Think positive! –
Comparing positive and negative experiences of bicycle riders

An empirical study using eye tracking and body motion capture

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Abstract

To enhance urban cycling, various studies have researched the perspectives of bicycle riders. One possible research approach is to analyze bio-physiological data to identify evidence-based indicators of cyclists' perceptions. So far, studies following this approach have primarily focused on negative aspects, such as perceived safety and risk. However, in order to make cycling more attractive positive experiences are valuable as well. Addressing this research gap, the present study compares eye and head movements between positive and negative experiences of bicycle riders. For this purpose an in situ study was conducted capturing eye and head movements of 28 participants during cycling. Preliminary results revealed significant physiological differences for the fixation durations as well as for the visual attention on vegetation, tram/bus, and traffic signage. No differences were found regarding head movements of positive and negative experiences. However, differences in head movements between experienced and inexperienced rider could be identified.

In verschiedenen Studien wurden subjektive Erfahrungen von Radfahrenden untersucht, um das Fahrradfahren in der Stadt zu verbessern. Ein möglicher Forschungsansatz dafür ist die Analyse bio-physiologischer Daten, mit dem Ziel, evidenzbasierte Indikatoren für subjektive Erfahrungen zu finden. Bisherige Studien befassten sich dabei im Wesentlichen mit negativen Erfahrungen wie etwa dem subjektiven Sicherheits- oder Risikoempfinden. Um das Radfahren zu attraktivieren, sind jedoch auch positive Erfahrungen von Interesse. Um diese Forschungslücke zu schließen, wurden im Rahmen dieser Masterarbeit die Augen- und Kopfbewegungen von 28 Radfahrenden in der Stadt während positiver und negativer Erlebnisse erfasst und verglichen. Erste Ergebnisse zeigten signifikante Unterschiede in der Fixationsdauer sowie in der visuellen Aufmerksamkeit auf Vegetation, Straßenbahn/Bus und Verkehrszeichen. In Bezug auf die Kopfbewegungen wurden keine Unterschiede zwischen positiven und negativen Erfahrungen beobachtet, es konnten jedoch Unterschiede zwischen erfahrenen und unerfahrenen Radfahrenden festgestellt werden.

Erklärung zur Verfassung der Arbeit

Sarah Prinz, Bsc.

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe. KI (namentlich ChatGPT und DeepL) wurde nur zu grammatikalischen und orthografischen Überprüfungen, als Thesaurus und zur Übersetzung verwendet.

Wien, 19. Februar 2025

Sarah Prinz

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CHAPTER 1

Introduction

Cycling is seen as a healthy and environmentally friendly alternative to motorized modes of transport. It is no surprise that different cities, especially in climate change contexts, therefore aim to improve their bicycle infrastructure to enhance cycling (e.g. Bundesministerium für Klimaschutz Österreich, 2021; Bundesamt für Strassen Schweiz, ASTRA; Great London Authority 2018). But how? One way to approach the question is through the perspective of the bicycle riders themselves. Cycling, especially in the city, is quite a demanding task (Acerra et al. 2023). Signs, different kinds of roads, pavements, surroundings and different driving speeds are factors that cyclists need to coordinate while driving. How cyclers perceive and evaluate these factors is crucial for mobility planning in terms of safety and attractiveness of bicycle infrastructure (Álvaro Fernández-Heredia et al. 2014). Safety is, for obvious reasons, a very highly weighted factor in planning. More and more not only „objective safety“ based on accident statistics but also "subjective safety" is considered and studied in more detail (von Stülpnagel and Krukar 2018). For (potential) cyclers, the feeling of being safe is just as important as actually being safe. This is especially relevant for inexperienced cyclers, since their first experiences are most likely to influence their future (not-)cycling (Gössling and McRae 2022). Friel et al. 2023 name perceived safety, comfort and comprehensibility as key factors for the choices of (potential) cyclists. As a result, numerous studies seek to establish quantifiable, evidence-based indicators for cyclists' perceived safety and overall comfort. Williams et al. 2023 have explored the topic through questionnaires and geoanalysis. Beck et al. 2024 try to quantify the interactions of the cyclers' ridership, the infrastructure and the built environment on a larger scale with travel surveys and land use characteristics. Further approaches include using simulators, virtual reality scenarios or image manipulation (Olsson and Elldér 2023; Nazemi et al. 2021; Friel et al. 2023; von Stülpnagel and Krukar 2018).

A relatively new approach to evaluating people's experiences is using sensors to measure bio-physiological data, such as heart rates, skin conductance or eye-movements. This allows evidence-based, quantifiable data to be generated and as a result makes subjective experiences measurable. Different disciplines interested in the ways cities are built and work, including geography, urban planning, geoinformation and behavioral psychology have begun to use such techniques to study people's perceptions in order to better understand how they behave, navigate and orient themselves in urban environments (Fitch et al. 2020; Motzer et al. 2023; Dörrzapf 2023; Werner et al. 2019). This opens up new opportunities and motivations for interdisciplinary work. Dörrzapf et al. 2015 for example, have already argued in 2015 for the establishment of a new interdisciplinary field in urban planning and geoinformation, called 'urban emotions'. Since then, numerous studies have explored urban emotions in cyclists, using qualitative approaches (e.g. Dunlap et al. 2020; Ravensbergen et al. 2020; Gadsby et al. 2021) as well as using bio-physiological measures, as described above (e.g. Fitch et al. 2020; von Stülpnagel 2020; Fournier et al. 2020). This study contributes to the field of urban emotions by analyzing eye and upper body movements to investigate in bicycle riders' experiences, hoping to strengthen informed decision-making in infrastructure development.

1.1 Related work

Eye movements

To research experiences of bicycle riders, eye movements have already been analyzed in simulated and real-world scenarios, typically focusing on safety, comfort, or stress (e.g. von Stülpnagel 2020; Acerra et al. 2023; Rupi and Krizek 2019; Pashkevich et al. 2022). An overview of this research is well presented by Kchour et al. 2025 and Ma et al. 2024 in their literature reviews. These studies have already shown, that eye movements of route segments where cyclists feel safe differ from those observed on other road segments (Ma et al. 2024). In addition, different variables were shown to influence eye movements of cyclers such as whether the cyclers know the surrounding (familiarity) or how experienced they are (Rupi and Krizek 2019; von Stülpnagel 2020). However, the focus of these studies lay on negative moments only. For cyclists, using a bicycle should not just be 'not negative' in order to encourage continued cycling; it should be a positive experience. For infrastructure design it is therefore valuable to know what factors can contribute to positive experiences. Focusing on positively perceived experiences fills a gap in current eye-tracking research as also highlighted by a literature review from Zhang et al. 2024. The goal of this study is to address this gap by comparing specifically positive experienced moments during cycling with negatively experienced moments.

Head movements

In studies focusing on pedestrians using motion-capture technology is a new approach to empirical and quantifiable indicators. By capturing body movements, new information about the way pedestrians move and orient themselves in urban settings is found (e.g. Boltes et al. 2021; Tavana et al. 2024). Thinking about the complexity of cycling a new understanding of bicycle ridership could be gained by using that motion-capture technique on bicycle riders as well. While eye-tracking can already give insights in visual aspects of cycling, the visual aspect does not make up cycling in total. Acerra et al. 2023 suggest, but could not validate in their study due to simulation capacities, that different road pavements and vibrations could be crucial points to bicycler's stability and therefore also for their perceived safety and comfort. Using motion-capture technology could provide a greater understanding of cyclists' perceived experiences in a more holistic manner. To the author's knowledge motion-capture hasn't been used on bicycle riders for that purpose yet, except for the study from Matviienko et al. 2023, which focuses on head movements only. Matviienko et al. 2023 have found that head movements can be indicators of perceived safety of bicycle riders. However, better results were obtained in their indoor experiment (simulator) compared to their outdoor experiment, where significant results were obtained for only one of the tested scenarios. In the experiment conducted for this study, participants' upper body movements (including head movements) were captured with IMU (Inertial Measurement Unit) sensors. We are therefore able to verify Matviienko et al. 2023 results and to put them in a broader context. While all upper body movements have been collected as well, within the scope of this master thesis only head movements are analyzed.

Differences to comparable in-situ experiments

To investigate differences in positively and negatively perceived moments of bicycle riders, an in situ experiment was designed and conducted. In addition to collecting eye and upper body movements, further variables were collected, resulting in a more comprehensive experimental setup. The broader data collection enables the opportunity for a more profound analysis of the factors that shape subjective experiences. This distinguishes the experimental setup from comparable in situ studies. An overview of the collected variables that differentiate this study from similar experiments is given below.

(1) In other studies using eye-tracking (e.g. von Stülpnagel 2020; Ma et al. 2024) the cyclist's sense of e.g. safety is typically assessed after an experimental ride by asking participants to mark locations where they felt unsafe on a map – a method that may be affected by recall bias. In the conducted experiment the study procedure was adapted to mitigate this recall bias as much as possible: Participants were asked to indicate changes in perceived safety by saying 'now' during the experiment ride. This reduced the mental workload compared to think aloud protocols. More details were asked during the post-task while participants were watching the video of their experiment ride. By doing so, the video could be used to recall the specific 'now' moment in the post-task. As Chow and Rissman 2017 state, ego-perspective videos allow to trigger specific moments of a person and result in higher ecological validity (for further details see chapter 2 subsection 2.6.3).

(2) Using the recorded video to trigger the recall of specific positive or negative moments allowed the post-task to be designed more comprehensively. E.g. a question to investigate in (urban) emotions could be added as well as questions on safety and comfort. Further,

a short, semi-structured interview was included, allowing participants to explain what made a moment positive or negative while also pointing to elements on the screen for clarification (for further details see chapter 2 subsection 2.6.3).

(3) Participants familiarity with the study route and its surrounding has been assessed since literature suggests that cycling experiences are influenced by the familiarity of cyclists with the environment (Harms et al. 2021; von Stülpnagel 2020; Fournier et al. 2020). Harms et al. 2021 state that in the context of road environments familiarity is a rather underestimated factor compared to other study areas (e.g. psychology), where it is well established that familiarity affects cognition, memory and attention. Therefore, it makes sense to especially consider different familiarity-levels when studying cyclists experiences. Within the conducted experiment participants rated their familiarity before and after the experiment drive: Before by indicating their familiarity of the surrounding and afterwards by indicating their familiarity with the exact study route based on the video from their experiment drive (for further details see chapter 2 subsection 2.6.2).

(4) A set of questionnaires regarding orientation skills, risk-taking behavior, and a basic questionnaire for personality traits (short form of the Big Five Inventory Ostendorf 1990) were included in the pre-task in addition to participant's cycling experience (for further details see chapter 2 subsection 2.6.1).

However, in the following many of the above mentioned aspects are not analyzed due to the capacity limits of a master thesis. Nonetheless, because developing and conducting the experiment was part of this thesis the experiment will be described in detail in chapter 2. The data and results presented here focus mainly on the collected eye-tracking and motion-capture data while including some results of the pre- and post-task. The following section describes the research questions and the hypotheses tested within this master thesis.

1.2 Research questions and Hypotheses

As described in section 1.1, previous studies have shown that eye movements of negatively perceived road segments differ from other ones. This brings up the question whether the same is true for positively perceived moments, which is a gap in current cycling research Zhang et al. 2024. In the experiment carried out, cyclists have marked positive and negative experiences by saying 'now', which allows us to compare specifically positive and negative perceived moments. Such marked moments are further referred to as a *spot*. This leads to the first research question:

- **How do eye movements of bicycle riders in an urban environment differ on positively and negatively perceived spots?**

In addition to eye movements, (upper) body movements could give more insights into the perception of bicycle riders as explained in section 1.1. As an initial analysis of upper body movements, it is reasonable to focus on head movements, since the findings Matviienko et al. 2023 indicate that perception (subjective safety) of cyclists could be described by head movements. Therefore the second research question of this master thesis, drawing on the first one, is:

- **How do head movements of bicycle riders in an urban environment differ on positively and negatively perceived spots?**

Several hypotheses can be explored with the collected data in order to answer the research questions. Within the scope of this master thesis the following three are tested:

- *On positively marked spots fixation durations are longer and fixation counts are lower compared to negatively marked spots.*

  This hypothesis is based on the findings of von Stülpnagel 2020 and Guo et al. 2023. Both studies show that fixation durations were shorter for locations in which a higher level of risk was experienced. Assuming that experiencing a higher level of hazard is negative it makes sense to hypothesis fixation durations are longer for positive experienced spots.

  Mantuano et al. 2017 have found that the number of fixations are significantly lower on a route segment rated as being of good quality compared to other segments. Therefore, we hypothesis that the number of fixations is lower for spots marked as positive compared to spots marked as negative.

- *On positively marked spots, people direct more attention to buildings, trees and other surroundings, whereas on negatively marked spots, they focus more on other traffic participants, street signs and the road itself.*

  Acerra et al. 2023 analyzed the visual attention of bicycle riders and observed that they tend to look at buildings, vegetation, or the sky when they are inattentive. This behavior indicates lower workload and stress levels. Assuming that a lower workload and stress level is a positive experience the above written hypothesis was formulated.

- *On spots marked as positive head movements are more stable meaning head rotation angles (yaw values) are smaller compared to negatively marked spots.*

  Matviienko et al. 2023 have analyzed head movements by analyzing the number of head turns. A head turn was defined as a head movement with a rotation angle larger than 20 degrees to either side. The analysis showed that cyclists performed fewer head turns when they felt safe compared to when they did not. Based on this the third hypothesis was formulated.

CHAPTER 2

Material and Methods

As mentioned in chapter 1 the data used to address the research questions is part of a larger in-situ experiment conducted in Vienna between July and October 2024. An experiment in a simulated scenario would have been safer (no risk of traffic accidents) and would have offered the possibility to create the exact same situation for each participant, which makes comparison easier. However, ecological validity is higher in real-world scenarios which are closer to every-day cycling experiences: temperature, wind, smells are likely to influence experiences and possibly eye-movements as well. Most importantly, people participating in a simulation study know that no accidents can truly happen which might affect their attention, actions and perceptions. Therefore, conducting an in-situ experiment was considered necessary.

The goal of the experiment was to collect quantifiable and evidence-based data to gain more insights on the experience of cyclists in an urban environment by using eye-tracking glasses and motion-capture sensors. Since developing and conducting that experiment also formed a component of this master thesis, it will be described in detail. However, only a fraction of the collected data will be analyzed in this thesis. The designed experiment consists of three main parts: a pre-task (1), the experiment ride (2) and a post-task (3). Before describing these parts in detail, a broad overview of the study procedure is provided, followed by information on the used equipment, ethical considerations and participant recruitment.

2.1 Overview of Procedure

First, participants were asked to fill out an online survey, which is called the pre-task. At the end of this online survey a date for the experiment ride could be scheduled. On the scheduled day participants were asked to cycle along a predefined, about 5 km long route on their own bicycle. A researcher followed (on a bicycle as well), which was necessary for equipment and safety reasons. While cycling, participants wore eye-tracking glasses, motion-capture sensors on their upper bodies and a GNSS antenna (for detailed information on the equipment see section 2.2). Each participant was instructed to say 'now' whenever their emotions changed during the drive. After cycling, they watched the video recorded by the eye-tracker together with the researcher. The video was paused at each 'now' and a short questionnaire was completed, which is called post-task. Participants rated the intensity of their emotional change, how safe and comfortable they felt, the reason for saying 'now' and whether the change was positive or negative for them.

2.2 Equipment

Eye tracker

In figure 2.1 the *Invisible* eye-tracker from *PupilLabs* can be seen. They look like 'normal' glasses with a strip on the back to ensure secure hold. The camera attached on the left side records a 'world' video while two infrared cameras at the bottom of each glass record the eye movements. For recording a mobile phone with the corresponding app *Invisible Companion Version 1.4.30* needs to be attached to the back of the eye-tracker's 'handle'. The device does not work wireless. However, the mobile phone could easily be attached to the participant's back as shown in subsection 2.6.2 figure 2.8, which made eye-tracking on a bicycle possible. The cable was fixated on the back of the participant with a safety pin to ensure it does not move around and does not restrict head movements. The recorded video was watched in the *PupilPlayer Version 3.5.1* and all data was uploaded to the *PupilCloud* after recording. The eye-tracker requires calibration for each new person to ensure better accuracy. Since the calibration was performed for tracking eye movements during cycling, it was optimized for medium distances. As a result, the accuracy of the eye-tracker decreases when the person looks either very far away or very close.

Figure 2.1: *PupilLabs* Invisible mobile eye tracker

Motion Capture

Movella Xsens IMU (Inertial Measurement Unit) sensors are highly accurate devices for motion-capture. The 'N-Pose'[1] was used for calibration. The corresponding software offers an 'upper body' scenario, which was used in the conducted experiment. While

[1]N-Position: A position in which a person is standing straight with feet hip-width apart, arms are placed naturally by the sides of the body, palms are touching the outer upper thigh and the head is looking forward.

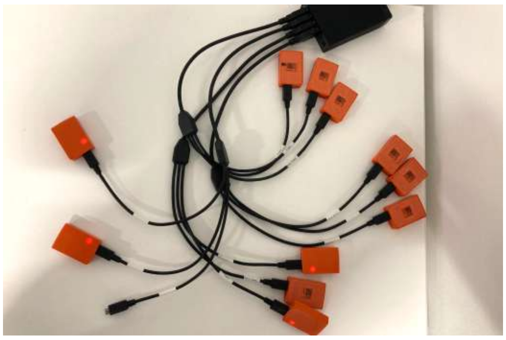


Figure 2.2: Xsens (Movella) Awinda Upper Body Motion Capture System

Figure 2.3: Laptop for IMU data collection

it would have been interesting to use the full body scenario, this would have made the outfitting process considerably more time consuming. In addition leg movements during cycling are quite complex since some people have coaster breaks on their bikes or different gear settings, etc. To evaluate this properly a larger dataset would have been needed. Therefore the upper body scenario was used. In this master thesis the focus lies on the head sensor, which was attached to the back of the helmet. In figure 2.2 all 11 sensors for upper body motion capture can be seen. This includes a head-, a stern-, a pelvis-, two shoulder-, two hand- and two upper and two lower arm-trackers. Each sensor is labeled and needs to be put to the correct position. The sensors work wireless, however the device where the data is saved to needs to be around. In this case a researcher carried a laptop with an antenna (see fig 2.3) in a bag while driving behind the participant.

Helmets

As shown in figure 2.4, additional larger sunshades were installed on the helmets to reduce the impact of the infrared light of sunlight on the cameras in the eye tracking glasses. Since participants rode in good weather conditions during summer, this was deemed a necessary measurement. However, the sunshade was also worn in case participants rode later in the afternoon when sunlight was less problematic to ensure consistency. Participants were always asked whether the sunshade bothered them or reduced their field of view and the sunshade's exact position was adjusted accordingly.

Figure 2.4: Helmets with additional sunshade

GNSS antenna

This Global Navigation Satellite System (GNSS) antenna allows high-precision geolocation, which allowed us to track participants bicycle tracks. From these tracks speed etc. can be calculated. The antenna was connected to a mobile phone with the *PPM Commander* app and for tracking the open source App *GPSlogger* was used. The mobile phone used for this purpose was attached to the participants back (see subsection 2.6.2 figure 2.8). Due to urban canyons, the antenna did not work properly all the time. For backup reasons we used another phone's GPS tracking with the open source App *GPS logger*. For the results of this master thesis neither GPS tracks were used.

Figure 2.5: PPM 10-xx38 high precision GNSS receiver

Navigation

The navigation was supposed to be common so participants would not be distracted by a system they are not familiar with. A very common navigation system in Vienna is *Google Maps*. Therefore, most people will be used to the interface and the way *Google Maps* gives instructions. Besides being a very familiar navigation tool, using a visual navigation system offered the possibility to track how often participants sought route information, which could be an interesting indicator for safety and familiarity. Therefore a mobile phone was attached to the participants' bicycle as shown in figure 2.6.

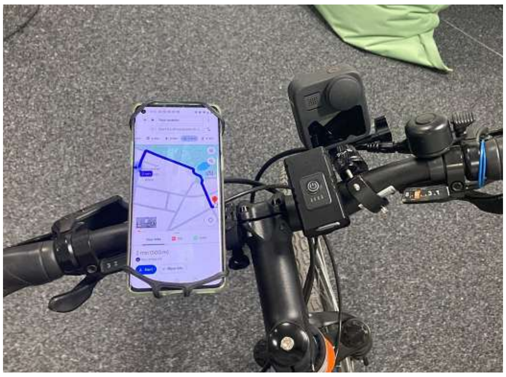


Figure 2.6: Set up for navigation

2.3 Ethical considerations

Experiments conducted in real traffic raise important ethical issues since cyclists are vulnerable traffic participants and the risk of accidents cannot be eliminated entirely. The following ethical concerns and the resulting measures to address them were presented and discussed within the Ethics Committee (Case Number: 053_19042024_TUWREC) of the Technical University of Vienna. A letter on confirmation from the Ethics Committee can be seen in appendix A.4

To reduce the risk of traffic accidents the experiment was conducted in good weather conditions only and not during rush hours. Participants were also informed that they are covered by insurance while cycling during the experiment. They further had to confirm that they had previously cycled in Vienna to ensure they could properly estimate the situation. It was also pointed out that risk minimization partly depended on the participants themselves, such as following traffic rules and ensuring their bicycle met the standards of the applicable traffic regulations(Fahrradverordnung - Österreich, Stand 2024).

Another ethical issue was the outfitting process because physical touch was necessary for IMU sensor placement. Specifically, the taping down of the pelvis tracker to the participants skin (see subsection 2.6.2 figure 2.9) was a concern. For both the researchers' and the participants' safety, a third person was asked to be present in the lab during this step. This also reassured participants that someone other than the researcher was present. Additionally, pictures and detailed descriptions were provided during the informed consent procedure so participants were informed properly. This also included the knowledge that the researcher doing the outfitting process would be a woman.

2.4 Pre-tests

Besides smaller tests to ensure technical functionality, 5 pre-tests have been done. These tests have helped to gain information on the studies duration and whether or not instructions are clear. The most important changes adapted due to pre-tests are:

- While a very common navigation tool in Vienna is *Google Maps*, it was not clear whether the visual navigation mode or the auditory instructions from *Google Maps* could easier be followed while being on a bicycle. A pre-test showed that the clues are insufficiently accurate for cyclists on our route, which led to the visual navigation setup described in section 2.2.

- Pre-tests showed that a post-task question requiring participants to rank a set of emotions was not intuitive to answer. Therefore, the number of emotions was reduced to 'basic emotions' used in psychology (Gu et al. 2019; Harmon-Jones et al. 2016). In this study we used: Anger, Fear, Anxiety, Relaxation, and Happiness. The basic emotions include other, more specific emotions and effectively act as broader categories. To give participants a bigger picture some examples were listed e.g. feeling nervous or worried belongs to the basic emotion *anxiety*. Test participants found this version of the question more intuitive to answer, which is why it was adopted for the study. The exact question can be seen in appendix D.1.

- As explained in chapter 1, in the conducted experiment, cyclists marked positive and negative experiences by saying ‘now’, which we refer to as a *spot*. Pre-tests have shown that some participants marked 10–15 spots, while others marked around 30. For those who marked more spots, the post-task was much more time-consuming. It was also particularly challenging to them to answer the question on emotions for every spot. To address this, an intensity scale (1–7) was used as a threshold to only display the question on emotions for marked spots with an intensity of 5 or higher. This not only reduced the time required for the post-task but also made the question on emotions more intuitive to answer for participants with many marked spot.

2.5 Participant recruitment and exclusion criteria

Potential participants were invited through a flyer containing basic information about the experiment (appendix A.1). As an incentive a 200 Euro lottery was advertised. The flyer was distributed via personal contacts that were used as multipliers and via newsletter to a large group of students in spatial planning. The students were asked to participate themselves or to share the flyer among their contacts. By following the link on the flyer, a limesurvey webpage was opened where interested people first received a brief explanation about the study goal before being asked 10 questions to determine their eligibility for participation. Restrictions included age (only adults could participate), availability to participate in the experimental ride within a specified time frame, or were due to equipment limitations e.g. visual impairment with more than 3 diopters. A list of the criteria is displayed in table 2.1 below along with the reason for exclusion. The original questions in German are listed in appendix A A.2. If no exclusion criteria were met, informed consent (see appendix A.3) was displayed on the following page. It included detailed information about the experiment, safety measures (described in section 2.3), how personal data would be handled as well as pictures of how participants would look like with the equipment. If people gave informed consent, the first part of the study, a series of questionnaires, was displayed.

2.6 Procedure

2.6.1 Pre-Task

The first part of the study consisted of a series of questionnaires which took about 20 minutes to complete. At first some basic information about the participants, namely age and gender were asked. For better preparation of the eye-tracker, we also asked participants to provide the diopters of their glasses, if they did not plan to wear contact lenses. Below, all questionnaires, a short description and why they were included can be seen. The exact questionnaires in German can be found in appendix B.1. Except for one, all questionnaires already existed and are routinely used in similar studies. After completing these questionnaires, the first part of the study concluded by asking

Table 2.1: Reasons for exclusion

Exclusion criteria	Reasons for exclusion
Possibility to take part in the experiment at the TU Wien within a certain time-frame	Pragmatic reasons
Participation in a course held by one of the supervisors of this master thesis in sommercourses 2024	Participants who attended such a course would have been too close to the supervisors, raising ethical concerns.
Possession of a bicycle that can be used in the experiment	By cycling on a familiar bike the experiment was closer to the real life experience of bicycle riders in comparison to cycling on a bicycle provided by us.Therefore, participants unable to bring their own bicycle were excluded. However, rental bikes like 'Wien Mobil' were acceptable if participants were accustomed to using them.
Age above 18	Only adults were allowed to take part in the experiment. Children were excluded for safety reasons (the experiment required participants to be able to drive through an urban environment independently). Including teenagers from eg. 16 to 18 would have been interesting but would have involved additional legal requirements and effort.
Willingness to share biological sex	The available equipment required knowledge of the participant's biological sex and did not offer an alternative option.
Body Mass Index (BMI) below 30	Due to equipment size limitations, participants needed to have a BMI below this threshold to make sure the equipment would fit.
Questions about visual aids (glasses and lenses)	The eye-tracking glasses used in the study could not be worn over regular glasses. Corrective lenses for the eye tracker were available for corrections within +/- 3 dpt but not beyond. However contact lenses could be worn regardless of the correction.
Color blindness	Participants with color blindness might perceive the environment differently. Because there was insufficient data to analyze such differences properly, we excluded individuals with color blindness.
Ability to cycle in Vienna	Participants were asked if they were able to cycled about 5 km in Vienna. To ensure people knew what they are getting into possible participants needed to confirm that they have already cycled in Vienna before. This requirement was suggested by the ethics committee.
Ability to stand in an N-position	The N-position was required for calibrating the motion capture system. Participants unable to stand in this position were excluded.
Ability to answer a question partly in English (question was displayed)	The post-task questionnaire (subsection 2.6.3) included a question partly in English, which unfortunately could not easily be translated into German due to the complexity of emotion translation. People who were not able to answer this question were therefore excluded from participation.

participants for their email address for further communication. Participants were informed that they would soon receive an email invitation to schedule an appointment for the second part of the study, using *termino.gv.at*. Once a date was selected, a confirmation email was sent, followed by a reminder email one day before the scheduled date. All email templates can be found in appendix B.6.

- **Questionnaire of bicycle behavior**

  The first questionnaire was the only one not pre-existing in that exact form but that was created for this study. Its purpose was to gather information about each participant's cycling behavior. This included questions about the frequency of bicycle use and whether a person is familiar with cycling in urban or rural surroundings. As shown by Stülpnagel (2020) and Rupi et al. (2019) the eye movement of people rating their cycling skills as fairly high differ significantly from those that do not. Further we asked participants whether they have had a bicycle accident before, and if so, how long ago it occurred. Research shows that having had an accident influences bicycle rider's further cycling behavior (Sanders 2015). They are potentially more cautious or more sensible to certain situations, which can influence their cycling experience. This makes it an essential factor for analyzing the collected data more comprehensively. Because participants were required to come to Vienna and to already having cycled in Vienna before to take part in the study, the answers are potentially biased.

- **Adolescent Cycling Behavior Questionnaire**

  The Adolescent Cycling Behavior Questionnaire (ACBQ) was developed based on the Driver Behavior Questionnaire (DBQ) and adapted for adolescent cyclists (Feenstra et al. 2011; Colwell and Culverwell 2002). Its primary focus is on assessing risk-taking behavior, which distinguishes it from general cycling or driving behavior questionnaires commonly used for adults. Studies have shown that risk perception significantly impacts cyclists' perceived safety and comfort, making it crucial to include a questionnaire for risk-taking behavior (Parkin et al. 2007; Sanders 2015; Kummeneje and Rundmo 2020). Since existing questionnaires for adults are designed for general cycling behavior, the ACBQ was chosen to address the specific risk-taking behavior even though all participants were adults. However, age might effect the bicycle riders risk perception. Josef et al. 2016 describe how risk perception and behavior may change over a persons lifetime. Therefore, age is a factor that needs to be considered in data analysis when working with the ACBQ results.

  The ACBQ was originally developed in English. Since no German translation exists, the items were translated while retaining the original english versions alongside the translations to enhance comprehension. Translating this questionnaire was considered less complex than translating emotion-related items, as it focuses on specific traffic situations, which are culturally and linguistically more universally defined than emotional terms. The resulting questionnaire, including both the original english questions and the german translations, is provided in appendix B.4.

- **Big Five Inventory 10**

  The Big Five Inventory-10 (BFI-10) (Rammstedt et al. 2013) is a short form of the Big Five Inventory, which categorizes personality into five traits. Originating from (personality) psychology, the BFI-10 is now widely used beyond the field of psychology. In this case, the short form of the BFI-10 was used because emotions are expressed during the experiment. The ability to express emotions effectively is, among other factors, influenced by personality. Further, research has shown that personality traits influence bicycle riders behavior in general (O'Hern et al. 2020). Therefore, the BFI-10 was included in the pre-task (for questions in German see appendix B.3).

- **Orientation Questionnaires SBSOD and FRS**

  All participants had to find their way along the study route by GoogleMaps Navigation shown on a mobile phone attached to their bicycle (see figure 2.6). Such a navigation task raises the mental workload of the experiment. The ability to follow the instructions may influence the driving experience and as a result the experiences during the ride. Therefore, it is crucial to be able to analyze the data in relation to participants' navigation skills. For this purpose we included two different orientation questionnaires: the Santa Barbara Sense of Direction Scale (SBSOD) Hegarty et al. 2002 and the Fragebogen Räumliche Strategien (FRS) Münzer and Hölscher 2011. Both are self-reported navigation and orientation skills but they differ slightly in focus. The SBSOD, developed by Hegarty et al. 2002 focuses on orientation abilities, whereas the FRS, developed by Münzer and Hölscher 2011 is more concerned with spatial strategies. While the SBSOD is more commonly used in english speaking studies, there is a german translation available which was used in our pre-task (see appendix B.2). The FRS was developed for german speakers so the original version was used (see appendix B.5). In our study, the questionnaires were presented in the following order: first, the SBSOD, followed by the Big Five Personality Test and the Adolescent Bicycle Questionnaire, and finally, the FRS. This order was chosen so that participants would not answer the FRS, containing similar questions, right after the SBSOD.

2.6.2 Experiment ride

Outfitting

On arrival in the lab, participants were first asked if they had any questions about the experiment and were reminded that they could ask questions or withdraw from the study at any time. Next, a check was made to make sure the participant was outfitted as required for the study. This included verifying the following: no jewelry or watches, tying back long hair and not wearing loose, long-sleeved clothing. In case participants wore glasses, the prepared eye tracker was tested, to ensure the corrected glasses fit properly. After this first check, the participants' body height and foot length were measured for configuration in the motion capture software. Before the outfitting started, participants were asked to indicate their familiarity with the study route by answering two questions for each hexagon on a paper Map (OpenStreetMap):

- On a scale from 1 (not at all) to 7 (very much) how familiar are you with each region covered by a hexagon?
- How often have you been in each region covered by hexagon within the last year? If the answer was more than 21 times, 21 could be written down.

Asking about both familiarity and frequency was based on the findings of Gale et al. 1990, which showed that measuring familiarity alone is less meaningful. Both questions were answered on separated pages to avoid carryover effects. The original questions in German, along with the 'hexagon map', are provided in appendix C.1 and C.3. While participants filled out the familiarity map, a mobile phone (for navigation purposes) and a GoPro camera[2] were attached to the participant's bicycle.

After this, participants were equipped with 11 motion-capture sensors, the eye-tracker and the GNSS antenna (for equipment details see section 2.2). The pelvis tracker had to be taped down to the participants' skin as shown in figure 2.9, for which a third person was asked to come to the room due to requirements of the ethics committee (see section 2.3). Once all sensors were put in place a participant looked like shown in figures 2.7 and 2.8. The eye-tracking glasses and the motion-capture sensors were calibrated inside. The GNSS antenna needed to be calibrated outside. Before leaving the lab, participants were shown the study route (see appendix C.2) to create an experience closer to increase ecological validity: In every-day life a bicycle rider usually knows whether he knows, partly knows or does not know the route at all. Being unaware of the approximate duration of the ride or the general direction of the destination, essentially being surprised at every turn, seems to be a very unrealistic experience.

Instructions

Once outside, participants were asked to briefly ride up and down a cycling path (see test route 1 in figure 2.10) to ensure that none of the equipment caused discomfort. During this part, participants were also instructed to look down at the attached mobile phone to see whether checking for navigation clues was fine with the equipment[3]. After eventual final adjustments, the following instructions were read to the participants (for the original

[2]The GoPro was used as a backup for the eye-tracker. In case the eye-tracker was to fail, the GoPro video could be used for post-task analysis, reducing data loss.

[3]In addition knowing how the 'checking for navigation' movement looks like for each participants is nice to have to work with machine learning later on — even though in this master thesis we did not use machine learning.

Figure 2.7: Equipped Participant with helmet, eye-tracker and motion-capture sensors

Figure 2.8: Equipped Participant from the back with eye-tracker phone and GNSS phone attached next to the GNSS antenna.

Figure 2.9: Pelvis tracker taped to participant’s skin with sport-tape

The participant shown in the images above has given his written consent for the use of the images in this work.

German version, see appendix C.3). The instructions were read to each participant in order to ensure that all participants get the exact same information. The instructions comprised: (1) following the navigation to the upcoming checkpoint and (2) saying 'now' whenever their mood or emotional state (german: 'Gefühlslage') changes. 'Now' was chosen as a signal word because it is short and the 'tzt' ending (german 'jetzt') facilitates hearing the signal word later on during the post task (see subsection 2.6.3). Also keeping the signal word simple (only one word instead of using 'positive' and 'negative' or a think aloud protocol) was necessary not to increase the cognitive workload of the task much further. This is crucial because studies show that increased cognitive demand reduces neural responses responsible for emotional perception (Kellermann et al. 2011; Uher et al. 2014). As mentioned in chapter 1 in other eye-tracking studies (e.g. von Stülpnagel 2020; Ma et al. 2024) the cyclist's sense of e.g. safety or comfort is typically assessed after an experimental ride – a method that may be affected by recall bias. In this study we aimed to reduce this recall bias by having participants indicate perceived changes by saying 'now' during the experiment ride.

In order to give participants a broad picture of reasons to say 'now' the following examples were given:

- You are passed uncomfortably.
- Parked cars could open doors (dooring).
- Other traffic participants are in your way.
- You have to cross tram tracks.
- A cycle path stops unexpectedly and you do not know where you are supposed to drive.
- Signals are unclear.
- You feel comfortable because it is calm, sunny, there is shadow.

This, of course, influences participant's attention during the ride and therefore also influences our data. However, pre-test have shown that giving examples are necessary to make the task comprehensible. Also, research indicates that cognition and emotion compete for attentional resources and lead to dual-task interferences (Uher et al. 2014, Watanabe and Funahashi 2014). Cycling and navigating can be seen as cognitive demanding tasks which, therefore, require many attentional resources (Uher et al. 2014). Since cognition and emotion compete for these resources an additional activation of emotional reactions makes sense in order to shift the attentional focus. It is possible that, in the absence of a change in attentional focus, changes in perception may occur without being perceived by the participants, thus resulting in less accurate results.

The ride

Figure 2.10: Experiment route including both test segments, the three segment start points (S1-S3) as well as four points (M1-M4) that were used in the post task (see subsection 2.6.3).

After having given the instructions a second test drive in which all instructions were followed was done (see test route 2 in figure 2.10). This allowed participants to get accustomed to the task as well as to ask questions before starting the experiment route properly. The experiment route can be seen in figure 2.10 and was chosen based on the following criteria:

- length: Cycling along the route should not take longer than 25 min.
- Start and end point should be at or near the lab.
- A variation of different kinds of bicycle infrastructure should be covered by the route including:
  - ∗ bicycle lanes (completely separated and not completely separated from car lanes)

  * shared lanes
  * driving against one-way streets for bicycles
  * driving in ‘normal’ traffic
  * driving on a street with tram tracks
  * junctions, including a larger one with more than two lanes

The study route was divided into 3 parts (see figure 2.10). The segments were almost equally long, the lengths varied slightly due to reaching suitable spots for a break. This division was done because stops along the route were necessary to ensure the equipment was still running. The way points were also used to ask the following two questions:

- How safe did you feel while driving on this segment of the route on a scale from 1 (not safe) to 4 (safe)?
- How comfortable did you feel while driving on this segment of the route on a scale from 1 (not comfortable) to 4 (comfortable)?

Before starting a new segment, a small reminder was read to each participant to ensure the task of saying ‘now’ would not be forgotten (see appendix C.3 for German reminder). In addition to the other two questions, at the end of segment 3 people were asked to rank the three segments in safety and comfort.

2.6.3 Post-Task

After returning to the lab, participants were offered a drink and a small snack while being informed about the post-task: They would watch the video together with the researcher and whenever they have said ‘now’ during the ride, the video will be paused to answer a short questionnaire. In addition to these the video was also paused at four specific locations during the route called M1 - M4 which can be seen in figure 2.10. Once at the beginning (M1) of the first route segment and in the middle of every route segment (M2 - M4). For every ‘now’ the researcher completed the first part of the questionnaire, which included pseudonym information and other details such as the time of each ‘now’. Below, all questions are listed (except pseudonym information), along with a brief explanation for its inclusion in the post-task. The original questionnaire in German can be found in appendix D.1.

1. **How intense was the change you marked by saying ‘now’ on a scale from 1 to 7?**

   This question was included to rank ‘nows’ by intensity. The intensity was used as a threshold: if an intensity of 5 or above was selected, the ‘emotion’ question (question 4, see below) was displayed. For ‘nows’ with lower intensities, the question was not shown. This was primarily done to reduce time demands, since pre-tests have shown that some people say ‘now’ more than 20 times.

2. **How safe did you feel when you were saying 'now'?**

   Ranking the 'now' in safety and comfort was necessary to evaluate the research hypotheses. The range from 1–4 was chosen according to Olsson and Elldér 2023. Offering a neutral position by using a 5-point scale isn't meaningful because a person cannot feel safe and unsafe at the same time.

3. **How comfortable did you feel when you were saying 'now'?**

   Reasons for asking this questions are identical with question 2.

4. **You see a list of five emotions. For your understanding, each emotion is accompanied by other emotions that fall into the same category. For each emotion, please indicate the intensity with which you felt it, at the moment you said 'now'.**

   To get more detailed information about bicycle riders' experiences, we included this question. Also focusing on emotions in addition to perceived safety and comfort can offer a deeper understanding of the positively and negatively perceived experiences. Especially, since safety and comfort are differently perceived by each person. The format of the question and its answer scale is based on Harmon-Jones et al. 2016 and Gu et al. 2015.

5. **Why did you say 'now' at this spot?**

   Knowing why people felt a change in their emotion during riding is essential to be able to connect the perceived experiences to the spatial surroundings and thus investigate how the built environment influences the perceived experiences of a cyclist.

   This question was answered in a semi-structured interview format. Participants were asked to tell the researcher why they said 'now'. Their answer was categorized by the researcher immediately. This reduced cognitive effort for participants compared to having to write their thoughts down and offered them the possibility to explain the situation by highlighting objects on the video. Further the question could be answered more intuitively and the researcher had the possibility to ask questions to clarify statements when necessary. The researcher chose one of the following categories (categories were not shown to the participant), which are based on Campos Ferreira et al. 2022.[4] This method reduced time efforts for both participant and researcher. To ensure categories were chosen plausibly and to be able to make further, more detailed qualitative evaluations participants were asked if they were comfortable with the post-task being audio-recorded.

[4] Certain determinants for safety and comfort were not included because they are specific to walking. Also, because 'slope' and 'road paving' were highlighted in Campos Ferreira et al. 2022 they were added as seperate categories although not as many situations are described for them as for other categories.

- traffic volume
- other traffic participants
- slope
- built environment
- other environment
- infrastructure
- road paving
- road signs /traffic signs
- other

6. **Was this a rather positive or negative change for you?**

   Pretests (see section 2.4) have shown that whether an experience is rather positive or negative is not obvious from the given answers above. Whether something is positive or negative for a person is highly subjective. Therefore, this question was included.

At the end of each video, participants were asked to answer the two 'familiarity questions', from the beginning (see subsection 2.6.2) again. While these questions were the same as those used for the hexagonal areas on a paper map (described above), this time participants evaluated their familiarity with the specific study route. For this, the route was divided into 17 segments (about 6 segments per video/route segment) as shown in figure 2.11. Another approach at hand would be to ask about familiarity at every crossing. However, this would have been too time-consuming which is why the segmentation into 17 parts was done. The segments were approximately 200 meters long, although their exact lengths varied to ensure each segment began and ended at a crossing. Participants were shown these segments by quickly navigating through the video using a mouse, focusing on the start and end of each segment.

After this the experiment was finished for the participants. The post-task on average took around 1 hour depending on how many times a participant has said 'now'. From arriving to leaving the lab the study took about 2 hours and 39 minutes.

Figure 2.11: Experiment route divided into 17 segments used to assess familiarity in the post-task.

CHAPTER 3

Analysis

In the following section, the codes and strategies used to analyze the data and answer the research questions are listed and explained. This includes how the data was processed and a description of the collected data. Only data and analysis used in this master thesis is described. Other data collected during the experiment is not listed.

3.1 Data Analysis

Defining a 'spot'

As described in chapter 1, the focus of this master thesis lies in comparing negatively perceived spots with positively perceived spots. In order to compare two spots, a definition of a 'spot' is needed.

While participants marked the spots by saying 'now', what prompted them to say 'now' must have occurred prior to their indication of the spot. A small analysis of the time slots between two subsequent 'nows' shows that these time-slots range from 1 s to 613 s. In figure 3.1, the histogram of subsequent time slots indicates that participants frequently marked events within 1–20 seconds although only 11 spots were marked within 5 s. However, to avoid overlapping data, one-second segments would have to be analyzed. One-second segments will most likely not be meaningful for movement analysis, which is why a larger time frame is required. Average urban cycling speeds are around 18.5 km/h.[1] This means that within 10 seconds, a cyclist travels around 51 meters. Considering that at crossings, people turn from one street into another, urban settings can change quite a lot within 51 meters. Even when a cyclist is not moving, other road users move, resulting in different situations again. Eye or head movements 51 meters earlier most likely do

[1] Depending on how the mean is calculated, this number varies, e.g., whether or not stops at crossings or the time needed to get to the bike is included. 18.5 km/h which was used here is based on Hasler 2016 in: Bundesministerium für Verkehr, (2016).

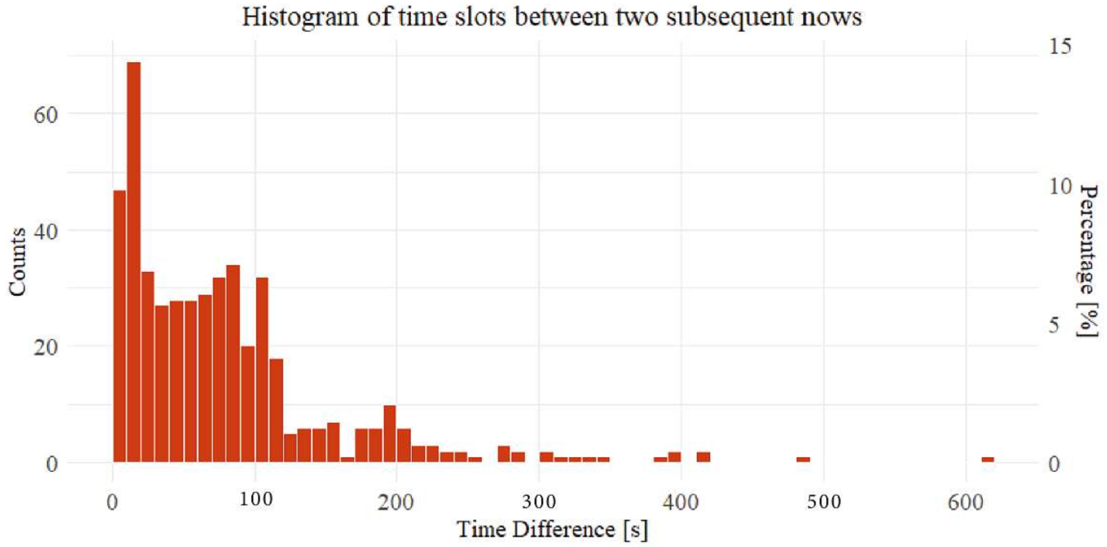


Figure 3.1: Time differences between two subsequent 'nows'

not relate to the context of the 'now' moment, which means using a time window longer than ten seconds before each 'now' may introduce irrelevant data causing different and less meaningful results.

In conclusion, both a one-second segment and a time frame longer than ten seconds would be insufficient. Within the 1–10 seconds range, it remains unclear which segment is most meaningful. Therefore, three different time frames within this range were analyzed and compared:

- 12 s time window [12 s]: meaning 10 s before and 2 s after the marked spot
- 7 s time window [7 s]: meaning 5 s before and 2 s after the marked spot
- 5 s time window [5 s]: meaning 5 s before the marked spot.

The additional two seconds after the 'now' were included for the 12 s and the 7 s not to cut of the 'now'-moment to early and to ensure the 'now'-moment is included in the analysis.

These time windows were then used to segment the data for analysis. As mentioned the time between two subsequent 'nows' was sometimes only a few seconds long (see figure 3.1). Therefore, some data points were collected twice within the segmentation process. As an example, one fixation could be part of the 7 s time window for one spot and the subsequent one, resulting in duplicates. To avoid interpreting these fixations twice, duplicates were deleted so each fixation would only be analyzed once.

Eye movement data

Measuring eye movements is commonly done using eye-tracking glasses, that track what a person is looking at with the help of infrared cameras. From these recordings the eye movements can be analyzed, which is typically done by calculating fixations and saccades (Yarbus 1967; Acerra et al. 2023; Ma et al. 2024; Kchour et al. 2025). Fixations are periods in which the eye movement is quite stable (Ma et al. 2024). This is interpreted as a period, in which something has been 'looked at'. Saccades are the movements between two fixations during which there is no cognitive perception of what is seen (Mantuano et al. 2017). The output of the eye-tracker recording does not offer information on fixations and saccades at first but 'raw' gaze points. This is a file where every 50 ms (20 Hz) the x and y coordinate of where the pupil was pointing at on the corresponding world video frame is noted. From this information the fixations and saccades can be calculated, which is usually done with an *Dispersion Threshold Identification* [idt] approach. Based on two thresholds (time and dispersion) clusters of gaze points are evaluated, which are called fixations. The distances between these fixations are consequently the saccades. Therefore, the results rely on the two thresholds that are set for this clustering. We obtained both, the fixations and saccades from the *PupilCloud*, which is a service provided by the vendor of the eye tracker. This comes at the cost that the parameter set for these calculations remains unknown. It is, however, common practice to use the calculations of the vendor (Ma et al. 2024; von Stülpnagel 2020; Schmidt and von Stülpnagel 2018).

Once having calculated fixations and saccades, eye movements can be analyzed. Standard metrics to do so include fixation durations, fixation counts, saccade velocity or saccade time (Kchour et al. 2025). In this study fixation durations and fixation counts were used as explained in section 1.2. However, these metrics do not capture information of the built environment directly. For Hypotheses 3 (section 1.2) we wanted to know the semantics of the objects (e.g. vegetation, road, building, etc.) participants were looking at. For this an analysis of what each fixation is 'pointed at' needs to be done. This step is usually done manually (Pashkevich et al. 2022; Jang and Kim 2019). Recently, an algorithm has been developed to automate this process (Alinaghi et al. 2024). In this study this '*myFix*' algorithm (Alinaghi et al. 2024) was used. The algorithm takes the world video from the eye-tracker and the fixations as input. The output is a CSV file with a label for each fixation as well as a folder with each analyzed frame (see figure 3.2). Compared to annotate fixations by hand this largely reduces time efforts. With an accuracy in outdoor scenarios of 81% this approach seems to be a good alternative to manual annotation (Alinaghi et al. 2024).

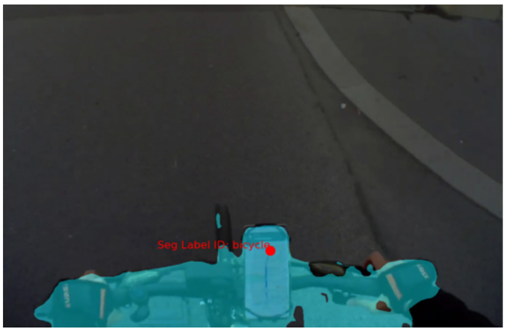
The labels listed below have been found by the *MyFix* algorithm for the data collected within the experiment:

car	sidewalk	sky	truck	road
pole	train	traffic sign	building	wall
bus	motorcycle	vegetation	bicycle	person
traffic light	terrain	rider	fence	cell phone
backpack				

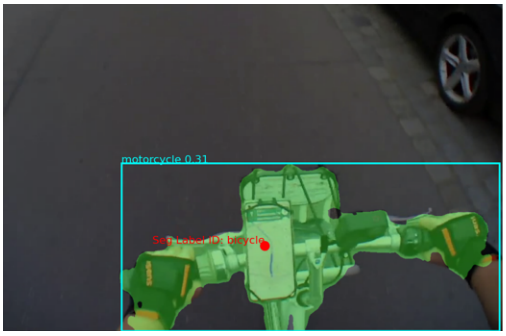
For analysis some of these categories have been merged, as can be seen in table 3.1. In a few cases 'backpack' has been recognized by the algorithm as can be seen in figure 3.2c. Because the interest in this study lies in the person wearing the backpack and not the backpack itself, the label 'backpack' has been merged with 'person'. Further 'rider' has been merged into that category as well since a bicycle rider has sometimes been identified as a rider, sometimes as a person (see figure 3.2d). 'Bicycle' and 'motorcycle' together with 'cell phone' have been merged to the category 'navi'. As can be seen in figure 3.2a and 3.2b when a person looked down at the handlebars it is most likely that the navigation phone was checked. The cellphone was only recognized in a few cases. This is most likely due to the offset that increases for fixations at a nearer distance because of the calibration of the eye tracker (see chapter 2 section 2.2). Further, as shown in figure 3.2e a tram or bus has sometimes been labeled as a 'train' and sometimes as a 'bus' which is why both categories have been merged. Another category has been created for labels of fixations that have been elsewhere. This included small walls or fences around a park or poles from flags that were hissed in front of buildings as well as from street lights. An example can be seen in figure 3.2f.

Table 3.1: Categories for analysis

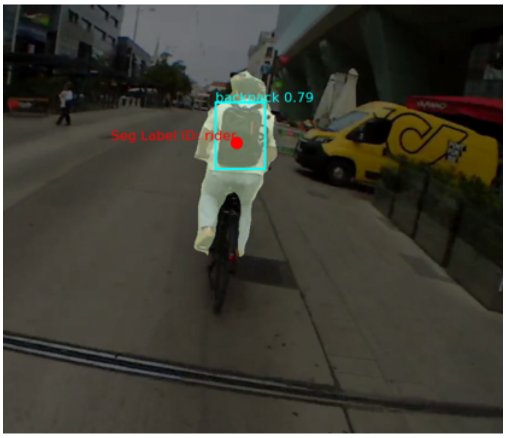
Category	**Merged labels**
navi	bicycle, cell phone, motorcycle
person	backpack, rider, person,
other	wall, pole, terrain, fence
car	truck, car
bus/tram	train, bus
traffic sign	traffic light, traffic sign
road	road, sidewalk
vegetation	vegetation
building	building



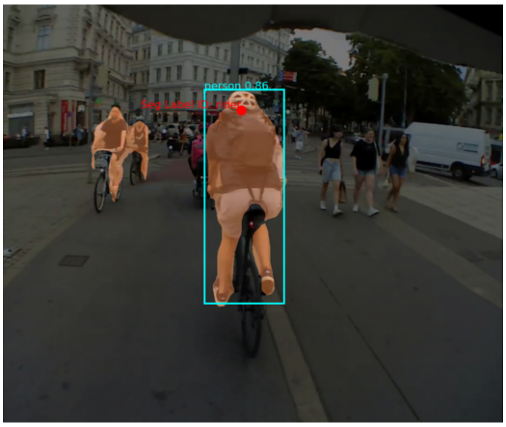
(a) label: bicycle



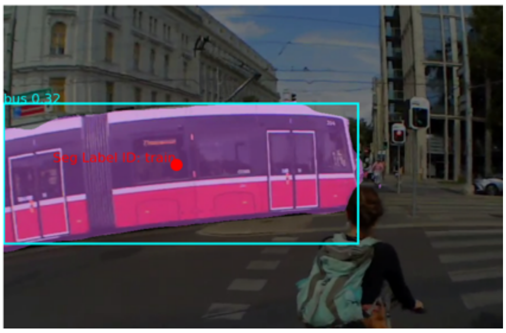
(b) label: motorcycle



(c) label: backpack



(d) label: person / rider



(e) label: train

(f) label: wall

Figure 3.2: Output from *MyFix* labels

Motion Capture Data

The motion-capture data was first checked for any disturbances that could have happened due to magnetic interferences (e.g. see figure 3.3) Such spots were marked and after reprocessing checked again. If the reprocessing did not solve the disturbances the spots were deleted. In total, this affected 3 'nows' of one participant, which were therefore not analyzed for head movements. After this the data was exported as an mvnx file[2] and transformed into csv format for easier analysis. Like the eye-tracking data the motion-capture data was filtered based on different time windows. As mentioned in the hypotheses (see chapter 1) the main interest in this master thesis lay on the head rotation movements (yaw) and the angular acceleration from yaw.[3] We therefore proceeded only with the data listed in table 3.2. A yaw value of 0 means the person is looking straight forward while positive or negative values show the rotation to the left or right in degrees. To analyze the differences in head movements between positively and negatively perceived spots we further calculated the differences between two subsequent yaw values. The results are the head movements in degrees.

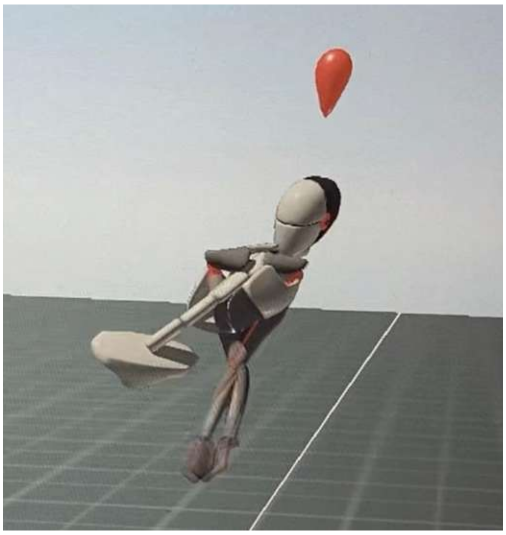


Figure 3.3: Disturbances in the motion capture data before reprocessing

Furthermore, Matviienko et al. 2023 have analyzed the number of head-turns where a head-turn was defined as a head rotation larger than 20 degrees. Following that example the number of headturns was calculated. Since a head turn is a change of direction in the head movement it can easily be calculated by calculating the first derivative of the yaw values. Counting the times the first derivative is 0 results in the number of head turns as is visualized in figure 3.4. These could then be filtered for head turns with yaw values above 20 degrees.

Post-Task and Pre-Task data

From the post-task, the information whether a spot was perceived as either positive or negative as well as why participants have marked a spot was extracted. Because previous research highlights significant differences in the eye movements of unexperienced and experienced bicycle riders (e.g. von Stülpnagel 2020; Rupi and Krizek 2019) responses from the pre-task were used to distinguish experienced from unexperienced participants.

[2] Mvnx format is an xml file format used by *Movella* to store the motion-capture data.
[3] In *Movella X sens* the head yaw value is called the 'jC1Head_z'value.

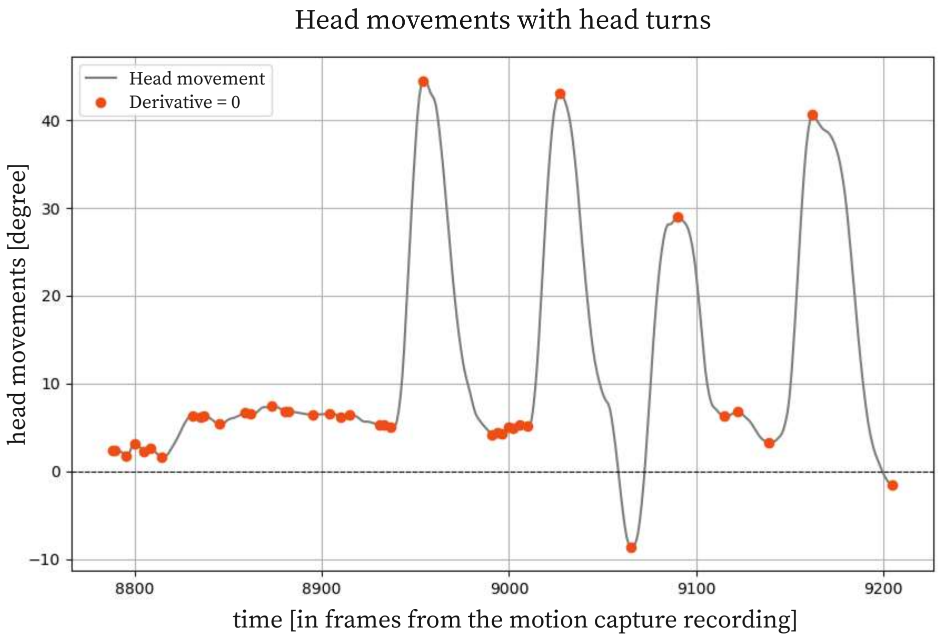


Figure 3.4: Head rotation values with marked head turns

Following the approach from Rupi and Krizek 2019 participants who cycled more than once a week were categorized as experienced, while others were classified as unexperienced. This distinction is particularly interesting for urban planning, as experienced and inexperienced cyclists likely have different infrastructure needs. However, urban planning often divides cyclists in three rather than two groups: (1) active cyclists, including the strong and fearless who cycle year-round and other regular cyclists; (2) potential cyclists, who express interest but do not cycle yet; and (3) non-cyclists, who remain uninterested in cycling no matter what (Guo et al. 2022; Félix et al. 2017). A distinction between these groups was not possible in this study, as the second and third group are unlikely to participate in an in-situ study. Future research could explore alternative methods, such as cycling simulators or offering incentives, to engage potential cyclists to participate.

3.2 Overview Data

In table 3.2 an overview of all analyzed values mentioned above including their units and abbreviations is given.

Table 3.2: Overview of analyzed variables, their units and their abbreviations.

Data set	Variables	Unit	abbreviation
Fixations	Duration	ms	FixDur
	Count	number	FixCount
	Categories	e.g. road, vegetation	-
Head movement	Angular Distance	deg	AngDist
(Yaw)	Angular acceleration	rad/s^2	AngAcc
	Headturns	number	Hts
Post-/Pre-Task	Categories	e.g. other road user	-
	Valuation	positive/negative	pos, neg
	Experience	experienced/unexperienced	Exp, Unexp

Overview Participants

In total, 29 participants took part in the experiment (17 men and 12 women[4]). All participants completed the experiment, which took 2 hours and 39 minutes on average. The age distribution can be seen in figure 3.5 with a mean of 37.64 years +/- 15.31 years. According to the definition in chapter 3 section 3.1 6 participants were unexperienced and 23 were experienced bicycle riders. Because it was quite dark during one of the experiment rides compared to the others the data of one participant (unexperienced, woman) was excluded from the analysis. This means that the data of 28 participants could be analyzed, although due to sensor malfunctioning data of some route segments got lost for parts of the analysis:

- One participant's (experienced, man) eye movement data is lost for all three segments.
- One participant's eye movement is lost for the first and one participant's eye movement is lost for the last segment.

[4]As the equipment was designed to work with binary gender categories, we did not collect further categories. Participants who did not identify as male or female either chose one of the two options or did not participate.

- Three participants' motion-capture data is lost for the last segment.
- One participant's motion-capture data is lost for the first segment.
- 3 marked spots of one and 2 marked spots of another participant could not be analyzed due to disturbances in the motion-capture data (see Figure 3.3).

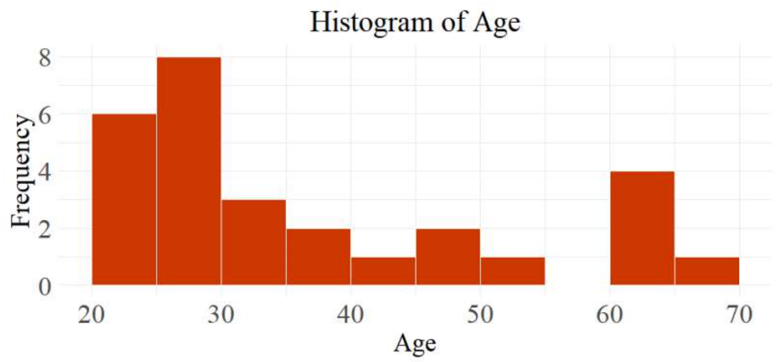


Figure 3.5: Age distribution of participants

Overview marked 'spots'

Besides 17 spots, that were marked but participants could not remember why they said 'now' in the post task, a total of 547 spots were marked of which 136 were rated as positive and 411 as negative. Only 25 % of the marked spots were rated positive. This does not necessary mean, that cycling prompts more negative experiences than positive once since negative emotions are often perceived more strongly (Baumeister et al. 2001; Vaish et al. 2008). As described in chapter 2 subsection 2.6.3 4 additional spots per participant have been included in the post-task, leading to 654 spots. However, the 4 additional spots were excluded from analysis because in this case only spots that had been indicated by the participants themselves were of interest.

The number of spots marked per participant varies between 5 and 38. Figure **??** shows the distribution of positive and negative spots per participant. On average 18 spots were marked per participant, of which 4 were rated as positive and 14 were rated as negative.

The reasons participants named for marking the spots were categorized as described in chapter 2 subsection 2.6.3 and can be seen in figure 3.7. Most negative spots were marked due to other traffic participants followed by infrastructure and traffic signage. Most positive spots were marked due to infrastructure followed by traffic volume and other factors in the environment such as smells, personal memories, good atmosphere. For both positive and negative spots, slope was the least frequently mentioned reason, which is reasonable given that the experiment route was relatively flat.

In figure 3.8 a map showing the densities of positive and negative spots marked by the participants can be seen. The map shows that spots were more frequently marked at

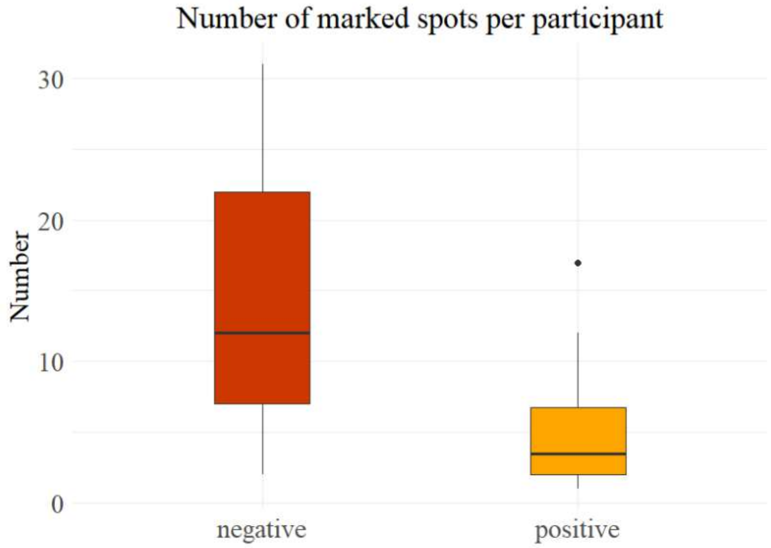


Figure 3.6: Number of marked spots per participant

certain locations. These locations are not further analyzed, however the map gives a broad idea about the spatial distribution of the spots.

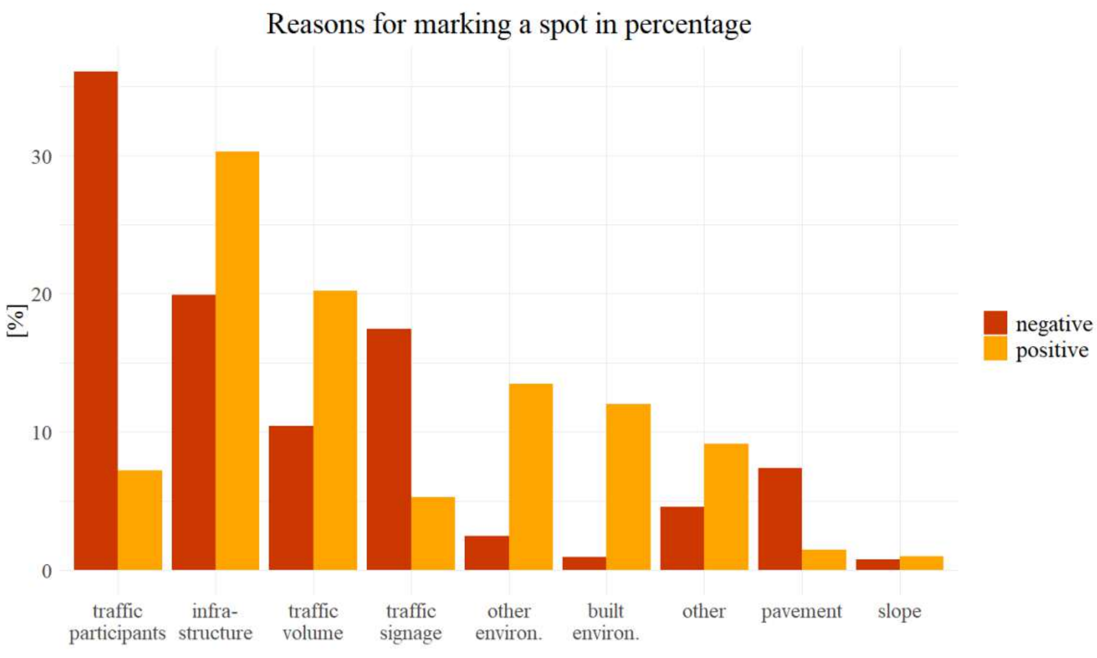


Figure 3.7: Participant's reasons for marking a spot

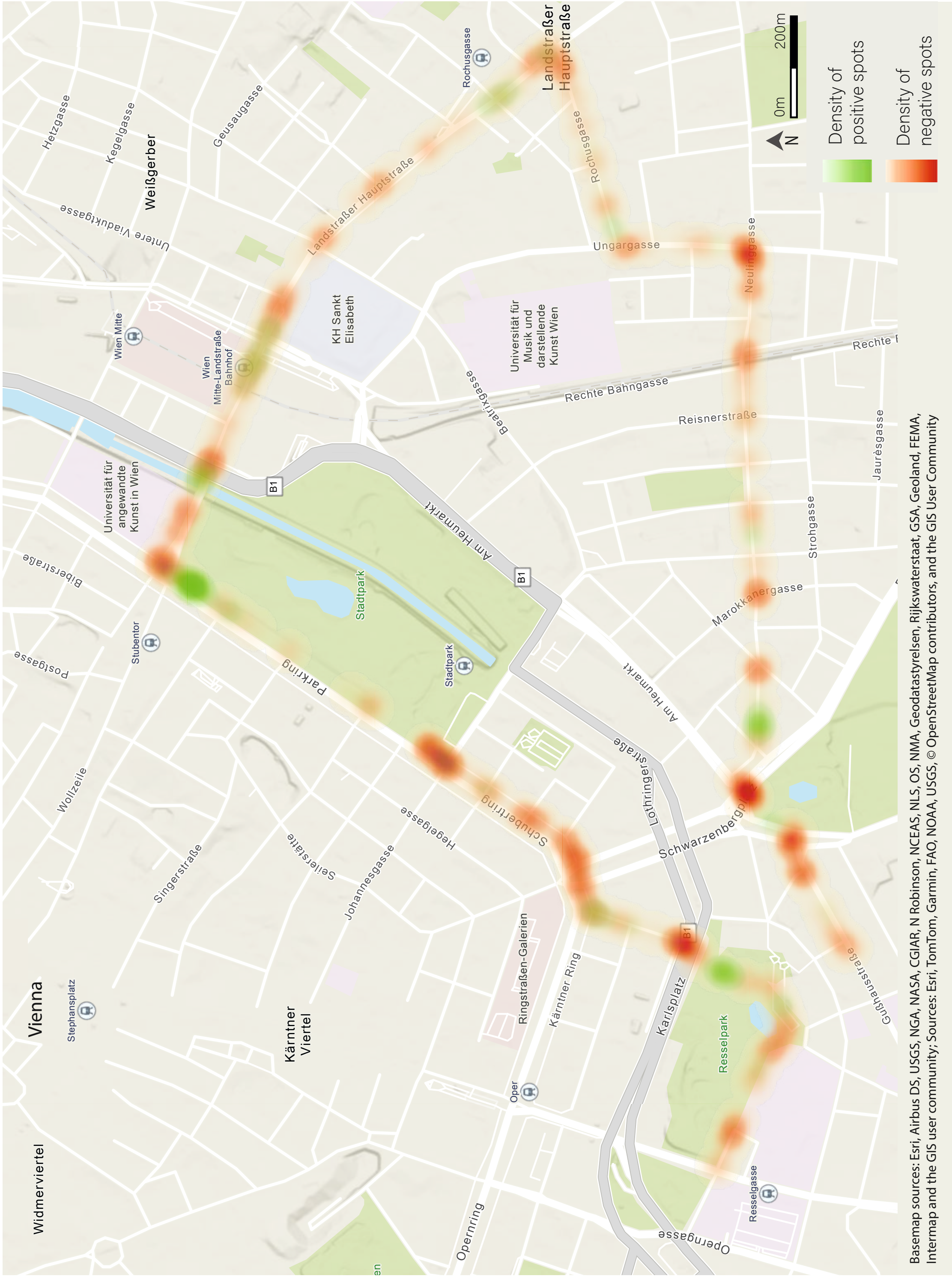


Figure 3.8: Heatmap of positive and negative marked spots

CHAPTER 4

Results

As explained in chapter 1, in order to determine whether specifically rated positive experiences can be distinguished from negative experiences, the goal of this master's thesis is to compare eye and head movements of positive and negative perceived spots marked by bicycle riders. For each hypothesis, the comparison of the spots was done for all participants and, in addition, for experienced and inexperienced bicycle riders separately. This was done because literature has shown that fixation durations of experienced bicycle riders are longer than those of unexperienced riders (e.g. Rupi and Krizek 2019; von Stülpnagel 2020). Also, experienced and unexperienced bicycle riders have marked different amounts of spots. This leads to the assumption that experienced and unexperienced bicycle riders perceive bicycle riding differently, which is why both categories have been analyzed separately in addition to the overall comparison.

The comparisons have been done with different time windows around a marked spot as explained in chapter 3:

- 12 s time window [12 s]: meaning 10 s before and 2 s after the marked spot
- 7 s time window [7 s]: meaning 5 s before and 2 s after the marked spot
- 5 s time window [5 s]: meaning 5 s before the marked spot.

Each hypothesis is listed below, followed by the obtained results. To test the hypotheses one-sided paired t-tests were used. Paired t-tests were appropriate to use since positive and negative spots were marked by the same participant. Therefore, the two compared groups are not independent. The use of one-sided tests was justified because, based on existing literature, a change in a specific direction could be assumed and the hypothesis was formulated accordingly.

Since multiple tests were done the question of whether or not to correct p-values emerges. Literature shows that the question of whether, how, and under which circumstances p-values should be corrected is still debated with no clear answers (e.g. García-Pérez 2023; Rubin 2021; Althouse 2016). In this master thesis the suggestions of Althouse 2016 are followed, which means p-values are not adjusted. However, readers are made aware of the fact, that multiple testing occurred. This also means that any significant results in this study need further exploration and are rather valuable for new hypothesis generation rather than drawing new conclusions.

4.1 Eye Movements

Hypothesis 1:

On positively marked 'spots'

- fixation durations are longer
- and fixation counts are lower.

Table 4.1 shows the results of the one-sided paired t-test comparing the average fixation duration and fixation counts between positive and negative spots. To ensure that spots with fewer fixations did not disproportionately influence the results, first the average fixation duration was calculated for each spot. These averages were then used to calculate the mean for positive and negative spots per participant in order to perform the paired t-test. One participant has not marked any positive spot which is why only the data of 26 participants could be compared.

Table 4.1 shows no significant results for neither the fixation duration nor the fixation counts for the 12 s and 7 s time window. For the 5 s time window, however, a significant results was obtained for the comparison of the fixation durations: on average, fixation durations on positively marked spots were 42 ms shorter than those on negatively marked spots ($t(25) = -1.98,\ p = .029$). As can be seen in figure, 4.1 the distribution of the data is considerable. However, because a paired t-test was done a categorization of an experience as positive or negative based on the fixation durations is still likely to be correct if fixation durations of one person are compared. Also other studies (e.g. Rupi and Krizek 2019; von Stülpnagel 2020; Guo et al. 2023) obtained similar distributions for mean fixation durations.

Table 4.1: Results of paired t-test for fixation durations and fixation counts for each time window

time window	**Diff FixDur [ms]**	**p-value**	**Diff FixCount [number]**	**p-value**
12 s	-6.26	0.346	-0.35	0.346
7 s	-11.12	0.366	0.15	0.593
5 s	-42.09	**0.029***	0.31	0.728

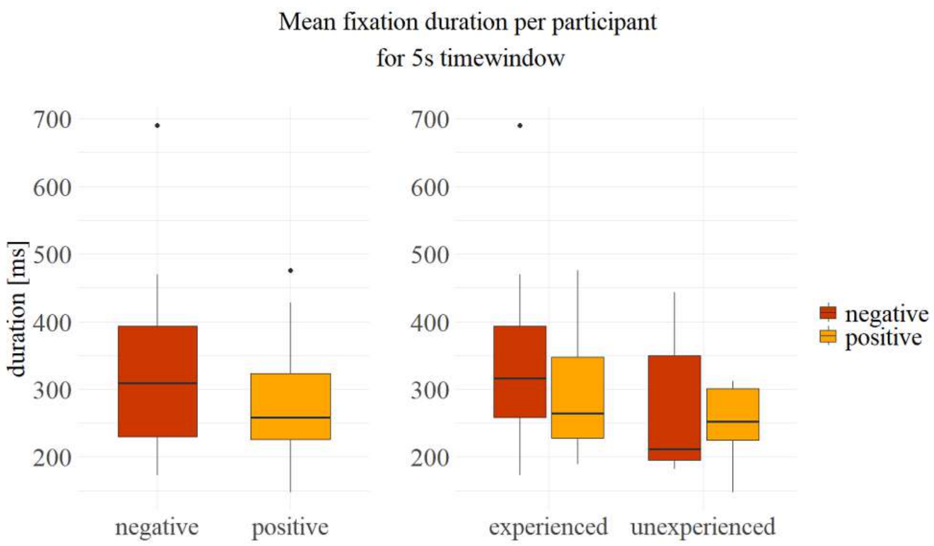


Figure 4.1: Mean fixation durations [ms] for the 5 s window

As no significant results were obtained for the 12 s and 7 s time window, the further analysis of the eye-tracker data, is only described for the 5 s time window. This includes the comparison of the subsample (experienced and unexperienced bicycle riders) as well as the analysis to test hypotheses 2.

The results for experienced and unexperienced bicycle riders can be seen in table 4.2. The data was visualized in figure 4.2 and 4.1. No significant results were obtained neither for comparing positive and negative spots of unexperienced riders nor for those of experienced riders. However, because a subset of the data is used for comparison there is very few data to test the hypotheses with. Especially for the unexperienced group which consists of only 5 riders. Unexpectedly, fixation durations of unexperienced cyclers seem to be higher for positive marked spots than for negative ones, which is the opposite

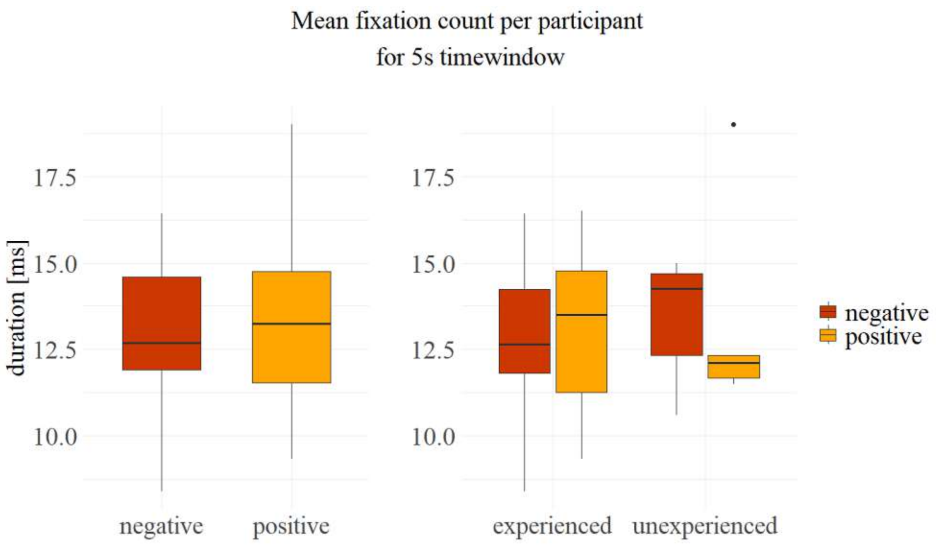


Figure 4.2: Mean fixation counts for the 5 s window

Table 4.2: Results of paired t-test for fixation durations and fixation counts for experienced and unexperienced riders

subset	**Diff FixDur [ms]**	**p-value**	**Diff FixCount [number]**	**p-value**
Exp 5 s	-45.28	0.088	0.40	0.487
Unexp 5 s	-28.67	0.459	-0.05	0.968

trend of the comparison above. However, due to the small dataset this is most likely a coincidence. More data is needed to see whether the difference in mean fixation durations for unexperienced riders has the opposite trend of experienced ones.

Based on these results the second part of the hypothesis, stating fixation counts are lower for positive experienced spots, needs to be rejected.

Hypothesis 2:

- On positively marked spots, people direct more attention to buildings, trees and other surroundings, whereas on negatively marked spots, they focus more on other road users, street signs and the road itself.

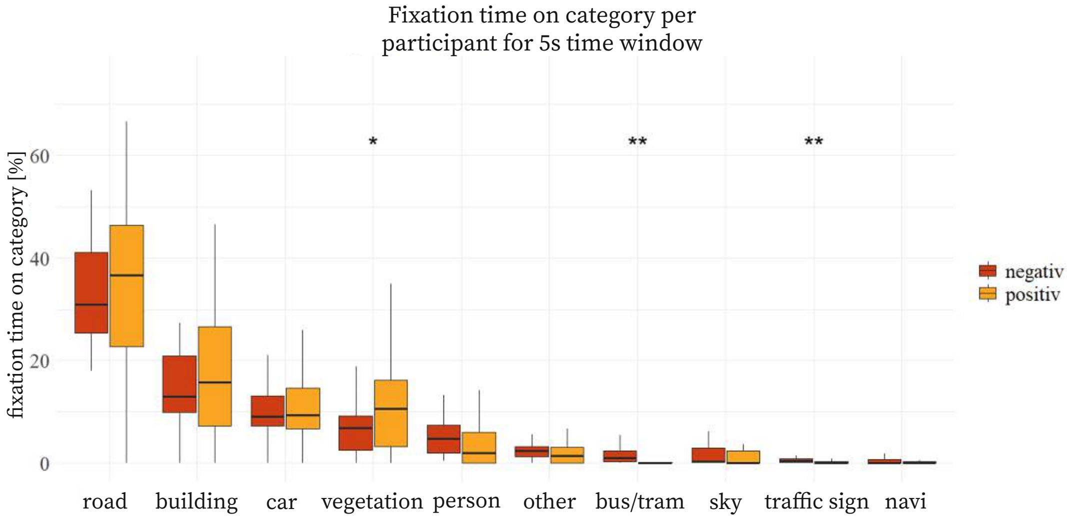


Figure 4.3: Percentage of Fixation time on category

To test this hypothesis, the fixation time for each category was first calculated as a percentage of the total fixation time for each spot. This was done to ensure spots with a longer total fixation time did not disproportionately influence the results as the goal was to compare what is being looked at per-spot. Next, for both positive and negative spots, the average percentage of each category was calculated per participant. The result can be seen in figure 4.3 (for better readability outliers are not shown). A paired t-test has been done to compare each categories percentages of positive and negative spots. In this case a two-sided t-test was done because no clear assumption about the direction of change can be made for all categories based on current literature. Figure 4.3 shows, that most attention, whether on positive or negative spots, is directed to the road. That the highest amount of attention is focused on the road has also been found in other studies (e.g. Pashkevich et al. 2022; Jang and Kim 2019). Besides the road riders tend to look at buildings, cars, vegetation and other people in decreasing order regardless of whether the spot was perceived positively or negatively. This seems reasonable since driving a bicycle is a task where watching the road as well as other traffic participants is necessary in every, positive and negative, moment.

No category gets much more attention on positive spots compared to negative ones. However, a paired t-test shows significant differences for the categories vegetation, bus/tram and traffic sign as can be seen in table 4.3. The biggest difference was found for the category 'vegetation' that on average is 5.4 % higher on positive spots. For the category 'bus/tram' the difference is only 1.2 % and for the category 'traffic sign' 0.5 %. Further the analysis for unexperienced cyclers doesn't show any significant results which again is no surprise because of the low number of unexperienced participants. However the results are displayed to provide a complete account. The comparison of experienced riders shows significant results for the categories 'traffic sign' and 'tram/bus'.

Table 4.3: Results of paired t-test for categories for all participants

category	**p value**	**Diff percentage**
car	0.859	-0.4
road	0.670	1.3
building	0.224	5.5
vegetation	**0.043***	5.4
other	0.353	-0.5
navi	0.946	0.0
person	0.179	-1.9
sky	0.675	-0.3
bus/tram	**0.000****	-1.2
traffic sign	**0.004****	-0.5

Table 4.4: Results for experienced cyclers

category	**p value**	**Diff percentage**
car	0.799	-0.6
road	0.424	2.5
building	0.216	6.7
vegetation	0.082	5.5
other	0.365	-0.6
navi	0.480	-0.3
person	0.130	-2.5
sky	0.163	-0.9
bus/tram	**0.001***	-1.4
traffic sign	**0.004***	-0.5

Table 4.5: Results for unexperienced cyclers

category	**p value**	**Diff percentage**
car	0.494	0.8
road	0.659	-4.2
building	0.974	0.2
vegetation	0.239	4.7
other	0.873	-0.1
navi	0.612	1.4
person	0.754	0.8
sky	0.566	2.1
bus/tram	0.454	-0.3
traffic sign	0.592	-0.2

Table 4.6: Results of paired t-test for angular distance, angular acceleration and the number of head turns for all time windows

time window	Diff AngDist [degrees]	p value	Diff AngAcc [rad/s^2]	p value	Diff Hts [number]	p value
12 s	8.89	0.760	0.16	0.775	0.30	0.681
7 s	-1.72	0.397	0.02	0.536	0.16	0.648
5 s	5.12	0.827	0.30	0.872	0.29	0.840

4.2 Head movements

Hypothesis 3:

- On positively marked spots head movements are more stable meaning head rotation angles (yaw values) are smaller compared to negatively marked spots.

This hypothesis has been tested in two ways: First, the head movements have been analyzed by comparing the angular distances of the head rotation. The angular distance was defined as the total sum of all angular changes in head rotation. This was done as a first comparison of how much participants' heads moved during the defined time window. In addition to the angular distance, angular acceleration has been analyzed. As a second analysis the amount of head turns has been analyzed, which was done based on Matviienko et al. 2023, where a head turn was defined as a head movement larger than 20 degrees to either side. These three values were compared for all three time windows.

Table 4.6 shows that no significant results were obtained for either of the values for each time window. Also the separate comparison of experienced and unexperienced riders does not show significant results as can be seen in table 4.7. This means based on the obtained results hypothesis 3 needs to be rejected.

Nonetheless to provide a complete overview the data of the 5 s time window is visualized in figure 4.4, figure 4.5 and figure 4.6. Looking at the visualization of the mean angular distance the higher distance for unexperienced riders compared to those of experienced riders stands out. A two-sided t-test between the groups shows a significant ($t(12.5) = -2.193,\ p = .047$) difference between the experienced riders ($M = 61.04,\ SD = 29.81$) and unexperienced riders ($M = 86.12,\ SD = 33.18$) resulting in a difference of 25 degrees. This indicates that the head movements as well as the eye movements from experienced bicycle riders differ from those of unexperienced ones. However, the low number of unexperienced bicycle riders has to be kept in mind.

Table 4.7: Results of paired t-test for angular distance, angular acceleration and the number of head turns for experienced and unexperienced cyclers

subset	**Diff AngDist [degrees]**	**p value**	**Diff AngAcc [rad/s^2]**	**p value**	**Diff Hts [number]**	**p value**
Exp 5 s	4.73	0.401	0.25	0.327	0.29	0.379
Unexp 5 s	6.75	0.709	0.47	0.615	0.28	0.693

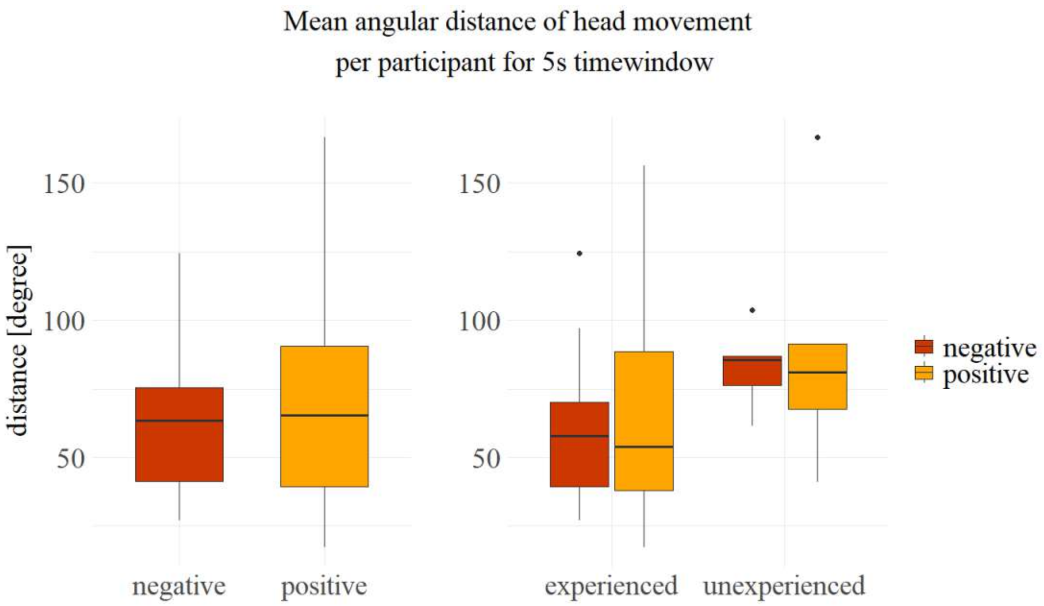


Figure 4.4: Mean angular distance per participant for the 5 s time window: over all participants, and for experienced and unexperienced cyclers separately

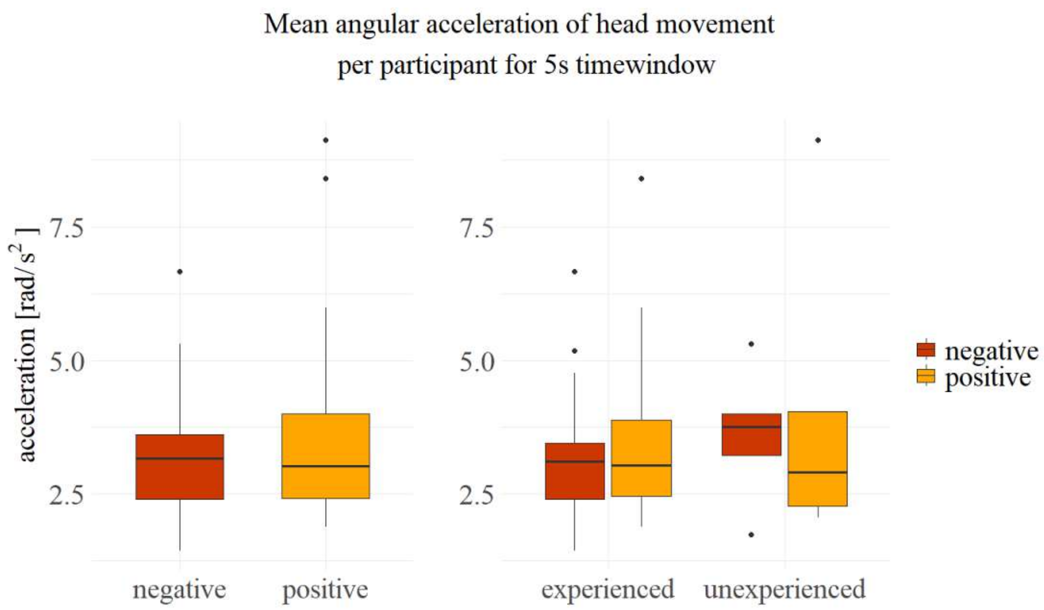


Figure 4.5: Mean angular acceleration per participant for the 5 s time window: over all participants, and for experienced and unexperienced cyclers separately

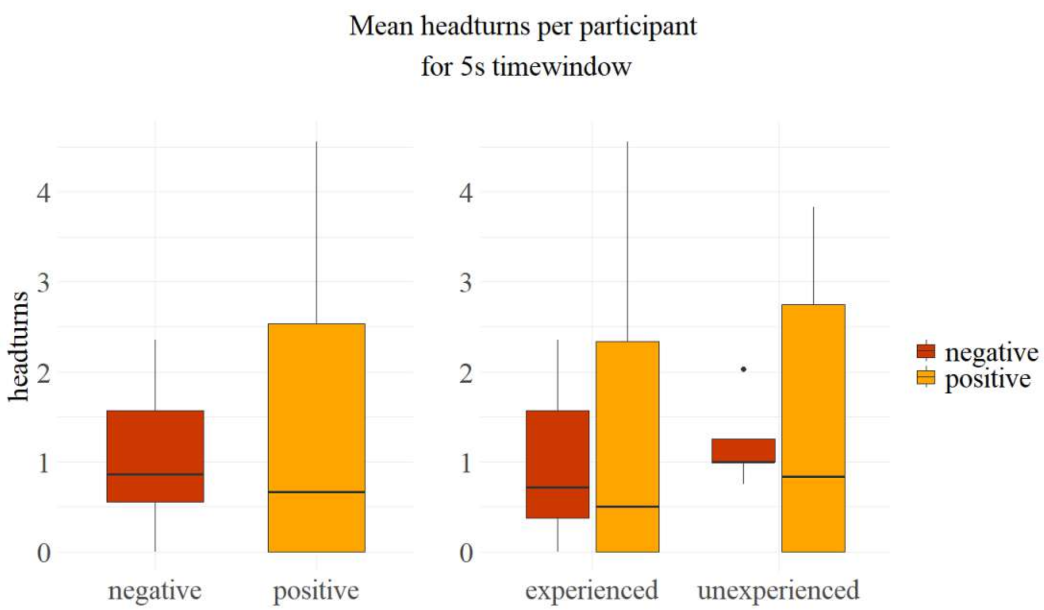


Figure 4.6: Mean number of head turns per participant for the 5 s time window: over all participants, and for experienced and unexperienced cyclers separately

CHAPTER 5

Discussion

5.1 Eye movements

As can be seen in chapter 4 between the three time windows analyzed, only the 5 s time window yielded significant results for the eye movements. As argued in chapter 3, using a larger time window than 12 s was unlikely to show meaningful results. The analysis of the 12 s time window did not result in significant findings, indicating that the 12 s time window was still too large. Compared to the 5 s window, the 7 s window included two additional seconds after a spot was marked, suggesting the significant results in the 5 s window stem from this difference. One possible explanation is that the eye movements in these extra seconds do not relate to the change participants marked before. Therefore, out of the three, the 5 s time window seems the most appropriate for analysis which is why only these results are discussed in detail below.

In addition eye movements were analyzed for unexperienced and experienced riders separately; however, no significant results were obtained for these groups. This is likely due to the small sample size which reduced the statistical power, making it challenging to detect meaningful differences. The separate analysis of experienced and unexperienced riders therefore is not discussed below.

Similar to other studies the analysis was done on quite a small sample (e.g. von Stülpnagel 2020, Rupi and Krizek 2019, Mantuano et al. 2017). Therefore, results need to be interpreted cautiously. To better evaluate the data, a more detailed comparison of the obtained values across similar studies by means of a meta-analysis will be helpful in providing a clearer picture of the current evidence.

Fixation durations

The analysis of the fixation durations has shown significant differences between positively and negatively perceived spots. However, fixation durations on positively perceived spots are on average 42 ms shorter compared to those on negative ones. This is the opposite of what has been hypothesized in chapter 1 section 1.2 based on existing prior evidence. Several different explanations for this contradictory result come to mind:

(1) Both von Stülpnagel 2020 and Guo et al. 2023 have focused on perceived safety or risk while the present study focused on positive and negative experiences in general. The spots participants marked therefore did not focus on safety only, which opens up various other reasons for defining something as positive or negative. This broader definition could be the reason for the different result obtained here. However, perceived safety and comfort belong to the key factors influencing bicycle riders' perceptions (Campos Ferreira et al. 2022). This suggests that, even though the experimental setup did not focus exclusively on safety, most marked spots will likely be related to safety, making the above-described explanation less probable. However, further analysis of the data could provide valuable insights to whether or not the focus on positive and negative experiences caused the contradictory trend by comparing fixation durations of spots rated as safe or unsafe during the post task.

(2) Another difference to von Stülpnagel 2020 and Guo et al. 2023 is that participants rated their experiences after the ride in both of these publications. Therefore, less intense changes might have been overlooked by participants. In contrast to their approach, in the present study experiences were marked during the ride which also captured less intense moments. Differences in fixation durations for intense and non-intense moments might explain the varying results. An analysis focusing solely on spots rated as intense could explore this further.

(3) von Stülpnagel 2020 describes how, among others, different fixation durations are indicating different visual behaviors. This has also been described in other eye tracking research, e.g. for car drivers where longer fixation durations have been found when drivers fixate on hazardous objects (Crundall et al. 1999; Chapman and Underwood 1998; Velichkovsky et al. 2002). Velichkovsky et al. 2002 differentiate between *preattentive* visual behavior, where no hazard has been detected yet, and *attentive* visual behavior, where a hazard has been detected. In the present study, participants explicitly marked spots, indicating awareness of a factor that caused their negative or positive experience. This indicates that the *attentive* visual behavior was measured. Our findings suggest that what causes negative experiences is fixated longer than what causes positive experiences. In contrast the studies of von Stülpnagel 2020 and Rupi and Krizek 2019 compared larger road segments, which were rated as safe or unsafe, rather than specific moments. Therefore, it is plausible that von Stülpnagel 2020 and Rupi and Krizek 2019 might have measured the *preattentive* visual behavior while in this study the *attentive* visual behavior was measured, which would explain the different outcomes.

Fixation counts

No significant results were obtained for the comparison of fixation counts in positive and negative marked spots. Therefore, the second part of the hypothesis needs to be rejected.

The following two interpretations are possible:

(1) There are no differences between positive and negative marked spots but there are differences in fixation counts between the marked spots and other ‘non-marked’ spots. This would mean there are peaks in the fixation counts for both positive and negative moments. However, further analysis of the data has to be done to test this interpretation.

(2) As mentioned in section 5.1, other studies (von Stülpnagel 2020; Rupi and Krizek 2019 focused on safety and comfort only and assessed participants’ experiences after a ride compared to during the ride. As explained above in section 5.1 1 and 2 these differences in the experimental set up may explain the different outcome. Further analysis of the data could help to determine whether the described differences are the reason for the varying outcomes.

Visual attention

Comparing what has been fixated during positive and negative spots showed significant results for three categories: ‘vegetation’, ‘tram/bus’ and ‘traffic signage’. The largest significant difference can be found for the category ‘vegetation’ for which the absolute percentage difference between the means of positive and negative marked spots was 5.4%. This does not necessarily mean that e.g. trees cause bicycle riders’ experience to be positive since trees also indicate other factors such as shadow, higher distance to car lanes, etc. Another plausible explanation might be that when participants can focus on vegetation due to the absence of potential hazards, they generally have a more positive experience. Furthermore, the results indicate that fixating longer on trams or buses and traffic signs relate with having negative experiences. Possible explanations for these relations include that trams or buses could be perceived negatively because they restrict cyclists’ field of view or because riders are required to wait. Focusing longer on traffic signs on negative spots could indicate non-intuitive signs. Alternatively, a longer focus on traffic signs might relate to other factors, such as waiting at traffic lights. As Rupi and Krizek 2019 discussed this might be particularly true for experienced riders since they focused significantly longer on traffic lights compared to unexperienced riders.

How vegetation, tram/bus and traffic signage are related to negative experiences cannot be answered based on the conducted analysis. However, analyzing specific scenes of the recorded videos could help to determine this. For example, by analyzing all video sequences where a traffic sign was looked at for a longer duration compared to sequences where traffic signs were not focused as long. Such an analysis would be especially valuable for infrastructure design, as more precise design recommendations could be identified. Until recently such an analysis would have been very time consuming because categorizing what has been looked at had do be done by hand. Algorithms like the *MyFix* (Alinaghi et al. 2024) make such evaluations less time consuming and therefore more practical for broader use.

5.2 Head movements

The analysis of the head movements has shown no significant differences for neither the angular distance, the angular acceleration nor the amount of head turns for all three time windows as can be seen in chapter 4 Table 4.6. Therefore, hypothesis 3 needs to be rejected as well indicating that head movements of positive and negative perceived spots do not differ. This seems reasonable since also Matviienko et al. 2023 did only find significant differences in head movements for one situation[1] in their in-situ experiment compared to four situations in the virtual reality study.

However, as explained in section 5.1 the analysis conducted here considered all spots regardless of different emotions or intensities. Since measuring head movements to analyze subjective perceptions of bicycle riders is a rather new method, it is reasonable to explore additional approaches. For instance, analyzing the data for specific emotions or intensities might yield valuable insights. Additionally, while the definition of a head turn was set to more than 20 degrees to better compare results with Matviienko et al. 2023, alternative thresholds could be explored. Further the conducted experiment did not only measure head movements but also other upper body movements. This offers the possibility to analyze e.g. hand, arms and shoulder movements. As Boltes et al. 2021 and Tavana et al. 2024 described for pedestrians this can lead to interesting information about e.g. the space required to move.

Also while no differences in head movements between positive and negative spots could be found, it is noticeable that the angular distance of unexperienced riders seems to be higher than the ones of experienced ones. The comparison (independent t-test) has shown that on average head rotation (yaw) values for experienced cyclists were 25 degrees less than those for inexperienced cyclists during the same time period ($t(12.5) = -2.193$, $p = .047$). This indicates that, similar to eye movements, head movements differ between experienced and inexperienced cyclists.

5.3 What this means for spatial planning

While further analysis is required for better interpretation of the above discussed findings, the obtained results suggest that fixation durations of positive and negative experiences of bicycle riders differ. This could be used to evaluate whether certain designs are perceived as positive or negative. In addition, with analysis methods like the *MyFix* algorithm (Alinaghi et al. 2024), more precise evaluations of certain road designs could be done. One possible approach would be to analyze what bicycle riders are fixating at a certain crossing. Possible findings could include which traffic signs are being overlooked or where the cycler's field of view is restricted. Such an evaluation could lead to more precise recommendations for infrastructure design.

Within this study first findings have shown that looking at vegetation is related to positive cycling experience while looking at trams or buses as well as at traffic signs

[1] turning left at uncontrolled intersections

relates with negative experiences. From an urban planning perspective, it would be particularly valuable to further analyze these findings in order to have more precise design recommendations. Besides analyzing the differences in the above mentioned categories valuable findings for infrastructure design might be found by analyzing the eye movements on locations that were oftentimes marked as positive or negative. While this was beyond the scope of this master thesis 'hot spots' of positive and negatively marked spots can be seen on the map in figure 3.8. These locations could be examined in greater detail by analyzing what has been focused. This would likely result in more detailed design recommendations for the analyzed locations as well as for general infrastructure design.

Further, it stands out that participants reported that more than 30% of all negative marked spots were caused by traffic participants. This is by far the largest category as can be seen in chapter 3 figure 3.7. Therefore, it is somewhat surprising that no significant differences were observed in the categories 'car' or 'person' in figure 4.3. However, traffic participants have to be watched at any time regardless of whether they are causing negative or positive reactions for bicycle riders, which might explain why no significant differences have been found for the relevant categories. In terms of improving bicycle infrastructure this is an important finding. While certain infrastructure designs may increase interactions with other traffic participants, not all negative encounters are likely to result from infrastructure. Therefore, the behavior of traffic participants seems to be an important factor for the experiences of bicycle riders. Other studies have shown that different social and behavioral factors influence the cycle attractivity in a city (Nello-Deakin and Nikolaeva 2021). As Nello-Deakin and Nikolaeva [2021] state, such factors are often underestimated in urban planning, as the focus tends to be on infrastructure only. With about one-third of negative spots being marked due to other traffic participants, an approach taking behavioral factors into consideration might be just as promising as focusing on infrastructure design.

While the analysis of the head movements did not reveal notable differences between positive and negative experiences, it did show significant differences between experienced and unexperienced cyclists. In eye-tracking research differences in eye movements from unexperienced and experienced bicycle riders have already been found (e.g. von Stülpnagel [2020]; Rupi and Krizek 2019; Guo et al. 2023). The fact that head movements of experienced and unexperienced cyclers also differ strengthens the argument that the two groups perceive the environment differently. These findings indicate that experienced and unexperienced riders may have distinct needs regarding infrastructure design. Future research could explore these differences in greater detail as well as how infrastructure can meet the needs of both groups.

CHAPTER 6

Conclusion

Within this master thesis positive and negative perceived experiences of bicycle riders were compared by analyzing eye and head movements. For this purpose an in situ study with 28 participants wearing eye tracking glasses and motion capture sensors on their upper body was conducted. While cycling on a predefined route participants marked positive and negative experiences by saying 'now'

Significant differences between positive and negative marked spots regarding eye movements were found for the fixation durations. However, fixation durations on positively marked spots were found to be 42 ms shorter compared to those on negatively marked ones, which contradicts the hypothesis. This contradiction may be explained by two factors: (1) differences in the experimental setup compared to the studies the hypothesis was based on and (2) varying visual behaviors, such as a 'potential hazard' mode versus a 'hazard detected' mode. While other studies might have analyzed segments, the 'potential hazard' mode takes up most of the time in this study the analysis was more punctual, analyzing the 'hazard detected'mode. However, further research is needed to verify this explanation. The analysis of what participants focused on positive and negative perceived spots showed differences in three categories: Vegetation is linked to positive experiences, while trams and buses as well as traffic signs relate to negative experiences. However, based on the obtained results, no precise recommendations for infrastructure design can be made yet. The different possibilities of e.g. how exactly traffic signs cause negative experiences, still need to be explored.

No significant differences between negative and positive experienced spots were found for the fixation counts and the head movements. The analysis of the head movement included the angular distance, the angular acceleration and the amount of head turns. None of the three showed significant results which leads to the conclusion that head movements of positive experiences are not different from those in negative experiences. However, since the analysis of head movements of bicycle riders is a rather new method further research could put the obtained results in a broader context. Further investigations could, e.g., explore different definitions of a head turn.

Although no differences were found in head movements on positive and negative perceived spots, significant differences were found between the angular distance of experienced and unexperienced riders. In total, unexperienced cyclers have moved their head 25 degrees further / more within 5 s than experienced cyclers did. This means that not only eye movements but also head movements of experienced cyclers are different to those of unexperienced cyclers. This strengthens the argument that the two groups perceive the environment differently, which highlights the importance of analyzing unexperienced cyclers' perceptions. As inexperienced cyclists represent potential new riders, this is particularly important for enhancing cycling attractivity for a broader audience.

Further, participants linked about one-third of all negative marked spots to other traffic participants. This indicates that addressing cycling issues might require analyzing social and behavioral factors as well as infrastructure design. Therefore, analyzing the behaviors of both traffic participants and cyclists themselves could help identify such factors to improve urban cycling. Eye-tracking – particularly the analysis of visual attention – could offer interesting possibilities to research behavioral factors that influence cycling experiences.

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Bibliography

Ennia Mariapaola Acerra, Murad Shoman, Hocine Imine, Claudia Brasile, Claudio Lantieri, and Valeria Vignali. The visual behaviour of the cyclist: Comparison between simulated and real scenarios. *Infrastructures*, 8(5), 2023. doi:10.3390/infrastructures8050092.

Negar Alinaghi, Samuel Hollendonner, and Ioannis Giannopoulos. Myfix: Automated fixation annotation of eye-tracking videos. *Sensors*, 24(9):2666, 2024. doi:10.3390/s24092666.

Andrew D. Althouse. Adjust for multiple comparisons? it's not that simple. *The Annals of Thoracic Surgery*, 101(5):1644–1645, 2016. doi:10.1016/j.athoracsur.2015.11.024.

Greater London Authority. The mayor's transport strategy. London, 2018.

Roy F. Baumeister, Ellen Bratslavsky, Catrin Finkenauer, and Kathleen D. Vohs. Bad is stronger than good. *Review of General Psychology*, 5(4):323–370, 2001. doi:10.1037/1089-2680.5.4.323.

Ben Beck, Chris Pettit, Meghan Winters, Trisalyn Nelson, Hai L. Vu, Kerry Nice, Sachith Seneviratne, and Meead Saberi. Association between network characteristics and bicycle ridership across a large metropolitan region. *International Journal of Sustainable Transportation*, 18(4):344–355, 2024. doi:10.1080/15568318.2024.2308266.

Maik Boltes, Juliane Adrian, and Anna-Katharina Raytarowski. A hybrid tracking system of full-body motion inside crowds. *Sensors*, 21(6), 2021. doi:10.3390/s21062108.

Energie Mobilität Innovation und Technologie Bundesministerium für Klimaschutz, Umwelt. Mobilitätsmaster plan 2030 für Österreich der neue klimaschutz-rahmen für den verkehrssektor nachhaltig – resilient – digital. Österreich, 2021.

Marta Campos Ferreira, Paulo Dias Costa, Diogo Abrantes, Joana Hora, Soraia Felício, Miguel Coimbra, and Teresa Galvão Dias. Identifying the determinants and understanding their effect on the perception of safety, security, and comfort by pedestrians and cyclists: A systematic review. *Transportation Research Part F: Traffic Psychology and Behaviour*, 91:136–163, 2022. doi:10.1016/j.trf.2022.10.004.

Peter R. Chapman and Geoffrey Underwood. Visual search of driving situations: Danger and experience. *Perception*, 27(8):951–964, 1998. doi:10.1068/p270951.

Tiffany E. Chow and Jesse Rissman. Neurocognitive mechanisms of real-world autobiographical memory retrieval: insights from studies using wearable camera technology. *Annals of the New York Academy of Sciences*, 1396(1):202–221, 2017. doi:10.1111/nyas.13353.

John Colwell and Angus Culverwell. An examination of the relationship between cycle training, cycle accidents, attitudes and cycling behaviour among children. *Ergonomics*, 45:640–8, 2002. doi:10.1080/00140130210156303.

David Crundall, Geoffrey Underwood, and Peter Chapman. Driving experience and the functional field of view. *Perception*, 28(9):1075–1087, 1999. doi:10.1068/p281075.

Rudy Dunlap, Jeff Rose, Sarah Standridge, and Courtney Pruitt. Experiences of urban cycling: emotional geographies of people and place. *Leisure Studies*, 40:1–14, 2020. doi:10.1080/02614367.2020.1720787.

Linda Dörrzapf. *Stress und Emotionen in der aktiven Mobilität messen: Potenziale und Grenzen der Humansensorik für die Verkehrsplanung*. PhD thesis, Technische Universität Wien, Vienna, Austria, 2023.

Linda Dörrzapf, Peter Zeile, Günther Sagl, Martin Sudmanns, A. Summa, and Bernd Resch. Urban emotions - an interdisciplinary interface between geoinformatics and urban planning. *gis.Science - Die Zeitschrift fur Geoinformatik*, 1:11–19, 2015.

Hans Feenstra, Robert Ruiter, Jan Schepers, Gjalt-Jorn Peters, and Gerjo Kok. Measuring risky adolescent cycling behavior. *International Journal of Injury Control and Safety Promotion*, 18:181–7, 2011. doi:10.1080/17457300.2010.540334.

Dillon T. Fitch, James Sharpnack, and Susan L. Handy. Psychological stress of bicycling with traffic: examining heart rate variability of bicyclists in natural urban environments. *Transportation Research Part F: Traffic Psychology and Behaviour*, 70:81–97, 2020. doi:10.1016/j.trf.2020.02.015.

Nicholas Fournier, Sarah Bakhtiari, Krishna Deep Valluru, Nicholas Campbell, Eleni Christofa, Shannon Roberts, and Michael Knodler. Accounting for drivers' bicycling frequency and familiarity with bicycle infrastructure treatments when evaluating safety. *Accident Analysis Prevention*, 137:105410, 2020. doi:10.1016/j.aap.2019.105410.

David Friel, Sina Wachholz, Theresa Werner, Liesa Zimmermann, Oliver Schwedes, and Rainer Stark. Cyclists' perceived safety on intersections and roundabouts – a qualitative bicycle simulator study. *Journal of Safety Research*, 87:143–156, 2023. doi:10.1016/j.jsr.2023.09.012.

Rosa Félix, Filipe Moura, and Kelly Clifton. Typologies of urban cyclists: Review of market segmentation methods for planning practice. *Transportation Research Record: Journal of the Transportation Research Board*, 2662:125–133, 2017. doi:10.3141/2662-14.

Bundesamt für Strassen Schweiz (ASTRA). Teilstrategie langsamverkehr. Schweiz, 2022.

April Gadsby, Marjan Hagenzieker, and Kari Watkins. An international comparison of the self-reported causes of cyclist stress using quasi-naturalistic cycling. *Journal of Transport Geography*, 91:102932, 2021. doi:10.1016/j.jtrangeo.2020.102932.

Nathan Gale, Reginald G. Golledge, William C. Halperin, and Helen Couclelis. Exploring spatial familiarity. *The Professional Geographer*, 42(3):299–313, 1990. doi:10.1111/j.0033-0124.1990.00299.x.

Miguel A. García-Pérez. Use and misuse of corrections for multiple testing. *Methods in Psychology*, 8:100120, 2023. doi:10.1016/j.metip.2023.100120.

Simeng Gu, Fushun Wang, Tifei Yuan, Benyu Guo, and Jason Huang. Differentiation of primary emotions through neuromodulators: Review of literature. *International Journal of Neurology Research*, 1:43–50, 2015. doi:10.17554/j.issn.2313-5611.2015.01.19.

Simeng Gu, Fang Wang, Nilesh P. Patel, James A. Bourgeois, and Jun H. Huang. A model for basic emotions using observations of behavior in drosophila. *Frontiers in Psychology*, 10:781, 2019. doi:10.3389/fpsyg.2019.00781.

Xiang Guo, Arash Tavakoli, Erin Robartes, Austin Valentine Angulo, T. Donna Chen, and Arsalan Heydarian. Roadway design matters: Variation in bicyclists' psycho-physiological responses in different urban roadway designs. *ArXiv*, 2022. doi:10.48550/arXiv.2202.13468.

Xiang Guo, Arash Tavakoli, Austin Angulo, Erin Robartes, T. Donna Chen, and Arsalan Heydarian. Psycho-physiological measures on a bicycle simulator in immersive virtual environments: How protected/curbside bike lanes may improve perceived safety. *Transportation Research Part F: Traffic Psychology and Behaviour*, 92:317–336, 2023. doi:10.1016/j.trf.2022.11.015.

Stefan Gössling and Sophia McRae. Subjectively safe cycling infrastructure: New insights for urban designs. *Journal of Transport Geography*, 101:103340, 2022. doi:10.1016/j.jtrangeo.2022.103340.

Cindy Harmon-Jones, Brock Bastian, and Eddie Harmon-Jones. The discrete emotions questionnaire: A new tool for measuring state self-reported emotions. *PL o S ONE*, 11:e0159915, 2016. doi:10.1371/journal.pone.0159915.

Ilse M. Harms, Bridget R.D. Burdett, and Samuel G. Charlton. The role of route familiarity in traffic participants' behaviour and transport psychology research: A systematic review. *Transportation Research Interdisciplinary Perspectives*, 9:100331, 2021. doi:10.1016/j.trip.2021.100331.

Christian Hasler. *Geschwindigkeiten in städtischen Netzen. Ansprüche und Optimum*. Bundesministerium für Verkehr, Innovation und Technologie, Wien, 2016.

Mary Hegarty, Anthony E Richardson, Daniel R Montello, Kristin Lovelace, and Ilavanil Subbiah. Development of a self-report measure of environmental spatial ability. *Intelligence*, 30(5):425–447, 2002. doi:10.1016/S0160-2896(02)00116-2.

Gukhwa Jang and Saehoon Kim. Investigating the effect of a raised cycle track, physical separation, land use and number of pedestrian on cyclists' gaze behavior. *Journal of Architecture And Urbanism*, 43:112–122, 2019. doi:10.3846/jau.2019.3786.

Anika K. Josef, David Richter, Gregory R. Samanez-Larkin, Gert G. Wagner, Ralph Hertwig, and Rui Mata. Stability and change in risk-taking propensity across the adult life span. *Journal of Personality and Social Psychology*, 111(3):430–450, 2016. doi:10.1037/pspp0000090.

Fatima Kchour, Salvatore Cafiso, and Giuseppina Pappalardo. Understanding cyclists' visual behavior using eye-tracking technology: A systematic review. *Sensors*, 25(1), 2025. doi:10.3390/s25010022.

Tanja S. Kellermann, Melanie A. Sternkopf, Frank Schneider, Ute Habel, Bruce I. Turetsky, Karl Zilles, and Simon B. Eickhoff. Modulating the processing of emotional stimuli by cognitive demand. *Social Cognitive and Affective Neuroscience*, 7(3):263–273, 2011. doi:10.1093/scan/nsq104.

An-Magritt Kummeneje and Torbjørn Rundmo. Attitudes, risk perception and risk-taking behaviour among regular cyclists in norway. *Transportation Research Part F: Traffic Psychology and Behaviour*, 69:135–150, 2020. doi:10.1016/j.trf.2020.01.007.

Shiyu Ma, Wenwen Zhang, Robert B. Noland, and Clinton J. Andrews. Eye tracking measures of bicyclists' behavior and perception: A systematic review. *Transportation Research Part F: Traffic Psychology and Behaviour*, 107:52–68, 2024. doi:10.1016/j.trf.2024.08.026.

Alessandra Mantuano, Silvia Bernardi, and Federico Rupi. Cyclist gaze behavior in urban space: An eye-tracking experiment on the bicycle network of bologna. *Case Studies on Transport Policy*, 5(2):408–416, 2017. doi:10.1016/j.cstp.2016.06.001.

Andrii Matviienko, Manuel Lehé, Florian Heller, Bastian Pfleging, and Max Mühlhäuser. Quantibike: Quantifying perceived cyclists' safety via head movements in virtual reality and outdoors. In *Proceedings of the 2023 ACM Symposium on Spatial User Interaction*, SUI '23, New York, NY, USA, 2023. Association for Computing Machinery. doi:10.1145/3607822.3614532.

Nicolaj Motzer, Peter Zeile, Bernd Resch, Nina Haug, Céline Schmidt-Hamburger, Martin Moser, Frank Otte, Maximilian Heinke, Carolina Mazza, Mira Kern, and Peter Klein. Emotionswahrnehmung für fahrradsicherheit und mobilitätskomfort: Analyse von humansensorischen messungen und korrelation mit umgebungsparametern. *Journal of Digital Landscape Architecture*, pages 381–389, 2023. doi:10.14627/537742015.

Stefan Münzer and Christoph Hölscher. Entwicklung und validierung eines fragebogens zu räumlichen strategien. *Diagnostica*, 57:111–125, 2011. doi:10.1026/0012-1924/a000040.

M. Nazemi, M.A.B. van Eggermond, A. Erath, D. Schaffner, M. Joos, and Kay W. Axhausen. Studying bicyclists' perceived level of safety using a bicycle simulator combined with immersive virtual reality. *Accident Analysis Prevention*, 151:105943, 2021. doi:10.1016/j.aap.2020.105943.

Samuel Nello-Deakin and Anna Nikolaeva. The human infrastructure of a cycling city: Amsterdam through the eyes of international newcomers. *Urban Geography*, 42(3): 289–311, 2021. doi:10.1080/02723638.2019.1709757.

Sara Rivera Olsson and Erik Elldér. Are bicycle streets cyclist-friendly? micro-environmental factors for improving perceived safety when cycling in mixed traffic. *Accident Analysis and Prevention*, 184:107007, 2023. doi:10.1016/j.aap.2023.107007.

Friedrich Ostendorf. *Sprache und Persönlichkeitsstruktur: zur Validität des Fünf-Faktoren-Modells der Persönlichkeit.* Roderer, Regensburg, Germany, 1990.

Steve O'Hern, Amanda N. Stephens, Kristie L. Young, and Sjaan Koppel. Personality traits as predictors of cyclist behaviour. *Accident Analysis Prevention*, 145:105704, 2020. doi:10.1016/j.aap.2020.105704.

John Parkin, Mark Wardman, and Matthew Page. Models of perceived cycling risk and route acceptability. *Accident Analysis Prevention*, 39(2):364–371, 2007. doi:10.1016/j.aap.2006.08.007.

Anton Pashkevich, Tomasz E. Burghardt, Sabina Puławska-Obiedowska, and Matúš Šucha. Visual attention and speeds of pedestrians, cyclists, and electric scooter riders when using shared road – a field eye tracker experiment. *Case Studies on Transport Policy*, 10(1):549–558, 2022. doi:10.1016/j.cstp.2022.01.015.

Beatrice Rammstedt, Christoph J. Kemper, Mira Céline Klein, Constanze Beierlein, and Anastassiya Kovaleva. A short scale for assessing the big five dimensions of personality: 10 item big five inventory (bfi-10). *methods, data, analyses*, 7(2):17, 2013. doi:10.12758/mda.2013.013.

Léa Ravensbergen, Ron Buliung, and Nicole Laliberté. Fear of cycling: Social, spatial, and temporal dimensions. *Journal of Transport Geography*, 87:102813, 2020. doi:10.1016/j.jtrangeo.2020.102813.

Mark Rubin. When to adjust alpha during multiple testing: a consideration of disjunction, conjunction, and individual testing. *Synthese*, 199:10969–11000, 2021. doi:10.1007/s11229-021-03276-4.

Federico Rupi and J. Kevin Krizek. Visual eye gaze while cycling: Analyzing eye tracking at signalized intersections in urban conditions. *Sustainability*, 11:6089, 11 2019. doi:10.3390/su11216089.

Rebecca L. Sanders. Perceived traffic risk for cyclists: The impact of near miss and collision experiences. *Accident Analysis Prevention*, 75:26–34, 2015. doi:10.1016/j.aap.2014.11.004.

Sonja Schmidt and Rul von Stülpnagel. Risk perception and gaze behavior during urban cycling – a field study. In Peter Kiefer, Ioannis Giannopoulos, Fabian Göbel, Martin Raubal, and Andrew T. Duchowski, editors, *Eye Tracking for Spatial Research, Proceedings of the 3rd International Workshop*, page 6, Zurich, Switzerland, 2018. ETH Zurich. doi:10.3929/ethz-b-000222474.

Hossein Tavana, Peter Thompson, Karen Boyce, Håkan Frantzich, Daniel Nilsson, and Denise McGrath. A novel approach to the investigation and quantification of the stop/start process for pedestrian traffic using motion capture devices. *Travel Behaviour and Society*, 34:100659, 2024. doi:10.1016/j.tbs.2023.100659.

Rudolf Uher, Samantha J. Brooks, Savani Bartholdy, Kate Tchanturia, and Iain C. Campbell. Increasing cognitive load reduces interference from masked appetitive and aversive but not neutral stimuli. *PL o S ONE*, 9(4):1–8, 2014. doi:10.1371/journal.pone.0094417.

Amrisha Vaish, Tobias Grossmann, and Amanda Woodward. Not all emotions are created equal: The negativity bias in social-emotional development. *Psychological Bulletin*, 134(3):383–403, 2008. doi:10.1037/0033-2909.134.3.383.

Boris M. Velichkovsky, Alexandra Rothert, Mathias Kopf, Sascha M. Dornhöfer, and Markus Joos. Towards an express-diagnostics for level of processing and hazard perception. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5(2): 145–156, 2002. doi:10.1016/S1369-8478(02)00013-X.

Rul von Stülpnagel. Gaze behavior during urban cycling: Effects of subjective risk perception and vista space properties. *Transportation Research Part F: Traffic Psychology and Behaviour*, 75:222–238, 2020. doi:10.1016/j.trf.2020.10.007.

Rul von Stülpnagel and Jakub Krukar. Risk perception during urban cycling: An assessment of crowdsourced and authoritative data. *Accident Analysis Prevention*, 121:109–117, 2018. doi:10.1016/j.aap.2018.09.009.

Kei Watanabe and Shintaro Funahashi. Neural mechanisms of dual-task interference and cognitive capacity limitation in the prefrontal cortex. *Nature Neuroscience*, 17(4): 601–611, 2014. doi:10.1038/nn.3667.

Christian Werner, Bernd Resch, and Martin Loidl. Evaluating urban bicycle infrastructures through intersubjectivity of stress sensations derived from physiological measurements. *ISPRS International Journal of Geo-Information*, 8(6), 2019. doi:10.3390/ijgi8060265.

Tessa Williams, David G.T. Whitehurst, Trisalyn Nelson, Daniel Fuller, Suzanne Therrien, Lise Gauvin, and Meghan Winters. All ages and abilities cycling infrastructure, cycling activity, and perceived safety: Findings from a natural experiment study in three mid-sized canadian cities. *Journal of Cycling and Micromobility Research*, 1:100005, 2023. doi:10.1016/j.jcmr.2023.100005.

Alfred L. Yarbus. *Eye Movements and Vision*. Springer US, 1967.

Ran Zhang, Marco Te Brömmelstroet, Anna Nikolaeva, and George Liu. Cycling subjective experience: A conceptual framework and methods review. *Transportation Research Part F: Traffic Psychology and Behaviour*, 101:142–159, 2024. doi:10.1016/j.trf.2023.12.021.

Álvaro Fernández-Heredia, Andrés Monzón, and Sergio Jara-Díaz. Understanding cyclists' perceptions, keys for a successful bicycle promotion. *Transportation Research Part A: Policy and Practice*, 63:1–11, 2014. doi:10.1016/j.tra.2014.02.013.

Appendix

Appendix A

Appendix A.1 – Flyer

Appendix A.2 – Prequestionnaire

Subjektives Sicherheitsempfinden von Fahrradfahrenden

Guten Tag!

Willkommen zu unserer Studie über das subjektive Sicherheitsempfinden von Radfahrer:innen in der Stadt! Wir schätzen Ihr Interesse an der Teilnahme sehr!

Für mehr Informationen und um zu sehen, ob Sie überhaupt für die Teilnahme in Frage kommen, klicken Sie bitte auf „weiter".

In dieser Umfrage sind 35 Fragen enthalten.

Pre-Screening

Können Sie an der Studie vor Ort (TU Wien, Freihaus, Wiedner Hauptstrasse 8-10) an einem Tag zwischen dem 11.09.24 und 05.10.24 teilnehmen? *

Bitte kreuzen Sie eine der folgenden Antworten an:

- ○ Ja
- ○ Nein

Nehmen Sie zur Zeit (Sommersemester 2024) an einer Lehrveranstaltung von Prof. Dr. Martin Berger (Raumplanung), Dr. Markus Kattenbeck (Geoinformation) oder Prof. Dr. Ioannis Giannopoulos (Geoinformation) teil?*

Bitte kreuzen Sie eine der folgenden Antworten an:

- ○ Ja
- ○ Nein

Können Sie ihr eigenes Fahrrad (Kein E-Bike) zum Startpunkt der Studie (TU Wien) mitnehmen, das den Bedingungen der Fahrradverordnung (Strassenverkehrsordnung RIS - Fahrradverordnung) entspricht? (Falls Sie gewohnt sind mit einem Leihrad zu fahren (z.B. Wien Mobil oder von Freunden/Bekannten) können Sie auch mit diesem Rad an der Studie teilnehmen) *

Bitte kreuzen Sie eine der folgenden Antworten an:

- ○ Ja
- ○ Nein

Sind Sie über 18 Jahre alt?*

Bitte kreuzen Sie eine der folgenden Antworten an:

- ◯ Ja
- ◯ Nein

Sind sie bereit uns ihr biologisches Geschlecht mitzuteilen? (Die Software des verwendeten Equippments benötigt die Angabe)*

Bitte kreuzen Sie eine der folgenden Antworten an:

- ◯ Ja
- ◯ Nein

Aufgrund der verfügbaren Größe des Equipments benötigen wir eine Angabe Ihres Body-Mass-Indexes. Falls Sie diesen nicht kennen, können Sie ihn hier berechnen BMI berechnen*

Bitte kreuzen Sie eine der folgenden Antworten an:

- ◯ BMI über 30
- ◯ BMI unter 30

Bitte wählen Sie, was auf Sie zutrifft.*

- ◯ Ich trage keine Brille/Kontaktlinsen und sehe gut.
- ◯ Ich trage eine Brille mit einer Korrektur von bis +/- 3 Dioptrien.
- ◯ Ich trage Kontaktlinsen.
- ◯ Ich trage eine Brille mit einer Korrektur von mehr als +/- 3 Dioptrien und habe keine Moeglichkeit, Kontaktlinsen fuer die Dauer des Experiments zu tragen.

Leiden Sie unter einer Form von Farbsehschwäche (z.B. rot/grün)?*

Bitte kreuzen Sie eine der folgenden Antworten an:

- ◯ Ja
- ◯ Nein

Sind sie bereits in Wien Fahrrad gefahren und trauen es sich zu, mit dem Fahrrad ca. 5 km weit zu fahren (in Wien bei flachen Verhältnissen)?*

Bitte kreuzen Sie eine der folgenden Antworten an:

○ Ja

○ Nein

Sind Sie in der Lage, in einer N-Position (Arme links und rechts vom Körper hängend) zu stehen?*

Bitte kreuzen Sie eine der folgenden Antworten an:

○ Ja

○ Nein

Könnten Sie diese teilweise auf Englisch gestellte Frage beantworten? *

Emotionen

*Nachstehend finden Sie eine Liste von fünf Emotionen. Zu Ihrem Verständnis sind fuer jede Emotion jeweils weitere Emotionen angegeben, welche in dieselbe Kategorie fallen. Bitte wählen Sie für jede der Emotionen die Intensität aus, mit der Sie sie empfunden haben.

	Not at all (überhaupt nicht)	slightly (kaum)	somewhat (etwas)	moderatly (moderat)	quite a bit (ziemlich)	very much (sehr fest)	an extreme amount (extrem)
Anger (Wut) - Mad, Rage, Pissed-Off, Anger	○	○	○	○	○	○	○
Fear (Angst) - Scared, Panic, Terror, Fear	○	○	○	○	○	○	○
Anxiety (Ängstlichkeit) - Nervous, Worry, Dread, Anxiety	○	○	○	○	○	○	○
Relaxation (Gelassenheit) - Easygoing, Chilled Out, Calm, Relaxation	○	○	○	○	○	○	○
Happiness (Freude) - Satisfaction, Enjoyment, Liking, Happy	○	○	○	○	○	○	○

Bitte kreuzen Sie eine der folgenden Antworten an:

○ Ja

○ Nein

Falls eine der oben gestellten Fragen so beantwortet wurde, dass eine Person nicht an der Studie teilnehmen konnte wurde Folgendes angezeigt:

Pre-Screening Out

Sie erfüllen einen der unten aufgeführten Punkte, weswegen Sie leider nicht an der Studie vor Ort teilnehmen können. Für etwaige Rückfragen können Sie sich gerne bei Sarah Volken (e12221657@student.tuwien.ac.at) melden.

Wir bedanken uns für ihr Interesse an unserer Studie!

Sollte keiner dieser Punkte zutreffen, haben Sie sich vermutlich vertippt. Gerne können Sie die Umfrage nochmal über den Einladungslink starten.

- Sie sind unter 18 Jahren alt
- Sie besuchen im Sommersemester 2024 eine Veranstaltung von Prof. Berger, Prof Giannapolous oder Dr. Kattenbeck.
- Sie können kein Fahrrad zur Studie mitbringen
- Sie können keine Linsen tragen und haben eine Korrektur von mehr als +/- 3 Dioptrien.
- Ihr Body-Mass-Index ist über 30
- Sie können bis Mitte August an keinem Tag zur Studie zu kommen.
- Sie leiden an einer Farbsehschwäche.
- Sie trauen es sich nicht zu 5 km in Wien Rad zu fahren.
- Sie können nicht in einer N Position stehen.
- Sie können bis im August an keinem Tag an der Studie vor Ort teilnehmen.

Appendix A.3 – Informed Consent

Informed Consent und Datenschutz

Guten Tag!

Willkommen zu unserer Radfahr-Studie, die im Rahmen der Diplomarbeit von Sarah Volken durchgeführt wird. Wir schätzen Ihr Interesse an der Teilnahme sehr!

Um das subjektive Sicherheitsempfinden von Radfahrer:innen in der Stadt zu untersuchen, bitten wir Sie, ein mobiles Eye-Tracking-Gerät (es ähnelt einer Brille und zeichnet auf, wo genau Sie hinschauen) und mehrere Bewegungssensoren zu tragen (vgl. Bilder unten). Dies ermöglicht es uns, Ihre Augen- und Oberkörperbewegungen aufzuzeichnen. So ausgerüstet, fahren Sie eine ca. 4,5 km lange Strecke auf Ihrem eigenen* Fahrrad (Dauer ca. 25 min) und beantworten uns anschließend einige Fragen im Labor an Hand des aufgezeichneten Videos.

Bitte lesen Sie folgende Beschreibung der Studie genau durch, damit Sie wissen, wie der Versuch genau ablaufen wird. **Am Ende des Dokuments bestätigen Sie, dessen Inhalt gelesen und verstanden zu haben und über den Ablauf der Studie informiert worden zu sein.** Falls Sie sich entscheiden, an der Studie teilzunehmen, wird Ihnen der Ablauf auch nochmal per Mail zugeschickt. Sollten Sie **Fragen zum Ablauf haben können Sie sich gerne an Sarah Volken (e12221657@student.tuwien.ac.at) wenden.**

*Falls Sie gewohnt sind mit einem Leihrad zu fahren (z.B. Wien Mobil oder von Freunden/Bekannten), können Sie auch mit diesem Rad an der Studie teilnehmen

Ablauf

In einem ersten Teil bitten wir Sie online einen Fragebogen auszufüllen (ca. 20 min). Der Fragebogen umfasst Informationen zu Ihnen als Person sowie zu Ihrem Orientierungssinn.

Im zweiten Teil bitten wir Sie, mit Ihrem Rad in unser Labor im Freihaus der TU Wien zu kommen. Nach einem kurzen Fragebogen (5 min) werden Sie mit einer Eye-Tracking-Brille (ähnelt einer normalen Brille) und Bewegungssensoren ausgerüstet. Dieses Equipment ermöglicht es uns, zu verstehen, wann Sie wohin sehen und wie Sie sich während der Fahrradfahrt bewegen. Falls Sie eine Brille tragen und keine Möglichkeit haben, Kontaktlinsen zu tragen, bitten wir Sie, uns im Fragebogen ihre Dioptriestärke anzugeben, damit wir den Eyetracker auf ihre Sehstärke anpassen können. Bei den Bewegungssensoren handelt es sich um IMU-Sensoren (Ein Smartphone hat auch einen solchen Sensor.) in der Größe einer Streichholzschachtel. Davon werden 10 Stück mithilfe von Bändern mit Klettverschlüssen an Ihrem Oberkörper befestigt (Video - Die Sensoren an den Beinen werden nicht benötigt). **Der Becken-Sensor muss wegen seiner Bewegungsempfindlichkeit mit Sporttape an Ihr Kreuzbein befestigt werden** (siehe erstes Bild unten). Zu diesem Zweck werden wir Sie bitten, den Bund Ihrer Hose bis zum Ansatz Ihres Gesäßes nach unten zu schieben, sodass das Befestigen des Sensors möglich wird. Während der Befestigung wird außer Sarah Volken und Ihnen eine dritte Person im Labor anwesend sein. Damit präzise Resultate mit den Bewegungssensoren gemacht werden können, benötigen wir außerdem 2 Körpermaße von Ihnen - die Körpergröße und die Schuhlänge. **Während wir die Sensoren anbringen, werden wir Sie berühren müssen. Dies wird von Sarah Volken (weiblich) durchgeführt.** Während Sie mit dem Equipment ausgestattet werden, wird eine weitere Person stets in Rufweite sein.

Damit die Sensoren gut befestigt werden können und während des Fahrradfahrens nicht verrutschen oder gestört werden, bitten wir Sie Folgendes zu beachten, wenn Sie zur Studie kommen: Bitte tragen Sie keinen Schmuck und keine metallischen Gegenstände (z.B. BH mit Bügel, Gürtel etc.) und binden Sie lange Haare zusammen. Der Kopf-Sensor wird an einem von uns zur Verfügung gestellten Helm befestigt. Sie benötigen keinen eigenen Helm für die Teilnahme an der Studie.

Zusätzlich zur Eye-Tracker-Brille und den Bewegungssensoren werden wir Ihnen einen hoch präzisen GPS-Tracker mitgeben. **Komplett ausgerüstet werden Sie in etwa so aussehen, wie die Person auf der Abbildung oben**. Das Ausrüsten findet im Labor im Freihaus der TU Wien (Wiedner Haupstrasse 8-10) statt.

Mit den Sensoren, dem GPS-Tracker und der Eye-Tracking Brille ausgestattet, werden **Sie zunächst die Möglichkeit haben, sich an das Fahren mit den Sensoren zu gewöhnen.** Daraufhin werden Sie eine vordefinierte ca. 4,5 km lange Route mit Ihrem Rad fahren. Zur Navigation werden wir eine **Handyhalterung auf Ihrem Rad befestigen,** so dass Sie sich mithilfe von Google-Maps im Navigationsmodus orientieren können. Während der Fahrt bitten wir Sie "jetzt" auszusprechen, wenn sie sich „sicher/wohl" oder „unsicher/unwohl" fühlen. Dies wird von der Audiospur des Eye-Trackers aufgenommen. Damit wir eine zweite Tonspur haben und keine Daten verlieren, werden wir, wenn Sie einverstanden sind, zusätzlich eine GoPro an ihrem Lenkrad befestigen. Sie können jederzeit anhalten, wenn Sie sich unwohl fühlen oder eine Pause benötigen. Sarah Volken wird hinter Ihnen fahren. Sollten Sie Fragen haben oder aus dem Versuch aussteigen möchten, können Sie sich jederzeit an sie wenden.

Nach der Fahrt wird das Equipment abgelegt und wir zeigen Ihnen Ihre Eye-Tracking-Aufnahme. An den Stellen, an denen Sie sich zu ihrem Wohlbefinden geäußert haben, werden wir Ihnen weitere kurze Fragen stellen.

Die Teilnahme an der Studie dauert ca. 2,5 Stunden. Der Tag der In-situ Studie wird flexibel via termino.gv.at vereinbart. Pro Tag werden maximal 3 Termine, einmal morgens, einmal nachmittags, einmal abends (aus Sicherheitsgründen nicht während der Stoßzeiten), angeboten.

Risiken

- Die größte Gefahr für Sie besteht während der Fahrradfahrt im Verkehr. **Das Risiko eines Unfalls kann nicht gänzlich ausgeschlossen werden**. Selbstverständlich sind Sie während der Fahrt für die Studie versichert. Um das Risiko so klein wie möglich zu halten, werden wir nicht zu den Stoßzeiten fahren. Die Studie findet nur bei guter Witterung statt. Das Tragen eines Helms ist obligatorisch, der Helm wird von uns zur Verfügung gestellt. **Sie sind verpflichtet sich jederzeit an die (Strassenverkehrsordnung) zu halten und auf risikoreiche Fahrmanöver zu verzichten**. Es liegt in Ihrer Verantwortung nur an der Studie teilzunehmen, wenn Sie grundsätzlich in der Lage sind, Verkehrteilnehmer:in zu sein (keine Drogen etc.). Aus Sicherheitsgründen werden Sie auch mit Ihrem eigenen/ihnen bekannten Fahrrad fahren, von dem Sie wissen, wie es reagiert. Es liegt in Ihrer Verantwortung, dass das Fahrrad den Anforderungen der Fahrradverordnung (Fahrradverordnung) entspricht.

- Während des Fahrens könnten Sie sich unwohl fühlen, wenn Sie darüber nachdenken, wie Sie mit der Ausrüstung aussehen. Ihre Bewegungsfreiheit ist durch die Ausrüstung jedoch nicht eingeschränkt und von anderen Studien wird berichtet, dass Teilnehmende die Eye-Tracking-Brille sowie die Sensoren nach einiger Zeit kaum noch wahrnehmen. Sie haben jederzeit das Recht, Ihre Teilnahme zu beenden.

- Während des Ausrüstens mit den Sensoren und dem Eye-Tracker könnten Sie sich unwohl fühlen, da doch einige Sensoren an Ihnen befestigt werden, was ungewöhnlich ist, und Ihre Körpergröße/Schuhgröße gemessen wird. Sie können die Studie natürlich jederzeit grundlos abbrechen und es ist zu jedem Zeitpunkt eine weitere Person mindestens in unmittelbarer Hörweite, so dass Sie nur zu rufen brauchen, sollte Ihnen unwohl sein.

Vorteile

- Sie könnten die Teilnahme an der Studie, insbesondere das Fahren mit der Ausrüstung interessant (und unterhaltsam) finden.
- Wenn Sie möchten, können wir Ihnen die Aufzeichnung ihrer Körperbewegungen (in Form eines Videos mit Avatar, der Ihre Bewegung ausführt) und das Video mit ihren Augenbewegungen zukommen lassen.
- Unter den ca. 40 Teilnehmenden verlosen wir einmal 200 Euro.

Datenschutz

- Alle während der Studie erhobenen Daten werden nur in pseudonymisierter Form verwendet (dies gilt auch für die Veröffentlichung der Forschungsdaten im Rahmen von Publikationen oder der Verfügbarmachung in Forschungsdatenrepositorien).
- Die Information Ihrer personenbezogenen Daten erfolgt auf Grundlage der Datenschutzerklärung der Forschungsgruppe Geoinformation der TU Wien (Datenschutzerklärung Geoinformation TU Wien).

Kontaktinformationen

- Wenn Sie glauben, dass Sie als Folge Ihrer Teilnahme verletzt wurden, wenden Sie sich bitte an den Versuchsleiter: Dr. Markus Kattenbeck, Forschungsgruppe Geoinformation, markus.kattenbeck@geo.tuwien.ac.at, +43 (1) 588 011 271 9.

Freiwilligkeit der Teilnahme und Möglichkeit, die Teilnahme zu beenden

Die Teilnahme an der Forschung ist freiwillig. Sie können die Teilnahme jederzeit grundlos abbrechen, indem Sie dies Sarah Volken persönlich mitteilen oder eine E-Mail an ihre E-Mail-Adresse (e12221657@student.tuwien.ac.at) senden.

Nachfolgend bestätigen Sie, die oben geschriebenen Informationen zur Studie verstanden zu haben und an dieser Studie unter den beschriebenen Bedingungen teilnehmen zu wollen.

Bitte kreuzen Sie die einzelnen Punkte zur Bestätigung an.*

- ☐ Mir ist bewusst, dass Körpermaße genommen werden und Sensoren an meinem Körper befestigt werden, insbesondere am Kreuzbein, wo der Sensor auf meiner Haut angeklebt wird. Ich bin damit einverstanden, dass dies von einer Frau gemacht wird.
- ☐ Mir ist bewusst, dass das Risiko eines Verkehrsunfalls trotz Sicherheitsmaßnahmen bestehen bleibt und dass mein persönliches Verhalten im Straßenverkehr einen Einfluss darauf hat. Mir ist bewusst, dass ich mich an die Straßenverkehrsordnung halten muss.
- ☐ Ich bestätige, dass das Fahrrad, das ich zur Studiendurchführung mitbringen werde, die Bedingungen der aktuellen Fahrradverordnung erfüllt. Ich bin bereit, für die Studie auf Schmuck zu verzichten sowie meine Haare zusammenzubinden.
- ☐ Ich bestätige, dass ich die oben geschriebene Erklärung gelesen und verstanden habe. Ich weiß, dass ich jederzeit weitere Fragen an Sarah Volken oder Dr. Markus Kattenbeck stellen kann.
- ☐ Mir ist bewusst, dass ich meine Teilnahme an der Studie jederzeit ohne Angabe von Gründen abbrechen kann.
- ☐ Ich bin damit einverstanden, dass meine Körperbewegungen, meine Augenbewegungen und meine verbalen Äußerungen während der Studie aufgezeichnet werden. Darüber hinaus bin ich bereit, Angaben zu meiner Person, meiner Sehstärke, meinem Fahrradverhalten und meiner Orientierungsfähigkeit zu geben.
- ☐ Ich bestätige, dass ich an der oben beschriebenen Studie teilnehmen möchte.

Nachfolgend bestätigen Sie, dass Sie mit der Verarbeitung Ihrer Daten im Rahmen dieser Studie, basierend auf der Datenschutzerkärung der Forschugsgruppe Geoinformation, einverstanden sind.

Bitte kreuzen Sie die einzelnen Punkte zur Bestätigung an.*

- ☐ Ich stimme der Verarbeitung meiner personenbezogenen Daten (Alter, Geschlecht, Orientierungsvermögen, Fahrradfahrverhalten, Blickbewegungen, verbale Äußerungen, Körperbewegungen, Körpergröße, Schuhlänge) im Rahmen dieses Forschungsvorhabens freiwillig zu.
- ☐ Ich wurde über die Verarbeitung meiner Daten, die im Einklang mit der Datenschutz-Grundverordnung durchgeführt wird, informiert.
- ☐ Mir ist bewusst, dass meine Daten solange gespeichert werden, wie es der Forschungszweck erfordert, und meine Daten Dritten ausschließlich zur pseudonymisierten Auswertung zur Verfügung gestellt werden.
- ☐ Mir ist klar, dass personenbezogene Daten, die bis zu diesem Zeitpunkt erhoben werden, nur beauskunftet, berichtigt, gelöscht oder eingeschränkt werden können, sofern durch die Ausübung dieser Rechte die Erreichung des Forschungszwecks voraussichtlich nicht unmöglich gemacht oder ernsthaft beeinträchtigt wird. Das gilt auch für den Widerspruch.

Bitte geben Sie zur Bestätigung, dass Sie die oben angegebenen Informationen gelesen und verstanden haben und an der Studie teilnehmen wollen, Ihren vollen Namen und das Datum an.

Bitte ein Datum eingeben: *

Vollständiger Name: *

Appendix A.4 – Letter Ethics Committee

TU WIEN ETHICS RESPONSIBLE RESEARCH PRACTICES

12 Feb. 2025

To whom it may concern:

This letter is to confirm that Sarah Prinz (previously Volken) has approached the Service Unit of Responsible Research Practices in order to address potential ethical questions concerning her research project titled “Subjective Safety Of Bicycle Riders In Urban Settings”. The planned research will be conducted at TU Wien. Six independent peer reviewers read the submitted proposal for review and participated in the meeting to discuss appropriate guidance.

The TU Wien Research Ethics Committee was formalized in October 2023. The TUW REC is consultative and supportive in its approach. Submission of research proposals to this research ethics peer review is on a voluntary basis. The focus of the TUW REC is human research participation.

Sarah Prince's proposal was discussed in the TUW REC meeting on 19 April 2024 and has the case number 053_19042024_TUWREC. The topics discussed included ethically relevant methodological clarifications, more specifically questions related to the involvement of human voluntary participants in the research. The members of the TUW REC provided a number of recommendations to mitigate potential concerns including: a focus on the clarity of informed consent, the emphasis on good preparation in case of incidental findings, privacy safeguards, and the diversity of participants.

TU Wien's research insurance covered all the participants and the researcher throughout the trial.

Sarah Prinz appreciated the comments and recommendations provided as well as the time taken to discuss her proposal. The researcher is aware that she can approach the REC for further peer review, dialogue and guidance at any point in time.

Submitting a proposal for peer review by the TUW REC is voluntary and the meeting and/or its documentation, such as this statement, do not constitute formal research ethical approval.

On behalf of the TUW Research Ethics Committee

Dr. Marjo Rauhala MSSc., BA
Head of Unit
Service Unit Responsible Research Practices
TU Wien
Favoritenstraße 16/DG/02
1040 Wien
T: +43-1-58801-406630
E-mail: ethics@tuwien.ac.at

Appendix B

Appendix B.1 – Demographics and bicycle behavior

Demographics and Bicycle Behavior

Radfahrstudie: Teil 1

Vielen Dank, dass Sie sich für eine Teilnahme an unserer Studie entschieden haben! Wir freuen uns sehr! Wie beschrieben, bitten wir Sie in einem ersten Teil der Studie, den folgenden Fragebogen auszufüllen. Dies dauert ca. 10 Minuten. Anschließend werden Sie gebeten, eine Email-Adresse anzugeben, damit wir Ihnen Informationen zum Termin vor Ort und eine Terminerinnerung schicken können.

Wie alt sind Sie? (In Jahren) *

Bitte geben Sie Ihre Antwort hier ein:

Die Normierung der standardisierten Fragebögen und die Interpolation der Körpermaße für die Bewegungsdaten basieren auf dem biologischen Geschlecht. Bitte geben Sie daher Ihr biologisches Geschlecht an: *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- ○ Weiblich
- ○ männlich

Seit wann fahren Sie in Wien Fahrrad (Jahreszahl - z.B. seit 2013)? *

Bitte geben Sie Ihre Antwort hier ein:

An welchen Monaten fahren Sie in Wien Fahrrad (Referenzjahr 2023)? *

Bitte wählen Sie entsprechend aus

	Jan	Feb	Mär	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
von	○	○	○	○	○	○	○	○	○	○	○	○
bis	○	○	○	○	○	○	○	○	○	○	○	○

Wie oft sind Sie im oben genannten Zeitraum im Referenzjahr 2023 in Wien Fahrrad gefahren? *

Bitte wählen Sie alle zutreffenden Antworten aus:

- ◯ Täglich
- ◯ Mehrmals pro Woche
- ◯ Mehrmals pro Monat
- ◯ Mehrmals pro Jahr

Wie oft fahren Sie ausserhalb von Wien Fahrrad? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- ◯ nie
- ◯ selten
- ◯ manchmal
- ◯ oft

Fahren Sie dann überwiegend in der Stadt, auf dem Land oder beides? *

Diese Frage wurde nur angezeigt, wenn die obere Frage nicht mit "nie" beantwortet wurde

Bitte wählen Sie nur eine der folgenden Antworten aus:

- ◯ Stadt
- ◯ Land
- ◯ Beides

Hatten Sie schon einmal einen Unfall mit dem Fahrrad? *

Bitte wählen Sie eine der folgenden Antworten aus:

- ◯ Ja
- ◯ Nein

Wenn ja, wie lange ist dieser Unfall her (in Jahren - z.B. vor **5** Jahren)? *

Diese Frage wurde nur angezeigt, wenn bei der Frage nach einem Fahrradunfall "ja" gewählt wurde

Bitte geben Sie Ihre Antwort hier ein:

Falls Sie eine Brille tragen und beim Versuch keine Kontaktlinsen tragen werden, bitten wir Sie hier ihre Dioptrien anzugeben, damit wir den Eye Tracker entsprechend vorbereiten können. *

Bitte geben Sie Ihre Antwort hier ein:

Appendix B.2 – SBSOD

Orientierungsfragen SBSOD

Die folgenden Fragen bestehen aus verschiedenen Aussagen über Ihre räumlichen Fähigkeiten, Vorlieben und Erfahrungen sowie Ihre Fähigkeiten, Vorlieben und Erfahrungen beim Finden von Wegen. Wählen Sie für jede Aussage diejenige Zahl, die den Grad Ihrer Zustimmung mit dieser Aussage am besten ausdrückt. Markieren Sie die „1", wenn Sie stark zustimmen, dass diese Aussage für Sie zutrifft, markieren Sie „7", wenn Sie dies stark ablehnen oder markieren Sie eine Zahl dazwischen, wenn Ihre Zustimmung dazwischen liegt. Markieren Sie die „4", wenn Sie weder zustimmen noch ablehnen.

Wählen Sie in der unten stehenden Tabelle die Werte 1 - 7 entsprechend aus. *

	1 - stimme stark zu	2	3	4	5	6	7 - lehne stark ab
Ich bin sehr gut im Geben von Wegbeschreibungen.	○	○	○	○	○	○	○
Ich kann mir nur schlecht merken, wo ich Dinge liegen gelassen habe.	○	○	○	○	○	○	○
Ich bin sehr gut im Schätzen von Entfernungen.	○	○	○	○	○	○	○
Mein „Orientierungssinn" ist sehr gut.	○	○	○	○	○	○	○
Wenn ich über meine Umgebung nachdenke, verwende ich meist die vier Himmelsrichtungen (N, S, O, W).	○	○	○	○	○	○	○
In einer neuen Stadt verlaufe ich mich sehr leicht.	○	○	○	○	○	○	○
Landkarten lesen macht mir Spaß.	○	○	○	○	○	○	○
Ich habe Probleme, Wegbeschreibungen zu verstehen.	○	○	○	○	○	○	○

Orientierungsfragen SBSOD

Die folgenden Fragen bestehen aus verschiedenen Aussagen über Ihre räumlichen Fähigkeiten, Vorlieben und Erfahrungen sowie Ihre Fähigkeiten, Vorlieben und Erfahrungen beim Finden von Wegen. Wählen Sie für jede Aussage diejenige Zahl, die den Grad Ihrer Zustimmung mit dieser Aussage am besten ausdrückt. Markieren Sie die „1“, wenn Sie stark zustimmen, dass diese Aussage für Sie zutrifft, markieren Sie „7“, wenn Sie dies stark ablehnen oder markieren Sie eine Zahl dazwischen, wenn Ihre Zustimmung dazwischen liegt. Markieren Sie die „4“, wenn Sie weder zustimmen noch ablehnen.

Wählen Sie in der unten stehenden Tabelle die Werte 1 - 7 entsprechend aus. *

	1 - stimme stark zu	2	3	4	5	6	7 - lehne stark ab
Ich bin sehr gut im Geben von Wegbeschreibungen.	○	○	○	○	○	○	○
Ich kann mir nur schlecht merken, wo ich Dinge liegen gelassen habe.	○	○	○	○	○	○	○
Ich bin sehr gut im Schätzen von Entfernungen.	○	○	○	○	○	○	○
Mein „Orientierungssinn“ ist sehr gut.	○	○	○	○	○	○	○
Wenn ich über meine Umgebung nachdenke, verwende ich meist die vier Himmelsrichtungen (N, S, O, W).	○	○	○	○	○	○	○
In einer neuen Stadt verlaufe ich mich sehr leicht.	○	○	○	○	○	○	○
Landkarten lesen macht mir Spaß.	○	○	○	○	○	○	○
Ich habe Probleme, Wegbeschreibungen zu verstehen.	○	○	○	○	○	○	○

Appendix B.3 – Big Five 10

BFI-10

Inwieweit treffen die folgenden Aussagen auf Sie zu? *

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Trifft überhaupt nicht zu - 1	Trifft eher nicht zu - 2	Weder noch - 3	Eher zutreffend - 4	Trifft voll und ganz zu - 5
Ich bin eher zurückhaltend, reserviert.	○	○	○	○	○
Ich schenke anderen leicht Vertrauen, glaube an das Gute im Menschen.	○	○	○	○	○
Ich bin bequem, neige zur Faulheit.	○	○	○	○	○
Ich bin entspannt, lasse mich durch Stress nicht aus der Ruhe bringen.	○	○	○	○	○
Ich habe nur wenig künstlerisches Interesse.	○	○	○	○	○
Ich gehe aus mir heraus, bin gesellig.	○	○	○	○	○
Ich neige dazu, andere zu kritisieren.	○	○	○	○	○
Ich erledige Aufgaben gründlich.	○	○	○	○	○
Ich werde leicht nervös und unsicher.	○	○	○	○	○
Ich habe eine aktive Vorstellungskraft, bin fantasievoll.	○	○	○	○	○

Appendix B.4 – Adolescent cycling behavior

Adolescent Cycling Behavior Questionnaire

Die folgenden Fragen wurde ursprünglich auf Englisch entwickelt.

Deutsche Übersetzungen und englische Originalfragen sind enthalten, um die Genauigkeit und Verständlichkeit zu gewährleisten.

How often, in the past month did you ... ?

(Wie oft haben/sind Sie im letzten Monat .... ?)

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus: *

	never/ nie	hardly ever/ kaum	occasionally/ manchmal	quite often/ ziemlich oft	frequently/ häufig	always/ immer
forget to signal when changing directions? (vergessen Handzeichen zu geben, wenn Sie die Richtung geändert haben?)	○	○	○	○	○	○
ride in threes? (in einer Gruppe Fahrrad gefahren?)	○	○	○	○	○	○
ride on the sidewalk? (auf dem Gehsteig Fahrrad gefahren?)	○	○	○	○	○	○
use a cell phone whilst cycling? (ein Handy während des Fahrradfahrens benutzt?)	○	○	○	○	○	○

	never/ nie	hardly ever/ kaum	occasionally/ manchmal	quite often/ ziemlich oft	frequently/ häufig	always/ immer
forget to look behind when turning left (vergessen, nach hinten zu schauen, wenn Sie nach links abgebogen sind?)	○	○	○	○	○	○
cycle when it was slippery and you could fall easily (sind sie bei rutschigen Strassenverhältnissen , wo man leicht hätte hinfallen können, Rad gefahren?)	○	○	○	○	○	○
ride at night without a working head- or tail-light (sind sie ohne Vorder- und Rücklicht bei Nacht Rad gefahren?)	○	○	○	○	○	○
ignore a red traffic light (eine rote Ampel ignoriert?)	○	○	○	○	○	○
ride so close to someone else, that the handlebars touched and you almost fell (so nah bei anderen Person gefahren, dass sich die Lenkräder berührt haben und Sie fast umgefallen sind?)	○	○	○	○	○	○

	never/ nie	hardly ever/ kaum	occasionally/ manchmal	quite often/ ziemlich oft	frequently/ häufig	always/ immer
swerve around crossing pedestrians on a zebra crossing (sind Sie um FussgängerInnen, die den Zebrastreifen benutzt haben, herumgefahren?)	○	○	○	○	○	○
not see a car coming from a side street (ein Auto von der Seite nicht kommen sehen?)	○	○	○	○	○	○
have to brake hard, because a car approached faster than you anticipated (abrupt bremsen müssen, weil sich ein Auto schneller genähert hat, als Sie gedacht haben?)	○	○	○	○	○	○
notice you ought to ride on the bike-way instead of on the road (realisiert, dass Sie anstelle der Strasse eigentlich auf einem Radweg fahren sollten?)	○	○	○	○	○	○

	never/ nie	hardly ever/ kaum	occasionally/ manchmal	quite often/ ziemlich oft	frequently/ häufig	always/ immer
stop on the right side of a truck that wanted to turn left, instead of waiting behind it (auf der rechten Seite eines Lastwagens stehen geblieben, der Links abbiegen wollte, anstatt dahinter zu halten?)	○	○	○	○	○	○
brake (too) late, because you were on someone else's bike and the brakes worked different ((zu) spät gebremst, weil Sie auf dem Fahrrad einer anderen Person gefahren sind und die Bremsen anders reagierten?)	○	○	○	○	○	○
feel uncertain about who had the right of way on a traffic circle (unsicher gewesen, wer an einem Kreisverkehr Vorrang hat?)	○	○	○	○	○	○
ride when having drunk alcohol (Fahrrad gefahren, nachdem Sie Alkohol konsumiert hatten?)	○	○	○	○	○	○

	never/ nie	hardly ever/ kaum	occasionally/ manchmal	quite often/ ziemlich oft	frequently/ häufig	always/ immer
notice you entered a one-way street on the wrong side (gemerkt, dass Sie falsch in eine Einbahnstrasse eingebogen sind?)	O	O	O	O	O	O
have to swerve in order not to get run over by a bus or truck turning right (mussten Sie einem Bus oder Lastwagen ausweichen, um nicht überfahren zu werden?)	O	O	O	O	O	O
get pushed or pulled by a moped rider (von einem Motorrad schieben oder ziehen lassen?)	O	O	O	O	O	O
almost hit a crossing pedestrian when turning right (fast eine*n FussgängerIn überfahren, als Sie rechts abbiegen wollten?)	O	O	O	O	O	O

	never/ nie	hardly ever/ kaum	occasionally/ manchmal	quite often/ ziemlich oft	frequently/ häufig	always/ immer
ride a bicycle while under the influence of marijuana or other drugs (Fahrrad gefahren, während Sie unter dem Einfluss von Marijhuana oder anderen Drogen standen?)	○	○	○	○	○	○

Appendix B.5 – FRS

FRS

Nachstehend finden Sie insgesamt 19 Aussagen zu Ihren räumlichen Fähigkeiten und Fertigkeiten. Bitte selektieren Sie für jede der Aussagen, den Grad zu welchem Sie diese ablehnen oder zustimmen.

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus: *

	Lehne stark ab - 1	2	3	4	5	6	Stimme stark zu - 7
Wenn ich durch eine unbekannte Stadt laufe, dann weiß ich, aus welcher Richtung ich gekommen bin und in welche Richtung ich mich bewege.	○	○	○	○	○	○	○
Wenn mich jemand in meiner Stadt nach dem Weg fragt, dann stelle ich mir meine Stadt wie auf einer Karte vor und ermittle daraus den Weg.	○	○	○	○	○	○	○
Wenn ich mich durch ein großes Gebäude bewege, dann stelle ich mir dabei eine Art Plan oder Grundriss (Überblicksansicht) vor.	○	○	○	○	○	○	○
Ich bin sehr gut darin, von meinem gegenwärtigen Standort aus Richtungen zu anderen Orten anzugeben.	○	○	○	○	○	○	○
In der freien Natur (z.B. Wald, Gebirge) kann ich mich an einen Weg sehr gut erinnern, wenn ich ihn einmal gegangen bin.	○	○	○	○	○	○	○

	Lehne stark ab - 1	2	3	4	5	6	Stimme stark zu - 7
Ich kann spontan zeigen, wo Norden, Süden, Osten und Westen liegen.	○	○	○	○	○	○	○
Ich stelle mir die Umgebung stets wie auf einer "mentalen Karte" (Überblicksansicht) vor.	○	○	○	○	○	○	○
Ich finde stets ohne Probleme zu meinem Ziel.	○	○	○	○	○	○	○
Ich verfüge über eine sehr gute Vorstellung von meiner Stadt, wie auf einer Karte.	○	○	○	○	○	○	○
In einer unbekannten Umgebung finde ich mich gut zurecht.	○	○	○	○	○	○	○
In der freien Natur versuche ich, die räumlichen Gegebenheiten aus der Vogelperspektive zu verstehen.	○	○	○	○	○	○	○
Ich bin sehr gut darin, mir Wege zu merken, und finde auch ohne Mühe den Rückweg.	○	○	○	○	○	○	○
In einem großen Gebäude habe ich keine Schwierigkeiten, einen Weg nochmals zu gehen, wenn ich den Weg einmal gegangen bin.	○	○	○	○	○	○	○
Mein Orientierungssinn ist sehr gut.	○	○	○	○	○	○	○

	Lehne stark ab - 1	2	3	4	5	6	Stimme stark zu - 7
In meiner Stadt kann ich von einem beliebigen Punkt aus spontan angeben, in welche Richtungen markante Gebäude oder Bezugspunkte liegen.	○	○	○	○	○	○	○
Wenn ich in meiner Stadt unterwegs bin, dann kann ich mir meine Position wie einen Punkt auf meiner "mentalen Karte" vorstellen.	○	○	○	○	○	○	○
In der freien Natur kann ich spontan zeigen, wo Norden, Süden, Osten und Westen liegen.	○	○	○	○	○	○	○
In einem großen Gebäude weiß ich spontan, in welche Richtung der Eingang liegt.	○	○	○	○	○	○	○
Wenn ich mich in einer unbekannten Stadt bewege, dann bilde ich in meiner Vorstellung eine Art "mentale Karte".	○	○	○	○	○	○	○

Appendix B.6 – Email Templates

Outlook

Terminvereinbarung Radfahrstudie

Von Administrator <limesurvey@geo.tuwien.ac.at>
Datum Mi, 26.06.2024 07:33
An Volken, Sarah <e12221657@student.tuwien.ac.at>

1 Anlage (203 KB)

Ablauf Radfahrstudie Detail(1).pdf;

Guten Tag,
vielen Dank für Ihre Teilnahme an unserer Radfahrstudie! Wir schätzen dies sehr und freuen uns, Sie in unserem Labor begrüßen zu dürfen.

Wir pseudonymisieren Ihre Daten, d.h. wir werden Ihren Namen und Ihre E-Mail-Adresse nicht speichern. **Ihr Pseudonym lautet: 3**
Bitte halten Sie diese Nummer bereit, wenn Sie zur Studie kommen. Vielen Dank!

Unter dem untenstehenden Link können Sie Ihren Termin für die Teilnahme vor Ort auswählen:
Termin vereinbaren

Treffpunkt vor Ort ist: Knockbox, der Kaffeestand vor der TU Bibliothek (erkennbar an der Eule), Treitlstraße 1, 1040 Wien

Bitte denken Sie daran, Ihr eigenes Fahrrad zur Studie mitzubringen. Am Tag der Studie bitten wir Sie außerdem, keinen Schmuck oder Metall zu tragen (wenn möglich, auch keinen BH mit (Metall-)Bügel). Falls Sie Brillenträger sind und das Tragen von Kontaktlinsen gewohnt sind, wäre es für die Studie hilfreich, diese zu tragen.

Während der Radfahrt werden wir Sie bitten, "jetzt" zu sagen, wenn sich Ihre Gefühlslage ändert. Damit Sie sich darunter mehr vorstellen können, geben wir Ihnen hier bereits einige Beispiele.

Uns interessiert besonders, ob Sie sich unsicher oder sicher, wohl oder unwohl fühlen, ob Sie sich ärgern oder freuen. Während Ihrer Fahrt werden Sie sicher auf unterschiedliche Situationen treffen, welche diese Gefühle in Ihnen hervorrufen. Denken Sie z.B. an den Fall, dass Sie unangenehm überholt werden, parkende Autos die Tür aufmachen könnten, Ihnen FußgängerInnen/Autos im Weg sind oder Sie Straßenbahnschienen kreuzen müssen. Es könnte sein, dass ein Radweg plötzlich aufhört und Sie nicht genau wissen, wo Sie fahren dürfen/sollen, z.B. wegen schlechter Signalisierung. Oder denken Sie an angenehme Situationen, wenn es besonders ruhig, schattig, angenehm oder sonnig ist.

Im Anhang finden Sie ein Dokument mit dem gesamten Studienablauf und der Einverständniserklärung, sollten Sie nochmal nachlesen wollen.

Wenn Sie irgendwelche Fragen haben, können Sie sich gerne an Sarah Volken unter e12221657@student.tuwien.ac.at wenden.

Mit freundlichen Grüßen

Sarah Volken

TERMINO

ABSTIMMUNG ERSTELLEN EINLOGGEN SPRACHEN

Radfahrstudie

Guten Tag und vielen Dank für Ihre Teilnahme an unserer Radfahrstudie!

Für den Teil vor Ort können Sie sich hier einen freien Termin buchen. Es gibt (fast) jeden Tag zwei, manchmal drei freie Termine - jeweils Vormittags, Nachmittags und Abends. Bitte buchen Sie ihren Termin mind. zwei Tage bevor Sie kommen.
Falls es ihnen wegen +/- einer halben Stunde nicht gehen sollte, können Sie Sarah Volken (e12221657@student.tuwien.ac.at) gerne kontaktieren und den Termin zeitlich etwas verschieben.

Treffpunkt ist bei der KnockBox (Kaffeestand) vor TU Bibliothek (erkennbar an der Eule) (Treitlstraße 1, 1040 Wien), wir werden dann gemeinsam ins Labor in der Wiedner Hauptstraße 8-10 gehen.

Falls es regnet, muss ihr Termin abgesagt werden. Bitte schauen Sie deswegen kurz vor der Studie nochmal auf ihre E-Mail. Vergessen Sie nicht, ihr eigenes Rad zum Termin mitzunehmen, keinen Schmuck oder Metallgegenstände zu tragen und lange Haare zusammenzubinden. Wir werden Ihnen vor dem ausgewählten Termin nochmal eine Erinnerungsmail mit diesen Inhalten zukommen lassen.

Montag, 30. September 2024 - 9:30	BUCHEN
Montag, 30. September 2024 - 14:00	(nicht verfügbar)

Outlook

Buchung auf TERMINO - Radfahrstudie

Von TERMINO <no-reply@termino.gv.at>
Datum Mo, 30.09.2024 17:33
An [redacted]

Termino

Hallo [redacted],

folgende Buchung wurde registriert:

03.10.2024 - 14:00

Die Buchung kann auf https://www.termino.gv.at/meet/de/b/4950e71b0335a9d1371ccd211bc51963-326844 eingesehen und gegebenenfalls storniert werden.

Allfällige Rückfragen bitte via E-Mail an den/die Organisator*in.

TERMINO ist ein Service der Digitalisierungsinitiative des BMF

--- English ---

Dear [redacted],

your booking has been registered:

03.10.2024 - 14:00

Access your booking here https://www.termino.gv.at/meet/de/b/4950e71b0335a9d1371ccd211bc51963-326844 in case you need to review or cancel it.

Please send any questions related to your booking by E-Mail to the organizer.

TERMINO is a service of the digitalisation initiative of the Federal Ministry Republic of Austria Finance

Outlook

Radfahrstudie

Von	Prinz, Sarah <e12221657@student.tuwien.ac.at>
Datum	Do, 05.12.2024 09:23
An	Prinz, Sarah <e12221657@student.tuwien.ac.at>

Guten Tag,

Sie haben für morgen den 04.10.2024 um 14:00 einen Termin für unsere Radfahrstudie gebucht!

Ich freue mich, Sie morgen in unserem Labor begrüssen zu dürfen. Treffpunkt ist der Kaffeestand "Knockbox" vor dem Gebäude mit der Eule, **Treitlstraße 1, 1040 Wien.**
Ich werde Sie dort abholen kommen. Ich trage eine Weste der Geoinformatik und sollte leicht erkennbar sein.

Bitte vergessen Sie nicht, keinen Metallschmuck zu tragen und lange Haare zusammenzubinden. Falls Sie eine Brille tragen und die Möglichkeit haben Kontaktlinsen zu tragen, ist dies hilfreich.

Falls Sie Fragen haben kontaktieren Sie mich gerne via Email:
e12221657@student.tuwien.ac.at

Freundliche Grüsse und einen schönen Tag,

Sarah Volken

Outlook

Radfahrstudie

Von Prinz, Sarah <e12221657@student.tuwien.ac.at>
Datum Do, 05.12.2024 09:23
An Prinz, Sarah <e12221657@student.tuwien.ac.at>

Guten Tag,

Sie haben für morgen den 04.10.2024 um 14:00 einen Termin für unsere Radfahrstudie gebucht!

Ich freue mich, Sie morgen in unserem Labor begrüssen zu dürfen. Treffpunkt ist der Kaffeestand "Knockbox" vor dem Gebäude mit der Eule, **Treitlstraße 1, 1040 Wien.**
Ich werde Sie dort abholen kommen. Ich trage eine Weste der Geoinformatik und sollte leicht erkennbar sein.

Bitte vergessen Sie nicht, keinen Metallschmuck zu tragen und lange Haare zusammenzubinden. Falls Sie eine Brille tragen und die Möglichkeit haben Kontaktlinsen zu tragen, ist dies hilfreich.

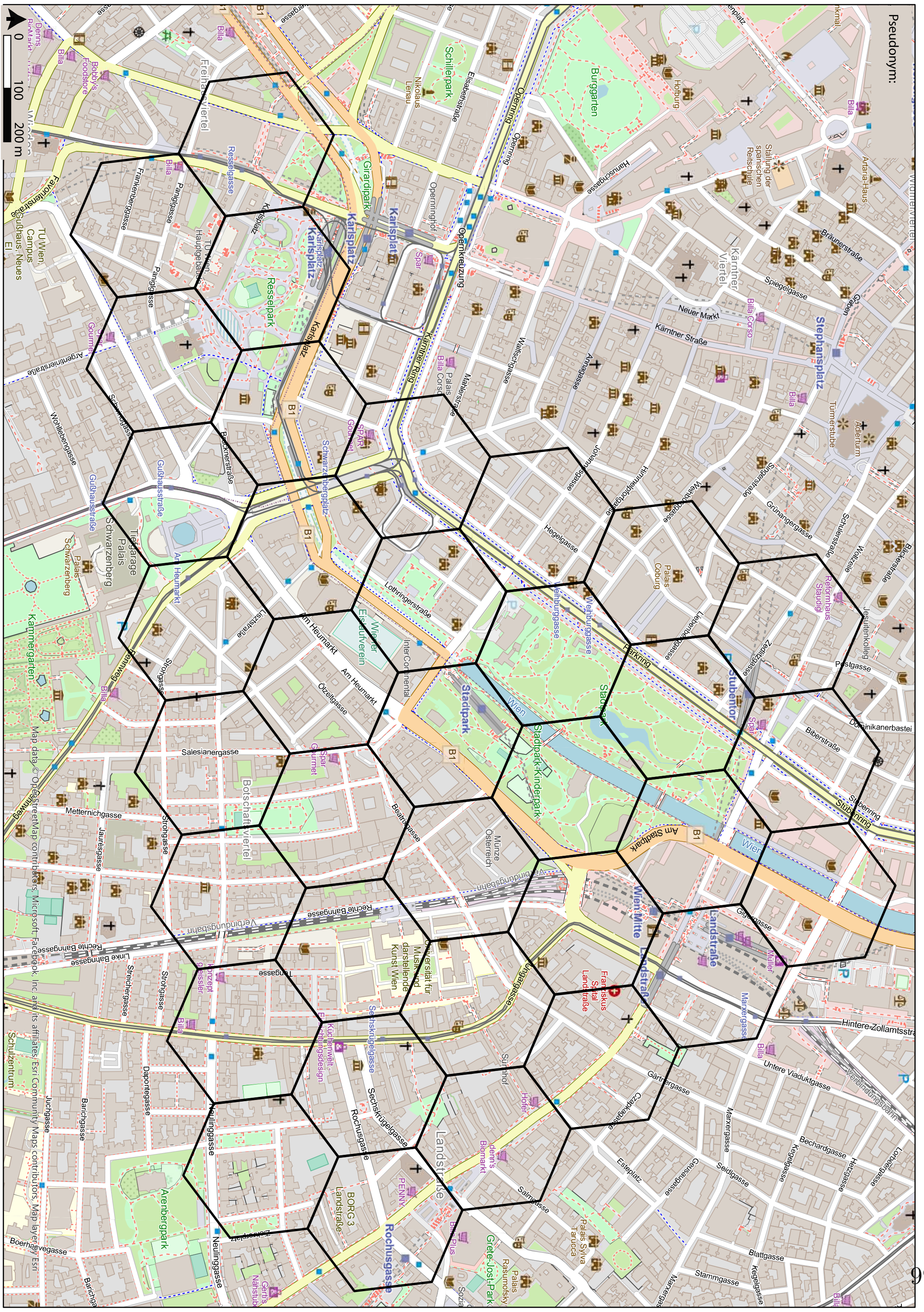
Falls Sie Fragen haben kontaktieren Sie mich gerne via Email:
e12221657@student.tuwien.ac.at

Freundliche Grüsse und einen schönen Tag,

Sarah Volken

Appendix C

Appendix C.1 – Hexagonmap



Appendix C.2 – Map: overview route

Appendix C.3 – Instructions

Questions for Familiarity on Hexagon Map:

Für jedes der Sechsecke: Wie vertraut sind Sie mit der Gegend, die von diesem Sechseck abgedeckt wird?
1 - gar nicht vertraut | 7 - sehr vertraut

Für jedes der Sechsecke: Wie häufig waren Sie innerhalb des letzten Jahres in dieser Gegend unterwegs?
0 - nie | 21 – 21 mal oder mehr

Text for Test Segment 1:

Nun sind wir quasi bereit für die Fahrt. Sie können nun gerne dort (handzeichen) auf und ab fahren, um ein Gefühl für die Ausrüstung zu kriegen. Bitte schauen Sie auch einmal bewusst auf ihr Navi und sagen Sie „Navi" während Sie das tun. Das hilft mir später in der Datenauswertung.

Text for Instructions:

Wir möchten ganz besonders wissen, wann sich Ihre Gefühlsage ändert.
Zum Beispiel interessiert uns, ob Sie sich unsicher oder sicher, wohl oder unwohl fühlen, ob Sie sich ärgern oder freuen.

Während Ihrer Fahrt, werden Sie sicher auf unterschiedliche Situationen treffen, welche diese Gefühle in Ihnen hervorrufen.
Denken Sie z.B. an den Fall, dass Sie unangenehm überholt werden, parkende Autos die Tür aufmachen könnten, ihnen FussgängerInnen/Autos im Weg sind oder Sie Strassenbahnschienen kreuzen müssen. Es könnte sein, dass ein Radweg plötzlich aufhört und sie nicht genau wissen, wo Sie fahren dürfen/sollen zb. Wegen schlechter Signalisierung, Oder denken Sie an angenehme Situationen, wenn es besonders ruhig, schattig, angenehm oder sonnig ist.

Questions at break Points:

Auf einer Skala von 1-4 wie sicher haben sie sich auf diesem Streckenabschnitt gefühlt? - 1 bedeutet unsicher 4 bedeutet sicher
Auf einer Skala von 1-4 wie wohl haben sie sich auf diesem Streckenabschnitt gefühlt? - - 1 bedeutet unsicher 4 bedeutet sicher

Task Reminder at Breakpoint:

Nun kommt die zweite Teilstrecke an die Reihe. Es bleibt alles beim alten. Sie fahren anhand des Navis zum nächsten Zwischenstopp und sagen immer „jetzt" wenn sie denken, dass sich ihr Wohlbefinden geändert hat. Z.B. wenn sie sich sicher/unsicher fühlen, etwas unangenehm/angenehm, schön/ärgerlich ist.

Appendix D

Appendix D.1 – Post Task

PostTask

Intensität

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	1 - überhaupt nicht intensiv	2	3	4	5	6	7 - sehr intensiv
Als Sie „jetzt“ gesagt haben, hat sich Ihr Gefühl verändert. Wie intensiv war diese Gefühlsänderung?	○	○	○	○	○	○	○

Sicherheit

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	sehr unsicher	eher unsicher	eher sicher	sehr sicher
Wie sicher haben Sie sich gefühlt, als Sie "jetzt" gesagt haben?	○	○	○	○

Wohlbefinden

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	sehr unwohl	eher unwohl	eher wohl	sehr wohl
Wie wohl haben Sie sich gefühlt als Sie "jetzt" gesagt haben?	○	○	○	○

Emotionen

Nachstehend finden Sie eine Liste von fünf Emotionen. Zu Ihrem Verständnis sind fuer jede Emotion jeweils weitere Emotionen angegeben, welche in dieselbe Kategorie fallen. Bitte wählen Sie für jede der Emotionen die Intensität aus, mit der Sie sie empfunden haben als Sie "jetzt" gesagt haben.

Diese Frage wurde nur angezeigt, wenn die Frage nach der Intensität mit 5 oder mehr beantwortet wurde.

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Not at all (überhaupt nicht)	slightly (kaum)	somewhat (etwas)	moderatly (moderat)	quite a bit (ziemlich)	very much (sehr fest)	an extreme amount (extrem)
Anger (Wut) - Mad, Rage, Pissed-Off, Anger	○	○	○	○	○	○	○
Fear (Angst) - Scared, Panic, Terror, Fear	○	○	○	○	○	○	○
Anxiety (Ängstlichkeit) - Nervous, Worry, Dread, Anxiety	○	○	○	○	○	○	○
Relaxation (Gelassenheit) - Easygoing, Chilled Out, Calm, Relaxation	○	○	○	○	○	○	○
Happiness (Freude) - Satisfaction, Enjoyment, Liking, Happy	○	○	○	○	○	○	○

Begründung

Warum haben Sie an dieser Stelle jetzt gesagt? Bitte geben Sie mir eine kurze Begründung.

Bitte geben Sie Ihre Antwort hier ein:

Die untenstehenden Kategorien wurden von der Forscherin ausgewählt.

Bitte alles markieren, was zutrifft.
Bitte wählen Sie alle zutreffenden Antworten aus:

- ☐ Verkehrsstärke
- ☐ Andere Verkehrsteilnehmende
- ☐ Steigung
- ☐ Gebaute Umwelt
- ☐ Andere Umwelt
- ☐ Straßenbelag
- ☐ Infrastruktur
- ☐ Signalisierung/Beschilderung
- ☐ Sonstiges:

Haben Sie die soeben besprochene Situation als eher positiv oder eher negativ empfunden?

Bitte kreuzen Sie eine der folgenden Antworten an:
Bitte wählen Sie nur eine der folgenden Antworten aus:

positiv ◯ negativ ◯