.). (2004). *The interface of language, vision, and action: Eye movements and the visual world*. Psychology Press.

Huerta, J., Schade, S., & Granell, C. (Eds.). (2014). *Connecting a Digital Europe Through Location and Place*. Springer International Publishing. https://doi.org/10.1007/978-3-319-03611-3

International Organization for Standardization (ISO). (2018). Ergonomics of human-system interaction - part 11: Usability: Definitions and concepts.

Just, M. A., & Carpenter, P. A. (1976). Eye fixations and cognitive processes. *Cognitive Psychology*, *8*(4), 441–480. https://doi.org/10.1016/0010-0285(76)90015-3

Krassanakis, V. (2011). An Application of Eye Tracking Methodology in Cartographic Research.

Krassanakis, V., Lelli, A., Lokka, I.-E., & Nakos, B. (2013). Searching for salient locations in topographic maps.

Krumpe, F. (2020). *Labeling Interactive Maps* [Doctoral dissertation].

Oosterom, P. (2005). Variable-scale Topological Data Structures Suitable for Progressive Data Transfer: The GAP-face Tree and GAP-edge Forest. *Cartography and Geographic Information Science - CARTOGR GEOGR INF SCI*, *32*, 331–346. https://doi.org/10.1559/152304005775194782

Pernice, K., & Nielsen, J. (2009). How to Conduct Eyetracking Studies.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*(3), 372–422. https://doi.org/10.1037/0033-2909.124.3.372

Røsand, T. (2012). Think Aloud Methods with Eye Tracking in Usability Testing.

Schwartges, N. (2015). Dynamic Label Placement in Practice.

Strandvall, T. (2009). Eye Tracking in Human-Computer Interaction and Usability Research.

Suba, R., Driel, M., & van Oosterom, P. (2016). Usability test plan for truly vario-scale maps.

Van Elzakker, C. P. J. M., Delikostidis, I., & Van Oosterom, P. J. M. (2008). Field-Based Usability Evaluation Methodology for Mobile Geo-Applications. *The Cartographic Journal*, *45*(2), 139–149. https://doi.org/10.1179/174327708X305139

van Oosterom, P., & Meijers, M. (2011). Towards a true vario-scale structure supporting smooth-zoom. *Proceedings of 14th ICA/ISPRS Workshop on Generalisation and Multiple Representation*, 1–19.

van Oosterom, P., Meijers, M., Stoter, J., & Šuba, R. (2014). Data structures for continuous generalisation: tGAP and SSC. In D. Burghardt, C. Duchene, & W. Mackaness (Eds.), *Abstracting geographic information in a data rich world: Methodologies and applications of map generalisation* (pp. 83–118, Vol. 15). Springer.

van Oosterom, P. J. M., Cemellini, B., & Thompson, R. (2019). Results of the Public Usability Testing of a Web-Based 3D Cadastral Visualization System.

Wenclik, L., & Touya, G. (2024). EyeCatchingMaps, a Dataset to Assess Saliency Models on Maps. *AGILE: GIScience Series*, *5*, 1–6. https://doi.org/10.5194/agile-giss-5-51-2024

You, M., Chen, C.-w., Liu, H., & Lin, H. (2007). A Usability Evaluation of Web Map Zoom and Pan Functions.

# A HREC Approval Process

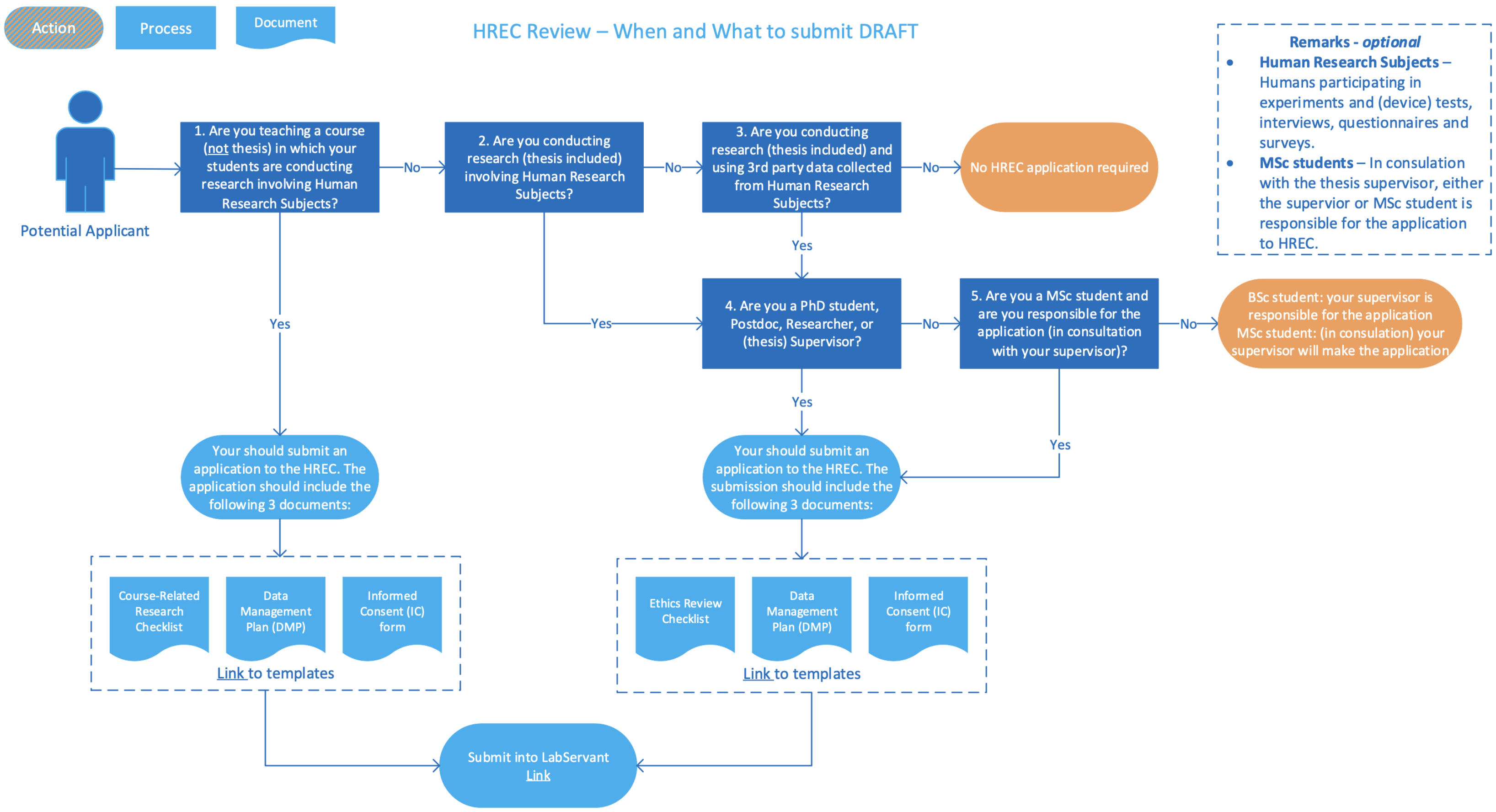


Figure 7: HREC approval process.

# B Eye-tracking Device Comparison

| a/n | Model | Screen comp. (inches) | Sampling Rate (Hz) | Oper. dist. (cm) | Precision (°) | Accuracy (°) | Pros | Cons | Software |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Tobii Pro - Spectrum | 24 | 1200 | 55-75 | 0.02 | 0.17 | Extremely high precision and sampling rate, ideal for detailed research. | Very expensive, may be over-spec for basic usability studies. | |
| 2 | Tobii Pro Fusion | 24 | 250 | 50-80 | 0.04 | 0.3 | High precision, sleek. | Quite expensive, might be more than needed for usability tasks. | |
| 3 | Tobii Pro X3 | 25 | 120 | 50-90 | 0.24 | 0.4 | | | |
| 4 | Tobii Pro - Spark | 27 | 60 | 45-95 | 0.26 | 0.45 | Good balance of performance and cost, suitable for larger screens. | Lower sampling rate than other high-end models. | Tobii Pro Lab, Tobii Pro SDK (requires programming knowledge) |

| a/n | Model | Screen comp. (inches) | Sampling Rate (Hz) | Oper. dist. (cm) | Precision (°) | Accuracy (°) | Pros | Cons | Software |
|---|---|---|---|---|---|---|---|---|---|
| 5 | Tobii Eye Tracker 5 | 27/30 | 133 | 50-95 |  | 1.01 | Very affordable and sufficient for entry-level research. | Lower precision and sampling rate, not ideal for detailed eye movement analysis, gaming focused. |  |
| 6 | Eye Link 1000 Plus | N/A | 1000 | 60-150 | 0.05 | 0.25 | High precision and accuracy, best for complex and detailed eye tracking. | Very expensive, quite large setup, perhaps overqualified. | EyeLink Data Viewer (Output: X and Y position data and pupil size) |
| 7 | GP3 HD | 24 | 60/150 | N/A | N/A | 0.5 | Affordable, adequate precision for most usability studies, recommended for developers and researchers. | Precision and sampling rate not suited for highly detailed tracking, extra monitor bracket mount. | API/SDK included |

| a/n | Model | Screen comp. (inches) | Sampling Rate (Hz) | Oper. dist. (cm) | Precision (°) | Accuracy (°) | Pros | Cons | Software |
|---|---|---|---|---|---|---|---|---|---|
| 8 | GP3 | 24 | 60 | 50-80 | N/A | 0.5 | Affordable model, suitable for basic research needs, recommended for eye tracking software developers. | Limited in high-detail tracking capabilities. | API/SDK included |
| 9 | Smart Eye AI-X | 24 | 60 | 45-85 | 0.1 | 0.5 | High sampling rate, sleek, fast setup, UX suitable | High-cost | Smart Eye Tracker (Output: Gaze point, pupil diameter, time stamp) |
| 10 | Smart Eye Aurora | 24 | 60/120 /250 | 50-80 | 0.1 | 0.3 | Small and discrete, quick setup. | Expensive and may provide more functionality than necessary. | iMotions, PST E-Prime 3.0 (Output: TCP/UDP/Text log) |

| a/n | Model | Screen comp. (inches) | Sampling Rate (Hz) | Oper. dist. (cm) | Precision (°) | Accuracy (°) | Pros | Cons | Software |
|---|---|---|---|---|---|---|---|---|---|
| 11 | EyeTech VT3 Mini | 22 | 40/60/ 120/200 | 50-70 | N/A | 0.5 | Compact and one of the most affordable, good for basic studies. | Low sampling rate, limited in capturing quick or subtle eye movements. | |