HOW DOES IT FEEL TO WALK IN BERLIN?

Designing an Urban Sensing Lab to explore walking emotions through EDA sensing

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CONTENT

ABSTRACT

Developments in technologies such as biosensors, GPS and ICT make real-time assessments in a participatory urban process increasingly efficient and accessible. With global, but also local ambitions to design sustainable, liveable, and barrier-free urban spaces, people and their desires are increasingly moving into the focus of science and practice. Urban walking and pedestrian-friendly cities have grown immensely in importance in recent years, reflecting not only necessary adaptations to climate change and the SDGs, but also the desires of modern citizens. For participatory and people-focused urban planning processes, the concept of Emotional City Mapping can help by providing an innovative approach to integrate people's emotions. With both subjectively and objectively measurable, physiological data, more holistic analyses and images of an environment can be generated, leading to better informed decisions. The aim of this thesis is therefore to explore whether and how it is possible to collect such objective, emotional data and, furthermore, how it can be combined with other data sets and ultimately visualised in emotional maps. In an Urban Sensing Lab environment, geo-referenced emotional data is collected from participants via EDA sensors as they walk through a Berlin neighbourhood. These sensors (EdaMove 4) are able to detect changes in skin conductance (SCL and SCR) that provide indications of participants' emotional arousal. Thus, both individual points and clusters of stress can be detected, which can provide further information about the emotional experience in the study area. Finally, the designed emotional maps can be used for participatory planning and decision-making processes and support local transformation projects towards a more sustainable, inclusive, and pedestrian-friendly city of Berlin.

Keywords: emotional city mapping, EDA, ambulatory assessment, walkability, urban emotions, people as sensors, sustainable urban planning, urban mobility, mixed methods

PREFACE

This thesis was completed in the 4th semester of the master's programme Cities & Sustainability at Aalborg University (AAU).

It is a collaboration between two master's students, Paulina Fried and Wiebke Blum, who both lived and researched in Berlin throughout the process. The Harvard referencing method was used and references were produced as follows: (author/editor, year, page).

This work could not have been done without the support of Movisens and the loan of five Movisens EdaMove 4 sensors and necessary equipment for the duration of the study. Through helpful advice and online seminars, additional necessary knowledge was acquired and could help to become sufficiently familiar with the research method for application in the project.

Furthermore, the repeated exchange with Peter Zeile from the KIT and Linda Dörrzapf from the TU Wien helped enormously in setting up the study design and carrying out the project. Despite initial uncertainties and recurring frustrations, the two experts were able to support the researchers on their way to data collection and analysis.

Finally, Lars Bodum, the thesis supervisor, with his expertise, curiosity about the project and enthusiasm for relevant technologies, helped to motivate the students and get them back on track after setbacks. Therefore, special thanks go to his support and encouraging words during the challenging research process.

COVID-19 context

The thesis was written in the period from 01 February to 04 June 2021. During this time, public life, work, and teaching were largely restricted due to the global Corona pandemic. Due to the practical approach of the thesis, study design and workshop implementation were in constant change, adapted to current local regulations in Berlin. Nevertheless, valuable data could be collected and included in the project. During the on-site measurements, hygiene, and distance regulations in force at the time were followed, which had no significant impact on the measurements per se. Nevertheless, the results about the emotions and subjective feelings of the participants as well as the researchers must be interpreted against the background of the pandemic. This means that due to wide-ranging restrictions on public life in Berlin caused by the closure of restaurants, bars and cafés, distance regulations and mobility restrictions, no analysis “under normal conditions” was carried out. Instead, in many places there were fewer people than average on the streets, shops were closed, and traffic was limited. A comparable measurement at another time before/after the pandemic would therefore most likely lead to different test results.

GLOSSARY

Aalborg University	AAU
Alternating Current	AC
Bezirksregion (District Region)	BZR
Black, Indigenous, and people of colour	BIPOC
Direct Current	DC
eDiary	electronic Diary
Electrodermal Activity	EDA
Electroencephalography	EEG
European Union	EU
Event-related SCR	ER-SCR
Galvanic Skin Conductance	GSC
Geoinformation System	GIS
Global Positioning System	GPS
Greenhouse Gas	GHG
Information and Communication Technologies	ICT
Karlsruhe Institute for Technology	KIT
Non-specific SCR	NS-SCR
Planungsraum (Planning Area)	PLR
Points of Interest	POI
Research Question	RQ
Skin Conductance	SC
Skin Conductance Level	SCL
Skin Conductance Response	SCR
Stadtentwicklungsplan (City Development Plan)	StEP
Sustainable Development Goals	SDGs
United Nations	UN
Urban Sensing Lab	USL
Volunteered Geographic Information	VGI
Walkability Indices	WI

FIGURE OVERVIEW

INTRODUCTION

Growing global challenges such as climate change, urbanisation and most recently the Corona pandemic with emerging impacts on public health call on humanity and especially urban populations, who form a global majority (The World Bank, 2019), to become active and creative. To face and adapt to global transformations on a local level, interdisciplinary and integrated approaches are needed that focus on the needs and sensibilities of people without disregarding overarching goals in the context of international agreements such as the Sustainable Development Goals (SDGs) or the Paris Agreement.

The prerequisite is therefore to collect the right data both on and with people to initiate the desired and necessary change in society towards people-oriented urban spaces. But, as Jan Gehl, the famous advocate and pioneer of “Cities for People”, points out: “We definitely know more about good habitats for mountain gorillas, Siberian tigers, or panda bears than we do know about a good urban habitat for Homo sapiens” (Jan Gehl, Interview with Green, n.d.). So, what kind of data is needed to address the pressing global challenges? And how can it be collected, analysed, and appropriately applied with the help of modern technologies to stimulate change towards a more sustainable, equitable and accessible urban future? The claim that “we measure what we care about” (Siggard Andersen & Schuff, 2017), thus implies that we need to value the human experience in a world we are increasingly creating based on data and evidence-based decision-making.

The research field of emotions offers an appropriate and “radical” approach by adding a human perspective and recognising subjective and individual sensations, i.e., emotions and feelings, as a valid data source. For this reason, the field has been discussed and critically researched outside its original discipline, psychology, for several years. As a result, research on emotions and their role in the human-environment relationship is becoming increasingly popular in academia and is often considered a profound component of analyses from an alternative, human-centred perspective (Bondi et al., 2012; Theodosius, 2012). Following earlier interpretations of emotions as ephemeral or unknowable automatic reactions of people to their built or natural environment (Kenny, 2015), corresponding data is now increasingly recognised as reliable knowledge in diverse research disciplines.

For some years now, studies on emotions have also been increasingly conducted in the field of urban planning and design, after recognising human emotions as an ever-present and crucial part of our everyday lives (see, e.g., Burns, 2000; Dörrzapf et al., 2015; Fathullah &

Willis, 2018; Nold, 2018; Pánek & Benediktsson, 2017; Pykett et al., 2020; Zeile, Resch, Exner, et al., 2015). From an urban historian perspective, emotions have been analysed (mostly through literature and document analyses, interviews or questionnaires) to understand how the particular circumstances of cities in a given period are producing distinct emotional responses and what role these emotional responses play in the shaping of political, social, and material realities of urban environments (e.g., when major infrastructure projects are planned and discussed) (Kenny, 2015). In urban design, it has been common practice since Kevin Lynch's "The Image of the City" (1960) at the latest, to acknowledge and explore emotional connections or reactions of people in public spaces. Lynch, and later Jane Jacobs (e.g., 1965), criticized the previous focus on the spatial and material in urban planning and design, and consequently inspired a revolutionary shift towards people-oriented research and development. With the identification of emotions as spatial processes in the field of urban geography, their local analysis becomes more evident and essential (Kenny, 2015).

Knowing that human actions are strongly related to the urban environment, it is argued for research to focus on the behaviour, perception and expectations of urban space users (J. Jacobs, 1965; Jarvis, 1980). In terms of walking in the city, this has become increasingly evident since the outbreak of the Corona pandemic, making high quality, and stimulating pedestrian environments even more important for people to relax and recharge. Historically, Baudelaire called a person, who walks and strolls around while merging with the surroundings and 'feeling' the atmosphere of the city, a *flâneur* (Geronta, n.d.). While at that time the activity was reserved for the bourgeoisie with plenty of free time, today strolling or walking through the city has become a "mainstream" leisure activity. Besides, the so-called "mobilities turn" (Cresswell, 2011) made clear that walking as a form of individual mobility is 'more than just movement from A to B' (Jensen, 2009), demonstrating its emotional component. All over the world, women organise so-called "Take Back The Night" marches and use walking as a tool to reclaim space and advocate for spatial justice (Kern, 2020). Today, walking can thus be radical, activist or evoke feelings of solidarity and responsibility when it takes over entire city areas as part of demonstrations.

With everyone nowadays having the opportunity to be a *flâneur* or *flâneuse* and merge with the urban environment, the importance and value of comfortable and accessible city spaces is becoming ever more apparent. There is a considerable amount of research arguing for the significance of walkable urban neighbourhoods to support the individuals' and communities' health (Doyle et al., 2006). However, when it comes to planning and designing walkable urban areas, practitioners so far have primarily focussed on the constitution of physical space, neglecting hereby the facet of subjective feelings and emotions (Baum, 2015; Kitson & Bratt, 2016; Mavros, 2019). Since studies, that are focussing on the perceived outcomes of walking environments, argue for their relevance in achieving both environmental preservation and social equity, walkability as a form of sustainable transportation options becomes a crucial aspect of climate-friendly and healthy cities (Forsyth, 2015). Likewise, it is criticised that there always seem to be reasons to maintaining the status quo on car dependencies (Banister, 2008), despite growing interest in some initiatives towards more human-oriented mobility (Papa, 2018; Walk21, n.d.).

This is both due to the complexity of the walkability topic (Annunziata & Garau, 2020; Choi, 2013, 2014; Forsyth, 2015) but also because of difficulties in collecting sufficient data on people's perceptions towards the walking environment and its design features (Ewing & Handy, 2009). However, Sauter and Wedderburn (2008, p. 6) argue that "[o]nly when we're able to depict and measure walking more adequately we will have better-founded decisions in planning and policy-making processes – and this is the ultimate goal of all these efforts". So, if we know how important pedestrian-friendly cities are for both people and the planet, how can we ensure meaningful and successful integration of relevant data into future planning processes? Can measuring human emotions through mobile sensors bridge the gap between theory and practice and serve as a supportive approach?

Exploring human emotions through mobile psychophysiological sensors is identified as an essential real-time assessment 'from below', by examining both the interior and intimate connections between citizens and their surrounding environment (Langhamer, in Kenny, 2015, p. 6). Hence, through modern, handy and easy-to-use end devices, it becomes feasible to transform people into "sensors" themselves and contribute to the participatory and collective recording and reporting of spatial phenomena such as walkability (Nold, 2018; Pánek & Benediktsson, 2017; Zeile et al., 2009). Some pioneering studies on the human-environment relationship were already carried out, able to provide information on local particularities and emotional reactions based on psychophysiological measurements and their localisations in different contexts (Dörrzapf, Zeile, et al., 2019; see, e.g., Kyriakou et al., 2019; Nold, 2018; Osborne & Jones, 2017; Zeile, Resch, Dörrzapf, et al., 2015). By applying different approaches, the researchers were able to provide valuable data on human perceptions for future urban planning, while allowing to move from questions of "What is the city?" to "How does the city feel?" (Brandl, 2013). This perspective from the point of view of people's inner emotional state can thereby help to overcome issues in assessing walkability perceptions as well as bridging the gap in data collection methods. In this way, not only can public spaces be designed according to the desires and ideas of citizens, but also overarching climate and sustainability goals can be achieved by creating an adequate and thus frequently used spatial environment as an encouragement to increase walking.

It is thus the aim of this thesis to investigate possible methods and their combination within the framework of an Urban Sensing Lab (USL). The attempt is to use emotional data to better understand walking activities in urban neighbourhood for the following development of suitable and well-accepted urban spaces. By approaching the problem interdisciplinary, a holistic investigation from different perspectives is given. Hence, to fill the research gap in using sensors to record and include emotions in urban planning, and to drive a change in the mobility sector towards walkable places, four research questions were formulated and throughout the project answered. They will be presented in chapter 4: Research Questions.

STEP 1: THE PROBLEMS

1) EMOTIONAL PERSPECTIVE

If an urban environment is to be examined in terms of its people-friendliness, various perspectives must be considered. The fact that the natural and built environment have an impact on people's emotions has been researched and demonstrated a few times (Bondi et al., 2012; Kenny, 2015; Theodosius, 2012). Because of the possibility to explore people's subjective feelings about certain issues or localities, a focus on human emotions offers a particularly suitable approach to the objective of people-centred cities.

Nevertheless, this perspective of the "emotional side of urban spaces" is rarely considered in practice so far (Baum, 2015; Bondi et al., 2012). Hence, there is a lack of adequate acceptance and incorporation of theoretical analyses on human emotions into planning practices. This is partly due to the general perception of feelings as the antithesis of reason and logic – although this image is slowly collapsing (Ryan, 2016) – but also due to the complexity of the topic (Baum, 2015; Bondi et al., 2012). Investigations on how emotions are constituted and what triggers them are demanding, multidimensional, and are highly context-dependent.

Developing methods for measuring emotions – hence, studying them – is challenging and not fully consistent yet. However, this lack of standardised methods for measuring and including emotions in urban planning makes it even more substantial to invest in relating research. Including emotions instead of ignoring their value, thus adds a perspective that helps to articulate the environment in a "human way".

Since emotions can address and express concerns about safety, identity and relationships, they reveal the importance of a particular habitat enhancing human well-being (Baum, 2015; Theodosius, 2012). In addition to or precisely because emotions have this people-centred character, they incorporate the capacity for stimulating transformations and initiating change. It is argued that positive emotions foster an engagement with a place and motivate certain behaviours and actions. For instance, an environment that makes people feel comfortable will motivate them to choose walking as a means of transport, as emotional attachment to the place can evoke positive feelings and even stimulate political action (Ryan, 2016). Moreover, the understanding of walking as a self-reinforcing mechanism that makes people more likely to walk when others do (Weinberger & Sweet, 2012), supports this collective and emotionally-bound shift towards a sustainable form of mobility. Particularly in the context of increasing global urbanisation, research into the characteristics of the built environment that influence certain human behaviours or have potential to support or hinder walking is of central importance for urban research and sustainable planning (Annunziata & Garau, 2020). Understanding how people relate to their environment can thus "provide clues to sustainability and capacity for transition/transformation" (Frantzeskaki et al., 2018). In this way, not only can public spaces be designed according to the desires and preferences of citizens, but also overarching climate and sustainability goals can be achieved by creating an adequate and thus frequently used spatial environment as an encouragement to increase walking (Ryan, 2016).

2) WALKABILITY PERSPECTIVE

Walking in all its forms (Choi, 2013) has gained immense importance in the past years. Not only in academia and research but also politics, media and several planning processes, a shift towards increased urban walkability has been recognised (Forsyth, 2015). Particularly, the Corona pandemic shed a spotlight on urban walking as one of the main activities in times of lockdowns, curfews, and social distancing measures (Frost, 2020; Gomes, 2020).

In addition, the current issue of increasing global urbanisation leading to a massive contribution of cities to global greenhouse gas (GHG) emissions, requires a shift towards a “post-car city”. This change can not only contribute to the climate goals of the Paris Agreement of 2016 (European Commission, 2016a), but also to a more equitable and inclusive city and a healthy natural and built environment, which are defined as two of the 17 Sustainable Development Goals (SDGs) set in 2015 (United Nations, 2020).

Looking closer at GHG emissions in Europe, transportation is the second-largest contributor and represents almost a quarter of all CO_2-Emissions (22,3%) (European Environmental Agency, 2021a). Within the transport sector, 71% of emissions are due to road traffic (European Environmental Agency, 2021b). Therefore, global agreements such as the United Nations’ SDGs or the Paris Agreement address a reduction of GHG emissions and global warming. In the Paris climate agreement, e.g., the member states commit to developing national climate action plans to keep global warming below 2°C (European Commission, 2016a). This includes the reduction of emissions and especially encourages cities and local authorities to act. Additionally, the European Green Deal from 2019 is aiming to create healthier cities with an increased quality of life for citizens. The deal is enforced to become the central part of climate politics in the EU, with the long-term goal to become climate neutral by 2050. This includes an action plan with measurements for a shift towards sustainable and smart mobility to reduce the emissions from the transport sector by 90% (Communication From the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions the European Green Deal, 2019). And finally, the European Strategy for Low Emissions addresses mobility and supports alternative modes of transport with lower emissions (e.g., e-mobility or public transport) as well as active travel, i.e. walking and cycling (European Commission, 2016b). Not only will the reduction of pollutions from carbon emissions lead to an increased quality of air and water, but also a better quality of life for all citizens. Planning urban environments that not only enable walking but at best motivate people to choose walking over alternatives, can achieve these goals.

In the course of urban planning history, the movement of people has changed from walking to carriages to public transport and cars, while in today’s modern cities being primarily characterised by the latter (Banister, 2008). From urban infrastructure to parking, the amount of space taken up by cars raises questions about spatial justice (Nello-deakin, 2019) and fair distribution of public space, considering that a car stands around unused at an average of 95% of its time (Barter, 2013; Savvides, 2012). More than 60 years after Lynch and Jacobs, there is still the need to ask whether this is an appropriate living environment in which people feel comfortable and can live happily, healthily, and sustainably. In an investigation by *Copenhagenize* (2017), the distribution of space in traffic was analysed in different cities around the world, including Copenhagen, Paris, Calgary and Tokyo. A similar study was done by the *Agentur für clevere Städte* (2014) for traffic space in Berlin. All results show that around double the amount of space is given to cars than to bikes and pedestrians together.

The example of Friedrichstraße in Berlin Mitte shows what a fair distribution of space with a car-free urban space can look like and proves the promotion of civic engagement and pedestrian activities through appropriate measures in this area. Hence, the successful pilot project has been extended until October 2021, illustrating the citizens' desire towards "cities for people" (S. Jacobs, 2021). Other districts are also actively working towards a pedestrian-friendly and car-free urban environment, e.g. the Wrangelkiez with its initiative *"Autofreier Wrangelkiez"* (Car-free Wrangelkiez) is a showcase for local commitment and the will for change (Stangenberg et al., 2018). On a larger scale, the problems of car-dominated streets and carbon emissions in the city, are tackled through the Berlin *Mobility Act*. The law was recently updated in 2020 and includes paragraphs focussing particularly on pedestrians' traffic, hence the walkability of the city (Abgeordnetenhaus Berlin, 2020; Senatsverwaltung für Umwelt, 2018). Accordingly, Berlin wants to strengthen local public transport, expand cycling infrastructure, and redistribute public space. In this way, the city, like many others at the moment (European Comission, 2020), is reacting to the changing mobility needs of its citizens, because more and more people want to travel in a climate-friendly, responsible way and independently of their cars. The goal of the *Mobility Act* is therefore an efficient transport system for Berlin that realises effective climate protection, a high level of traffic safety, guaranteed mobility for all and fair distribution of space (Senatsverwaltung für Umwelt, 2018).

Although there is a growing awareness of the need for "cities for people" and the mobility shift is steadily progressing, there is not yet enough knowledge about the nature of spaces where people feel comfortable on foot to promote a shift towards vibrant urban environments. Still, cars and other carbon emitting vehicles dominate road traffic and drive people and physically active individual activity to the margins of public space. In the context of the challenges outlined above regarding a climate-friendly, sustainable, and accessible urban future, it is therefore of crucial necessity to explore the research field of emotions and feelings more deeply and to make a valuable contribution to previous research approaches through this human-centred perspective.

3) SENSING PERSPECTIVE

While the recognition of emotions in urban planning research is growing and geography is engaging with emotions theoretically, there is still a tendency in practice to focus on 'objective' understandings and technical solutions. For a necessary transition towards a more sustainable and citizen-oriented urban future, integrated and interdisciplinary investigations are needed to not only consider emotions theoretically but also incorporate them in future decision making (Fathullah & Willis, 2018).

Initiated by the "situationist international" group, a revolutionary and stimulating approach to perceiving urban space through emotional engagement emerged over many decades. In the field of psychogeography, researchers and pioneers of the field established the notion of *dérive* as an activity of wandering around to lose oneself in urban space while immersing oneself in it. In this, a sense of belonging and participation in the space is essential (Pyyry, 2019; Smith, 2010). Such a sensory-oriented perspective was radical and new in the 1950s and has been developed and used ever since. The *dérive* aims to "overcome functionalist city planning that threatened to clear cities from spontaneity and to know the city from within" (Pyyry, 2019). In doing so, it challenges a way of thinking rather than focusing on gaining objective knowledge. It is more about the process of engaging with and 'feeling' the city itself rather than collecting outcome data (Pyyry, 2019).

More recently, the movement of new urbanism focuses on "human-scaled urban design", while influencing contemporary urban design thinking and practice (Congress for the New Urbanism, n.d.). Sustainability – explicitly including walkability – connectivity, diversity and community are thus key principles of the agenda (NewUrbanism.org, n.d.). It is strongly influenced by famous scholars like Jane Jacobs (1965), who criticized conventional modernist planning techniques and made a point for bottom-up approaches while using mental maps to consider people's perceptions (Fulton, 1996).

While these movements already have done a great deal to put people in the focus of urban planning, consider feelings as a tool for urban explorations, and developing people's understanding of space, emotions must also be integrated and applied in practical planning processes. Fathullah & Willi, (2018) state, that a "problem in urban planning [is] that, while people's emotional connection with the physical urban setting is often valued, it is rarely recognised or used as a source of data to understand future decision making".

Therefore, one approach to place people in the centre of planning processes, is to consider humans themselves as “sensors”. With their natural senses and emotions, direct reactions to the current situation or location can be recorded and used to better understand the human-environment relationship (Fathullah & Willis, 2018; Goodchild, 2007). For this, modern sensors offer new possibilities to record and analyse psychophysiological data of people in different locations. Further, developments and improvements in technologies such as communication devices like smartphones, mobile networks or the Global Positioning System (GPS), expand the possibilities of using different types of sensors, collecting real-time data and linking it to associated locations (Exner et al., 2012; Goodchild, 2007; Kanjo et al., 2015).

A useful parameter, through which psychophysiological reactions can be detected, is the electrodermal activity (EDA) of the skin. With the help of adequate EDA sensors, so-called “emotional sweating” can be detected, which is considered as valid objective data due to its genesis and can provide information about environments and situations that trigger emotional arousal or stress (Christopoulos et al., 2019). Accordingly, there are now attempts to apply this originally medical technology to urban planning research using various data collection techniques to investigate, e.g., urban cycling behaviour (Pánek & Benediktsson, 2017; Zeile et al., 2016) or touristic sites in cities (Kim & Fesenmaier, 2015). Still, the approach is not explored at its full potential yet and there are several challenges concerning the suitable methodology and data sources existing. A significant aspect is thus the successful selection and combination of appropriate additional methods to the psychophysiological measurements, which allow a holistic and integrated assessment of the conditions on site (Dörrzapf, Kovács-Győri, et al., 2019; Dörrzapf, Zeile, et al., 2019; Pykett et al., 2020; Resch et al., 2020).

Walking as an emotionally charged activity thus offers an exciting and promising opportunity/application for exploring human emotions in an urban context. Recent public debates and discussions in the media demonstrate the increasing significance of walkable urban areas, particularly since the outbreak of COVID-19 (Goetsch & Peralta Quiros, 2020). As described in the Introduction above, various activist, social, health-related, or practical aspects of this form of mobility can contribute to people feeling strong, happy, sad, angry, healthy, or free. Accordingly, it is important to research and best understand these and other emotions in an urban context to be able to specifically incorporate them into planning contexts.

However, in connection with urban walkability, there are only a few study results to date which in turn only provide small-scale and limited information not allowing any general conclusions to be drawn about the city as a whole and its emotional characteristics (Dörrzapf, Kovács-Győri, et al., 2019; Dörrzapf, Zeile, et al., 2019; Osborne & Jones, 2017). With more comprehensive and large-scale assessments, not only can public spaces be designed according to the desires and preferences of citizens, but also overarching climate and sustainability goals can be achieved by creating an adequate and thus frequently used spatial environment as an encouragement to increase walking (Ryan, 2016). Therefore, it is important to explore further research possibilities of EDA measurements with "people as sensors" to make "walking emotions" tangible and applicable to create people-centred, comfortable spaces that drive a change towards walkability.

Consequently, it is this thesis aim to create methods that show a possibility to record subjective spatial data within the framework of an Urban Sensing Lab and to present it cartographically. Like this, it is attempted to further explore the emotional perspective of the human-environment relationship and to better understand how feelings can be integrated into urban planning. Accordingly, this thesis builds on state-of-the-art knowledge by investigating walkability with the help of psychophysiological sensors and drawing conclusions about the perception of an environment to pedestrians. At the same time, the project shall give an insight into the USL methodology in general and discuss its adequateness in the context of human sensing approaches. With subjective and geo-localised data to ground-truth the sensor output, conclusions about the "real" feelings towards the district's walkability can be drawn, support the knowledge gap in local research and enrich well-informed decision-making processes. By approaching the topic interdisciplinary at the intersection of geography, urban planning and design, GIScience, computational linguistics, sociology, computer science, neuroscience, and psychology (Theodosius 2012; Hoch 2006; Mavros 2019; Christopoulos, Uy, and Yap 2019), it is an attempt to use emotions for a better understanding and creation of walkable urban spaces. For this purpose, one main research question as well as three supporting sub-questions were formulated, which were constantly adapted and transformed during the master project to do justice to the ever-new knowledge gained and the problem areas investigated. They are presented in the following.

4) RESEARCH QUESTIONS

Based on the background of the problem formulation presented above as well as the motivation and starting position of this work, four research questions are posed and answered throughout the text. The main research question is supported by three further sub-questions and should contribute to a clearer understanding of the contents. While SQ1 still refers in general to the research and application of emotions in a planning context, SQ2 and SQ3 are directly addressed to the practically conducted Urban Sensing Lab in Berlin. Their answers should therefore provide information about the tested methodology and contribute to a better understanding of the application of biosensors in such a research context. In general, the questions should make clear that a mix of qualitative and quantitative methods from different disciplines was tested and examined for their suitability.

Main Research Question (RQ):

How can emotional data be measured, combined, and applied in urban research to investigate the walkability of an urban area using EDA sensors, questionnaires, eDiary, and emotional city mapping?

Sub-question 1 (SQ1):

How can an emotional perspective enrich urban planning research and practice to develop walkable neighbourhoods?

Sub-question 2 (SQ2):

How can subjective and objective emotional data be collected through a mixed-methods approach applied in an Urban Sensing Lab to create a more holistic picture of an urban environment?

Sub-question 3 (SQ3):

Which conclusions about an urban environment can be drawn from mapping pedestrians' emotions in a GIS?

STEP 2: THE SCIENTIFIC APPROACH

5) THEORY OF SCIENCE

This project aims to take a stand for considering emotions to describe the reality of walkable urban spaces. Since emotions and feelings are predominantly seen as subjective perceptions and thus in research often characterised as unreliable and not quantifiable, it is important to clarify the underlying ontology and epistemology, as well as the researchers' own biases and attitudes within this study (Baum, 2015).

When scientifically exploring emotions, not only the research subjects' emotions but also the awareness of the investigators' own emotions and emotional attachments to the study are of importance. In walkability studies carried out at a certain location, questions must be asked about the researchers' backgrounds: What is their preferred mode of transportation? Is there a special connection or memory with the study site or participants? And how do one's socialization and cultivation influence the way one conducts a study? (Bondi et al., 2005)

Although attempts are made to make emotions measurable in a standardized approach, it must be clear from the outset that knowledge is believed to be not value-free and – especially in this case – dependent on the context and the individual, i.e., always biased. Nevertheless, subjective perspectives are still considered valuable and reliable data, contributing to making sense of the surrounding environment from a "human perspective" (Brooks, 2013; Moon & Blackman, 2014).

From an ontological point of view, this research adopts the perspective of (bounded) relativism. Relativists, in contrast to realists, believe that there is no one and only (external) reality that can be studied, but the reality is constructed in minds and thus multiple realities exist (Moon & Blackman, 2014). In other words, reality is relative to the individual mind for a specific time and space. Although reality changes through time and space and varies for individuals, shared realities among groups exist and are bound, e.g., by culture, socialisation, ethnicity, gender, or moral values (Moon & Blackman, 2014). In this research project, it is argued that the reality of walkable spaces is different for individual people, depending on their worldview, background, and feelings towards a certain space. Nevertheless, it is possible to identify a shared reality of walkability since common emotional reactions to certain environmental conditions occur. Thus, the walkability of an area can be evaluated through shared emotional reactions, even though different walking realities are constructed in different minds.

Further, collecting emotional data to describe a physical environment, can be localized in the epistemological view of subjectivism and social constructivism. As already argued, different realities exist and are created within different individual minds. Likewise, it is believed that knowledge is created by subjects and is hence not objective. It is therefore difficult to clearly distinguish knowledge in “subjective” and “objective”, because what a subject feels "inside" determines how they act and see the "outside" (Moon & Blackman, 2014). This implies, that personal experiences (including emotions) are connected to how walkability is perceived in this study. Accordingly, it is the purpose to understand what walkability “means to different people and determine how believable and widely held those meanings are” (Moon & Blackman, 2014), by collecting knowledge from the participants’ “inner”. With the belief that moral values, culture, and socialisation, as well as other external factors, influence subjective meanings, the one-sided objective perspective from social and cultural constructivism is added to the subjectivist approach (Reich, 2001). Even though emotions are seen as an inner component, influencing the subjective perception of the environment, there are exterior conditions that can be measured objectively, like the constitution of the physical environment. This will be done by analysing the walkability of the study area, using existing tools like walkability indices, to evaluate the neighbourhood’s condition for pedestrians.

Finally, the researchers of this project consider it important to make their philosophical perspective and bias transparent. Both authors are born and raised in Germany, able-bodied, have an academic background and consider themselves as cis female, which not only influences their worldview but also their chosen methods and literature. Furthermore, they apply a feminist perspective to the study, believing that in a patriarchal world, female voices and perspectives need to be raised and made visible. Opening research for the inclusion of feelings and emotions, which are often considered as ‘typically female’, is already an enrichment to more inclusive (social) sciences (Thien, 2005). However, not only female voices but also voices of diverse genders, BIPOC, disabled, and other marginalized and less recognized groups need to be strengthened and multiplied, which is why the authors of this project recommend reading publications of diverse authors to get an awareness of the variety of different existing realities.

6) METHODOLOGICAL ‘COLLAGE’

In the phase of designing research, it is proposed by Farthing (2016a) to pose two important questions about the methods being used: First, what methods are available? Second, why using a particular method for generating data? Hence, a range of issues and possible shortcomings from one method need to be critically assessed and balanced out to come to a solution about the final choice. It is hereby important to select adequate methods regarding (1) the research questions and purpose; (2) methodological arguments; (3) practical consideration; (4) potential data sources and sampling. The main question being asked at the beginning of the research design process is thus which data is needed to answer the research questions.

The methodological framework of a ‘collage’ is described by Freeman (2020) as an alternative to the common concept of a ‘triangulation’ in a multiple methods approach. This ‘alternative language’ (2020, p. 329) in the field of empirical geography offers a new way to conduct multi-methods research, be more specific and precise about differences between the different types of research approaches and, finally, strive relevant discussions on how and why researchers combine these different methods. Hence, Freeman asks to “[…] put triangulation aside in favour of a new language” (2020, p. 329).

She further elaborates on two key aspects, in which collage differs from triangulation. First, triangulation combines multiple methods to study a precise topic whereas collage combines multiple methods to research a broad research area. Accordingly, the use of multiple methods supports an investigation from different angles to gather fragments of information, which are in the end pieced together to explain a broad research area. If the purpose of a collage, to provide different perspectives on the broader research area, is met, the particular methods and sources of information are open to the researcher and depend on both the context and the research focus. In the context of this study project, diverse perspectives from various disciplines and sources – both academic and non-academic – are included to understand the context of the research field as much as possible and get the best possible overview of the state-of-the-art knowledge. In addition to standard literature in urban planning, theories and publications from psychological sciences and medicine were studied to learn about the psychophysiological part of the research and get deeper into the field of emotion research.

Second, triangulation works from a pre-decided set of multiple methods whereas collage is more open to spontaneity and the shifting of the frame of the research. Freeman gives an example of her research, needing spontaneous adaptations to the research methodology, which is not supported by triangulation. Hence, a “highly subjective process” (ibid., 2020, p. 333) of redrawing or shifting the frame of the study is necessary and supported by a collage. This not only reflects the always adapting and changing the construction of knowledge by the researchers but also gives the possibility of improvisation, a substantial advantage in fieldwork contexts in which the environment cannot be controlled or determined by the researchers. Hence, a collage offers the possibility "[…] to change the focus of [the] research and bring in new sources and methods in a more ad-hoc away than triangulation allows for" (ibid., 2020, p. 330). From an artistic point of view, there can thus be overlaps as well as blank areas deriving from the varying fragments and information brought together in the collage. Blank areas are thereby identified as particularly interesting areas, provoking critical reflections and gaps to be further analysed (ibid., 2020, p. 335).

Still, with the ontological understanding in mind, that there is no single reality or 'absolute richness' (ibid., 2020, p. 336), it is only possible to get an improved picture or idea of a complex problem or research area (see also, chapter 5: Theory of Science). There is however no objective truth to be uncovered, Freeman instead highlights the researcher's framing of a certain perspective by (re-)producing certain knowledge and neglecting others. Likewise, Farthing (Farthing, 2016b) reminds to critically reflect on the researchers' impact and biases in a study, particularly in those to examine people in a natural setting. In these, he argues, an 'ecological validity' or 'naturalism' is only given when encouraging to minimise one's influence on the situation (Farthing, 2016b). In the context of this project, this was particularly ambitious since the study design and the chosen methods were more of a "laboratory environment", e.g., sensors applied on the participants' wrists while walking through the study area. Still, the researchers decided upon a set of different methods for the Urban Sensing Lab, which they thought to be the least influencing and distracting ones for the pedestrians.

Further on, when it comes to visualising the collected data with an adequate system, it is likewise important to critically reflect on one's implications but also the risk to (purposefully or not) influence the reader's opinion and understanding of the situation. Read more on this issue concerning mapping methods in chapter 7: Emotional City Mapping.

The collage framework adopted by the researchers in this study differs from Freeman's proposal in two ways: first, the used methods are not necessarily telling different stories about the research object. Instead, some overlaps are of particular interest because they give a better overview of the physical area, but also some knowledge gaps, highlighting the need for further methods to be included in future research projects. Second, Freeman (ibid., 2020) writes about her use of a collage with only qualitative methods being included in the multi-methods approach. In this project, however, the researchers make use of both qualitative and quantitative knowledge since the research topic requires an even broader mix of tools and methods to better grasp the local situation. Farthing calls it “going beyond the traditional quantitative methods of research to include qualitative methods of various kinds” and refers to Sandercock’s (1998) expression of ‘epistemology of multiplicity’ (Farthing, 2016b). This allows emphasizing the multiple perspectives that exist of any situation.

The composition of various qualitative and quantitative methods within the framework of a self-created Urban Sensing Lab is therefore explained in more detail in the following. Due to the comprehensive subject matter of the research work and the numerous disciplines involved in the research process, an attempt was made to achieve the most comprehensive methodology and analysis possible through the USLs and their subsequent analysis.

STEP 3: THE FRAMEWORK

7) THEORETICAL FRAMEWORK

The underlying concepts of this research will be explained in the following. They establish the basis for the understanding of emotions in urban planning, walkability, as well as psychophysiological measurements of electrodermal activity. The practice of developing an Urban Sensing Lab will be built upon these theories.

Human Emotions

History and Relevance

Resulting from the enlightenment culture in western societies, in which epistemology is based on a belief in rational thinking, emotions are historically seen as competing with reason. Hence, emotions are often afflicted with negative connotations and dismissed as irrational, invalid or unrealistic (Baum, 2015). With the ‘emotional turn’ emerging from criticism on rationality throughout the past decade, this negative image of emotions however has started to decay. Especially, the growing feminist debate makes an impact on shifting narratives. But also, the increase of commercialising emotions in the consumption culture, as well as public debates on mental health are pushing the interest in research on emotions (Thien, 2005). Hence, instead of defining emotions as an antithesis to reason, they are today perceived as a fundamental component of it (Theodosius, 2012).

Their increasing relevance in a broad variety of research disciplines makes the complexity of the topic evident. There is no absolute and uniform definition existing, of what emotions are and what they are comprised of. Instead, the understanding of emotions depends on the researcher's interest and focus. In social sciences, e.g., the meaning of emotions for communication, human interactions and understanding the self is in the focus, while in biology and neuroscience the biological components and reactions are more of interest. In the field of geography, emotions are seen as a connection between the human and the environment (Bondi et al., 2005). They represent and influence how one experiences, navigates through, and responds to natural as well as social environments. With the awareness of certain emotions and behaviour resulting from a particular environment, sites can be planned to trigger positive emotions of their users (e.g., safety or relaxation). On the other hand, negative emotions like fear or stress play a central role in geographies of exclusion. Consequently, an understanding of the correlation between emotions and the (urban) environment can be valuable for the development of inclusive public spaces (Bondi et al., 2012; Theodosius, 2012).

Emotional Spaces

When looking into spatial planning research, emotions are often linked to behaviour, i.e., assessing their influences on people's actions and vice versa (Baum, 2015). In this context, it is proposed to approach emotions from a "Bordieuan perspective" by conceptualizing them as practices framed by social contexts and, consequently, having social and historical meaning and consequences (Scheer, 2012). When acknowledging peoples' emotional experiences as being driven by their way of sensing the world, as well as their beliefs (e.g., feeling ashamed because they believe it is "wrong" what they did), the relation to urban practice becomes apparent. Bowlby (1969, in Baum, 2015, p. 12) explains that 'people seek relationships that provide emotional and social security by offering consensus about values, agreement about norms of conduct, and, consequently, certainty about conditions and the consequences of action'.

Moreover, as mentioned before, emotions play a significant role in the context of geographies of exclusion. In spaces, which are supporting heteronormative behaviour, everyone acting differently will feel uninvited and consequently avoid the place. Also, a feeling of insecurity due to, e.g. poor street lighting can be unpleasant for vulnerable groups, while attracting other people, who feel comfortable when unseen (Bondi et al., 2005). The permeability theory of environmental perception and preference states, that feeling safe in environments depends on how and how easy one can overlook and move through spaces (Stamps, 2013). Other factors, that influence emotions in urban spaces, are personal memories, that are triggered at certain places; familiarity will create an attachment to a place and also the setting itself contributes to the emotional reaction: A night out can feel frightening, but also adventurous or cosy, depending on the specific circumstances and own experiences (Bondi et al., 2005).

In an urban planning context, issues to be addressed by professionals are thus how to build an environment, that triggers positive emotions and leads to a particular behaviour, while avoiding the appearance of negative emotions or actions. Sites can be constructed to generate – intentionally or unintentionally – emotions such as relaxation, excitement, or the feeling of danger. Furthermore, urban spaces can be planned more sustainably to afford sustainable mobility behaviours, like walking or cycling. It is, therefore, essential that urban planners are aware of the correlation between space, emotion and behaviour – both of the citizens and themselves (Bondi et al., 2005).

Neurological Processes

For this project, António Damásio's understanding of emotions will serve as an orientation, as it did for several other scholars in the field of emotions in geography as well. His work on understanding emotions by linking internal body functions with the external environment is thus frequently cited in diverse publications on emotional geography, providing an adequate understanding of human feelings for this thesis (Theodosius 2012; Hoch 2006; Mavros 2019; Christopoulos, Uy, and Yap 2019).

Emotions can therefore be understood as "chemical and neural responses to 'environmental stimuli' that 'shape beliefs' regarding interests in and evaluation of social relationships" (Hoch, cited in Baum 2015). From a neurological perspective, emotions, as reactions to environmental stimuli, send signals through the vascular system and neural pathways to the brain. In the limbic system, these stimulations, as well as bodily responses, can be processed to direct attention, provoke orientation and steer 'survival-oriented behaviours'. Thus, they allow humans to react and adapt to situations (Baum, 2015; Christopoulos et al., 2019).

On the one hand, emotional memory makes us learning to react automatically, shapes our identity, helps to navigate and orientate, and supports decisions between what is “right” and “wrong” (Baum, 2015). On the other hand, bodily reactions to rewarding stimuli are supported by the sympathetic system and foster a process of learning through emotions. This stimulus can be unconditioned or conditioned when the brain has learned that a certain action will (or will not) lead to a certain outcome or reward. Accordingly, emotions shape our behaviour and habits (Christopoulos et al., 2019).

Emotional Processes

As activities of the sympathetic nervous system, emotional responses can be measured through physiological reactions like heart rate, sweating or eye blinking. Signals, which are sent by the sympathetic system, cause “fight or flight” reactions and influence behaviour triggered by threatening events. It is further suggested that physiological reactions caused by a stimulus, inform the limbic system about current external circumstances. Thus, responses such as sweating or increased heart rate are not seen as an output but rather as an input, that “helps the brain assess the present motivational and emotional state” and precedes an emotion (Christopoulos et al., 2019). In other words, the brain will be informed through physiological responses to environmental conditions or possible threats and can react to them accordingly. These responses are referred to as “stress” and are part of the emotional experience. This understanding of emotions succeeding bodily responses is supported by the James Lange theory of emotions, and challenged by the Cannon-Bard theory that follows the opposite approach in stating that emotions are leading to physical reactions. These two central theories of understanding emotions about bodily reactions are illustrated in figure 1. In both cases, emotions can be seen as “interpretations of the peripheral changes” (Christopoulos et al., 2019) and can be detected through changes in, e.g., the heart rate, sweating or breathing of an individual (Christopoulos et al., 2019).

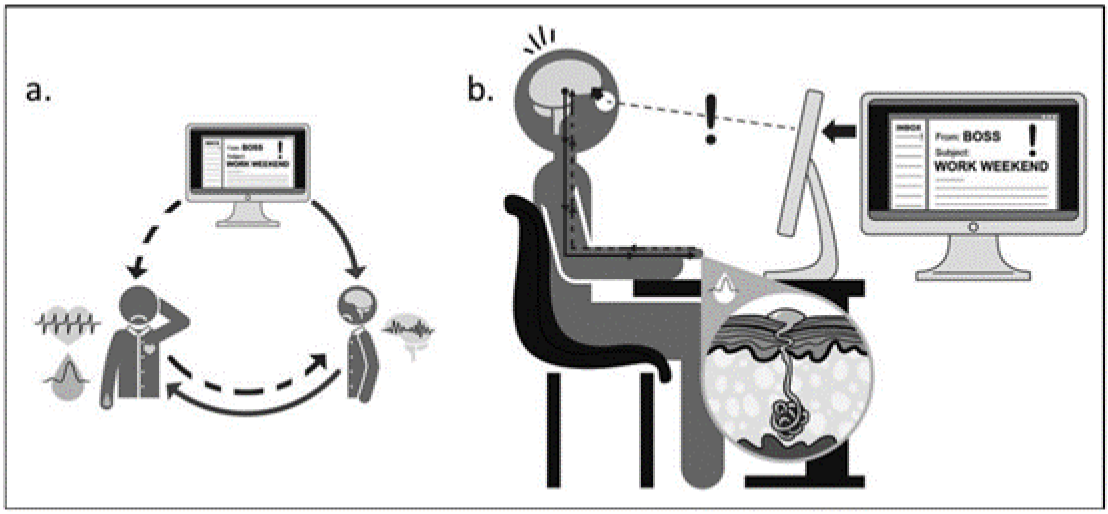

Figure 1. (a) The two major theories of Emotion: The "James Lange" loop (solid line) suggests that the stimulus is followed by a bodily response which subsequently influences the cognitive evaluation of the stimulus ("I see a bear, I run and then I am afraid"). The "Cannon-Bard" theory (dotted line) suggests that the bodily response follows the cognitive evaluation. (b) The dual role of Skin Conductance Response. Imagine you are at work and an (apparently stressful) email from your boss arrives stating that you have to work over the weekend. This will generate a SCR (solid line), as the sweat glands are activated (circled). This mostly nonconscious response (SCR) is used as input to evaluate the stimulus and the associated emotions (dotted line). Images by Jessica Emmett.

Figure 1: The body and the brain (source: Christopoulos et al., 2019)

Categories of Emotions

There are different attempts to categorise emotions according to what caused them, namely background (or basic), primary (or first-order), and secondary (or second-order) emotions. Generally, background emotions refer to a constant state of the body due to physiological processes, like stress or fatigue. Primary emotions describe universal feelings, which are again classified and clustered in groups like fear, anger, surprise, disgust, happiness, and sadness based on different approaches. Lastly, the secondary, sometimes also called social emotions, are intrinsic and emerge from internal believes and self-reflection. Examples are jealousy, shame or guilt, linked to an action that is believed to be wrong (Baum, 2015; Theodosius, 2012). An example of how to classify basic, primary, and secondary emotions can be seen in the feeling wheel by Dr Gloria Willcox below in figure 2.

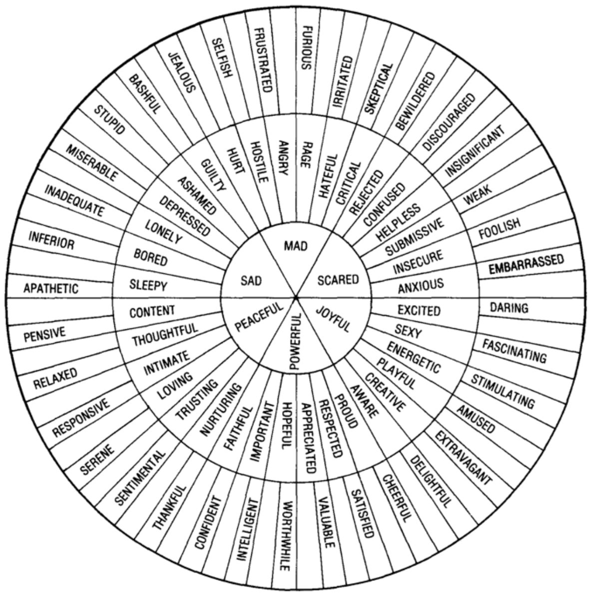

Figure 2: The feeling wheel (source: Willcox, 1982)

While some scholars use “feelings” and “emotions” interchangeably (e.g., Margaret S. Archer) or perceive feelings as a form of emotions (e.g., Arlie R. Hochschild), others differentiate between both terms. Damásio, e.g., understands emotions as an unconscious and constantly present state of mind, in contrast to feelings as “awareness and conscious understanding of emotion” (Theodosius, 2012). According to this understanding, “to feel a feeling” brings emotions into consciousness, and, subsequently, human consciousness derives. There are, however, discussions to what extend emotions are conscious or unconscious. As supported by Damásio, emotions can be unconscious, but at the same time form consciousness and thus build identity. Hence, emotions without consciousness exist, but consciousness would not exist without emotions (Theodosius, 2012).

While internal, conscious thoughts can impact emotions, it is also agreed that physiological reactions to changes in the environment are mostly uncontrollable and sometimes unconscious. Therefore, physiological reactions are reliable, objective indicators for emotions, even though subjective thoughts and beliefs should not be neglected (Christopoulos et al., 2019). To measure these physiological reactions, the electrodermal activity of the skin is an adequate and currently widely discussed approach, which will be explained in more detail in the following.

Electrodermal Activity

Defining EDA

The skin, as well as sweat glands, have resistive and capacitive properties, that can be measured. On the one side, the body uses sweating for the thermoregulation of the body in, e.g., warm environments or during exhausting physical activities. This type of sweating is produced in the apocrine sweat glands, which can be found e.g., in the armpits and the anogenital regions. On the other side, there is the form of emotional sweating, which results from psychological stimulations within a human body. The later type of sweating is produced in the eccrine sweat glands in the hand palm, where it is measurable via sensors attached at these very same. Hence, psychological stimulus resulting from internal or external trigger can lead to a sweating reaction within the body and serve as an input for evaluating the emotion of a human being in relation to their environment (Christopoulos et al., 2019).

The overall term for electric phenomena on the skin is electrodermal activity (EDA) or, in earlier publications also called galvanic skin conductance (GSC). A part of the EDA is the measurable Skin Conductance (SC), which describes the "[…] mostly uncontrollable and unconscious process through which the skin momentarily acquires better conductivity properties due to increase in perspiration. At this point more sweat glands conduct electricity to the skin." (Christopoulos et al., 2019). Through recording changes in resistance, changes in sympathetic arousal can be detected, to indicate emotional and cognitive states (Birenboim et al., 2019; Braithwaite et al., 2013), making the measurement of SC as an indicator for emotions and psychological arousal to a more objective method compared to conventional self-reported assessments. Furthermore, EDA can be measured continuously over some time and the burden of responsibility for remembering to do an assessment is taken from the participants, which results in more natural reactions to the test environment (Birenboim et al., 2019).

There are phasic (rapid) as well as tonic (background) components of the SC, that are resulting from sympathetic neuronal activity. The Skin Conductance Level (SCL), as a tonic component, describes the underlying baseline of individual arousal. On the other hand, the Skin Conductance Response (SCR), as phasic EDA, refers to punctual responses of an individual, that is exposed to emotional stimuli. Hence, it is well suited for the identification of emotional arousal (Kapp et al., 2017).

Ohms law is used to describe the relationship between the voltage (U), current (I) and resistance (R):

$$U = I * R$$

While the SR can subsequently be calculated as $R = \frac{U}{I}$, the skin conductance (SC) is the reciprocal of R: $SC = \frac{1}{R} = \frac{I}{U}$. With a fixed voltage and by measuring I, R (hence, SC) can be determined. The unit of SR is kilo Ohm (kΩ), while SC is expressed in micro-Siemens (µS).

Critiques argue that through the polarization of the electrodes when applying a voltage, a counter electromotive force will be built by the electrodes due to the electrolysis, and the current will be reduced. Therefore, the resistance (and EDA signal) is displayed as high, although there is no stimulus. This must be considered when analysing the EDA signal and is one reason, why it is suggested to wait for some time before starting the actual EDA measurement after the voltage has been applied (Boucsein et al., 2012).

Measuring EDA

The phasic and tonic phenomena of EDA can be measured with three methods: (1) endosomatic, without applying an external current (2) exosomatic, by applying a direct current (DC) (3) exosomatic, by applying an alternating current (AC) (Boucsein et al., 2012). Before choosing a device, one must decide on an approach to measure EDA (endosomatic, exosomatic DC, exosomatic AC), the applied voltage, and the location of the electrodes. Pressure on the electrodes, gross movements or external, disturbing stimuli can cause artefacts during the measurement. Therefore, it is recommended to use pre-wired electrodes that can be plugged into the amplifier to keep their pressure low. Also, using tape to additionally fix the wire, can be helpful (Boucsein et al., 2012). The part of the hand where the electrodes will be applied needs no pre-treatment before the assessment. Only if the skin is extremely oily, it can help to clean the site with 70% ethanol. Although this may cause a change in the salt concentration of the skin, it is the preferred method over cleaning with soap since this can cause swelling of the epidermis (Boucsein et al., 2012).

In this project, the EdaMove4 Sensors, which are used to measure EDA, are based on the second, exosomatic method by applying a DC. For this, two electrodes will be placed next to each other at the palm of the non-dominant hand, where eccrine sweat glands are located, and emotional sweating can be detected. A low voltage of 0.5 V will be applied and turn the electrodes into an anode and a cathode so that a current through the skin surface flows between them. Now, the changing resistance and conductance of the skin, depending on the moisture and level of sweating, can be measured.

Analysing EDA

When analysing the data, several data analytic strategies can be applied to explore EDA. Ranging from fully structured protocols over unstructured or semi-structured protocols to segmenting of physiological data, estimating emotional stability, detecting points of abrupt change, estimating causality, or controlling for physical activity variation, the right strategy profoundly depends on the researcher's aims and the questions being asked (Wilhelm & Grossman, 2010). For this project, semi-structured protocols will be used for segmenting physiological data, as explained in the following.

First, the raw data must be processed, to obtain the values of interest. With the supporting software "DataAnalyzer" by Movisens, a variety of individual signals can be retrieved from the recorded EDA signal. The SCL and SCR signals can be individually extracted, as well as amplitudes, rise time, half recovery time, but also step count, acceleration and movement class or environmental temperature, just to name a few. It is important, to identify, which values are needed and helpful to evaluate the specific cause. This was achieved through pre-assessment unstructured interviews with experts (see chapter 8: Unstructured Interviews) as well as a literature review on state-of-the-art research (see chapter 8: Literature Review).

When overlaying the data, it must be considered, that the sample rate of the used sensors is 32 Hz. Thus, it is possible, that the results must be sampled to match data with different output rates. The segmenting of physiological data offers a strategy to reduce the sampling rate of the collected data to a similar unit, to allow meaningful cross-validation of the different datasets and make them comparable (Wilhelm & Grossman, 2010).

Another crucial aspect of analysing the EDA data is detecting peaks. This is particularly difficult to standardise because the intensity of emotional reactions, such as sweating, is not only individual per person but also dependent on certain unique conditions. In other words, there is no absolute threshold, that can generally be applied, to define peaks and moments of high arousal. Besides individual reactions, also "noise", like artefacts, resulting from disruption or pressure on the sensor, as well as a startle reflex when applying the electrodes, influence the signal, and must be considered (Boucsein et al., 2012). The detection of abrupt changes can help to identify specific moments in time when sudden and statistically significant level shifts occur, which may be associated with psychological or other events (Wilhelm & Grossman, 2010). This approach is adapted from statistical control theory and its adoption in this thesis will be explained in chapter 18: Data Processing.

Additionally, a challenge is to differentiate between event-related (ER-SCR) and non-specific SCR (NS-SCR). When a high frequency of NS-SCR peaks is detected, this can be interpreted as long-term tonic states, i.e. background arousal, and hence understood like SCL (Boucsein et al., 2012; Braithwaite et al., 2013). Hence, controlling for physical activity variation or external variables is a major problem in the data interpretation, which can be overcome by strategies to adjust for physical activity biases such as self-reported activity or the definition and comparison of activity classes (Wilhelm & Grossman, 2010).

Although there are programs available (e.g., "AcqKnowledge" by BIOPAC Systems inc.) to support automated processes, they are firstly not free of charge and secondly, even the calculated results must be checked manually. Therefore, an alternative is to identify peaks manually. This method is not only subjective and highly relies on the analyst's expertise and bias, but also limits when it comes to a great amount of test data. To standardise and cross-validate the process in this project, two researchers will do the analysis and use mean values and standard deviation to identify peaks, as described later in chapter 18: Data Processing.

A typical shape of phasic SCR can distinguish ER-SCR and, thus, enable the isolation of single SCRs from the EDA signal. The curve of a typical SCR signal is displayed in figure 3. It includes a latency that is between one and five, but usually around two seconds. The latency is the time needed to initiate the response to a stimulus. To successfully identify a stimulus, it is important to keep in mind that its trigger did not happen immediately before the EDA's rise but a few seconds earlier. Succeeding the latency, the rise time follows and describes how long it takes to reach the peak. The SCR amplitude is the difference between the peak and the onset of the response and indicates the number of active sweat glands (Christopoulos et al., 2019). After the peak, the SCR gradually decreases. This period is called "SCR recovery", with "half-recovery time" defining the time between the peak and the point where the response has reached 50% of the peak. The half-recovery time is used because no full recovery may happen. Especially due to the following stimuli but also because of a risen background excitement level (Christopoulos et al., 2019). For this reason, it is generally recommended for an EDA measurement to incorporate a sufficient temporal distance between two stimuli (Boucsein et al., 2012).

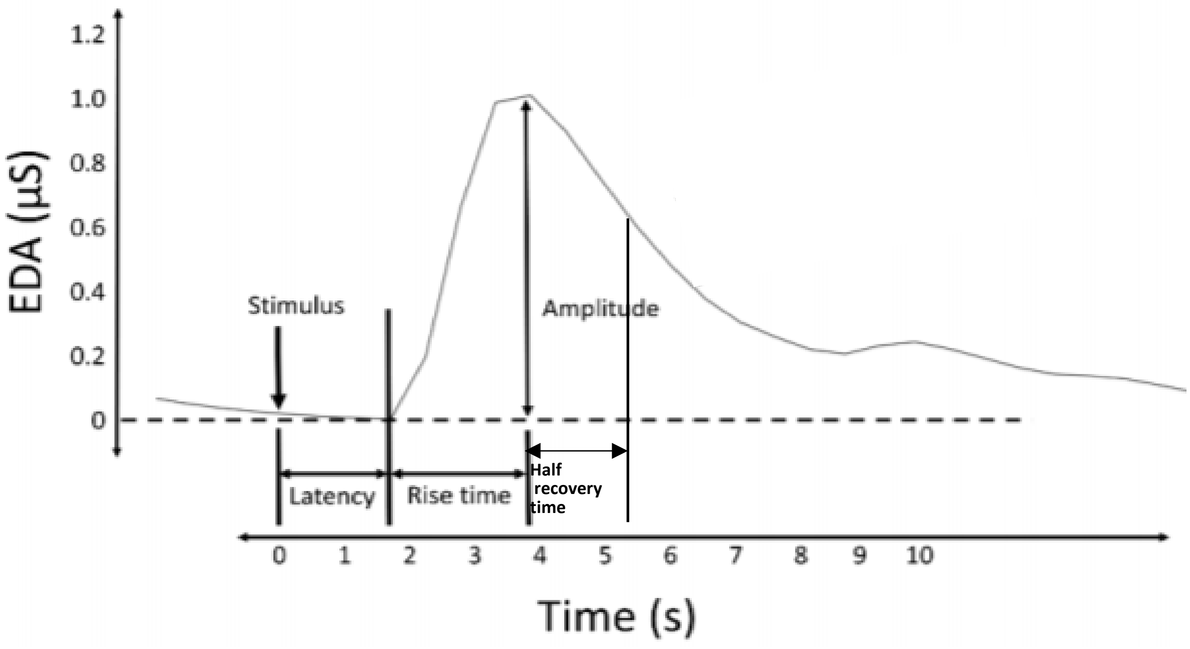

Figure 3: An ideal EDA curve (source: Christopoulos et al., 2019; Posada-Quintero & Chon, 2020)

Applying EDA

As with the analysis of EDA, there are also additional challenges of bringing emotions into urban planning practice. Due to the subjectivity of personal impressions of urban spaces, it is difficult to measure, standardize, generalize, or compare the datasets. As already argued, it is however of considerable importance to incorporate personal feelings and perspectives in urban planning and design decisions. Since emotions are understood as bodily responses to stimuli, (see chapter 7: Human Emotions), psychophysiological reactions can be recorded to draw conclusions about the correlation between emotions and the environment. Regardless of the approach and data collection technique, to reliably detect and visualise human emotions in different contexts, it is however important that (1) the recording is in real-time and at all times to identify local particularities; (2) the measurements are not hindering or disturbing the participants to prevent the recording from distorted emotions (Exner et al., 2012, p. 692). If these conditions are met and biosensing is linked to spatial information, the measurement technique provides an objective and continuous assessment compared to only self-reported analyses, it reduces the burden of engaging in studies as participants do not have to actively report their thoughts, and it gives an idea of the real-time situation in a local context (Birenboim et al., 2019). The assessment in the framework of an ambulatory setting will be explained in more detail in the following chapters.

Sensor Networks

Modern technologies and ubiquitous available recording devices contribute to the constant development of monitoring equipment and techniques. Additionally, with the rise of GPS as "[…] the first system in human history to allow direct measurement of position on the Earth's surface" (Goodchild, 2007, p. 216), sensing approaches have attained an essential spatial asset. These sensor networks can generally be differentiated between three types: (1) network of static, inert sensors designed to capture specific measurements of their local environments; (2) sensors carried by humans, vehicles (see, e.g., AMS Institute, 2020), or animals; (3) humans themselves, equipped with some working subset of five senses and with the intelligence to compile and interpret what they sense (Goodchild, 2007, p. 218).

Human Sensors

As a part of sensor networks, all either used for surveillance or observational purposes, the concept of "human sensors" is barely examined despite its enormous potential and power.

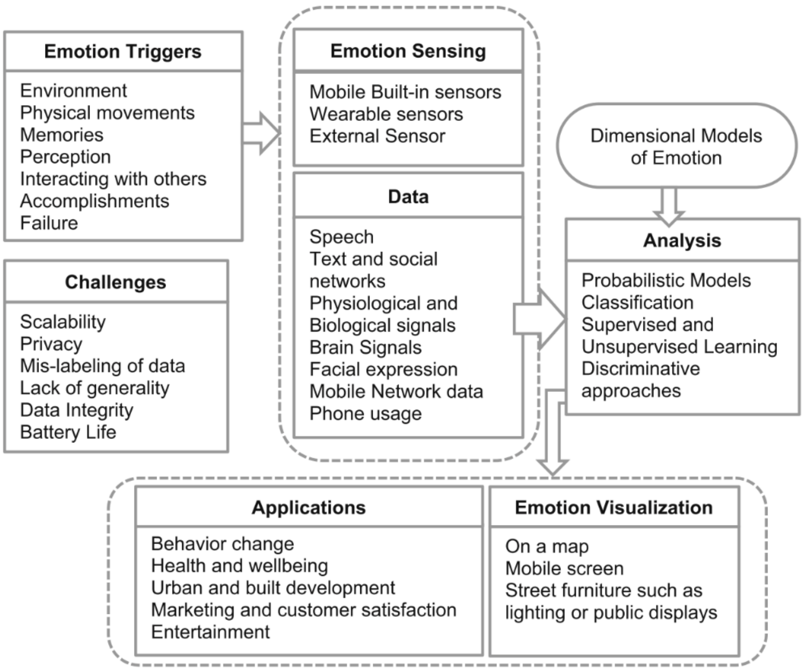

Figure 4: Pervasive Affective Sensing (source: Kanjo et al., 2015)

Nevertheless, some approaches exist, and the so-called “affective sciences” (Exner et al., 2012) or “pervasive affective sensing” (Kanjo et al., 2015) are using the increasingly available interconnected sensors in human environments to generate relevant data for spatial planning processes (Exner et al., 2012; see also figure 4: Pervasive Affective Sensing).

In an urban context, “urban affective sensing” (figure 5) is currently discussed to understand the emotional reactions of people towards particular urban places in different time and space dimensions (Kanjo et al., 2015). Within this context, electronic diaries (or eDiaries) are nowadays often used in combination with psychophysiological assessments to overcome biases and measurement errors that occurred in previous studies with retrospective self-reports. Ambulatory psychological assessments with eDiaries thus allow greater proximity in terms of time and space to real-life situations, which is of great advantage in an urban planning context and provides ecological valid applications in emotion research (Wilhelm & Grossman, 2010). Next to experience sampling, in which eDiaries (often in combination with other parameters) are used to investigate particular stimuli or events outside the laboratory and their emotional effects on the human being, psychophysiological monitoring can be performed to gather information on the emotions of an individual in a wider context (Wilhelm & Grossman, 2010).

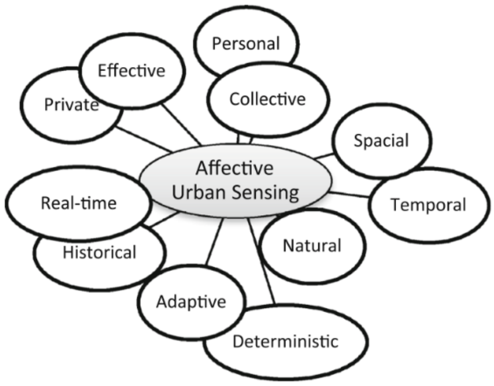

Figure 5: Urban Affective Sensing (source: Kanjo et al., 2015)

Ambulatory assessments

For recording individual feelings, to map and represent them visually, a variety of methodologies exists, and various assessments can be made. Hence, different approaches to capture and analyse human emotions are used, including surveys, interviews, psychophysiological measurements, or diary reports. From a theory of emotion perspective, laboratory, and non-laboratory (i.e., “real-life” or ambulatory) approaches are fundamentally complementary and thus not opposing to each other. Rather they both offer data from different angles to get a clearer picture of participants’ emotional experiences.

From a human psychology perspective, sensing or monitoring techniques are distinguished between self-reports, physiological recordings, and behavioural observations. Emerging from the field of medical research, ambulatory assessments monitoring psychophysiological states are increasingly applied in other disciplines, too. The three characteristic processes that are commonly used in ambulatory assessments are "sensing" (collecting affective data through pervasive tools), "analysis" (recognizing and visualizing collected affects), and "applications" (promoting health and well-being of people and communities) (Kanjo et al., 2015).

While most of the current scientific knowledge on emotions is based on laboratory assessments, ambulatory assessments advocate for tests in real-life, non-laboratory environments. Even though a controlled laboratory environment allows for a relatively simple, reliable and valid analysis of information about people's perceptions, they lack the explanation of emotional activities in a real environment outside the laboratory (Wilhelm & Grossman, 2010). However, the challenge of non-laboratory assessments is to measure emotions objectively, based on body and brain activities in a more uncertain environment. The widespread use and availability of sensor networks and the mobile sensing approaches they enable have therefore made an immense contribution to the real-time measurement of emotions outside of laboratories in recent years.

To conclude, it can be said that the development of mobile and networked sensor-based communication devices is enabling the recognition and processing of human affective states at a given location. Hence, people and their feelings can finally be placed at the centre of planning processes (Exner et al., 2012; Kanjo et al., 2015) and, at the same time, function as active sensors for themselves or their environment (Exner et al., 2012; Resch, 2013; Resch et al., 2016; Zeile, Resch, Dörrzapf, et al., 2015). Sensing human emotions with the help of modern technologies in an ambulatory assessment provides an adequate alternative to the traditional approaches by objectively exploring how people feel about their environment in a real-life setting. Particularly, in an urban planning context to study people's mobile behaviour, e.g., when analysing urban walkability, these sensor techniques thus offer a reliable approach.

Still, there are some general research challenges concerning sensing methods that need to be considered in an ambulatory assessment, such as data privacy, data integrity, limited datasets and lack of generality, diversity, advocacy and civic engagement, as well as the battery life of the devices. Other challenges, such as study design decisions based on the data needed and the research questions asked, can be overcome by a clear definition of choices and approaches used during the field studies. Their application and consideration in this project will be further explained in chapter 8: Mobile sensing.

Emotional City Mapping

As with monitoring and sensing methods, also the application and use of the collected data have developed and improved immensely in the past years due to modern technology. Driven by the nowadays established, general presence of user-generated data on the internet, the special case of so-called "volunteered geographic information (VGI)" (Goodchild, 2007) has experienced a particular upswing in recent years thanks to modern techniques and broadband connections available almost everywhere. The approach involves mostly untrained and voluntary people collectively compiling data on local conditions and feeding them into openly accessible and user-friendly systems. Through these practices and supporting platforms like Google Earth, Wikimapia or OpenStreetMap, Geographic Information Systems (GIS), which consist of the hardware and software used to store, query, display, manipulate, and analyze geographic information (Montello & Sutton, 2006), have been 'democratised' (Butler, 2006 in Goodchild, 2007, p. 213) and made more available to the public.

GISs have become an influential tool for conducting spatial research in many different disciplines, as they can store information with a geographical component. It can be referenced to an earth coordinate system (e.g., latitude-longitude or map projection) and thus allows to spatially 'cross-reference' different datasets with geo-references. This geographic information can be stored as points, lines, polygons, or fields and are linked to a relating table, which contains further information such as numbers, text units, or images (Montello & Sutton, 2006).

An important aspect in a GIS context is however the process of data manipulation and analysis after collecting the geo-located information. Montello and Sutton (2006) refrain from distinguishing between the two processes. Instead, suggestions are given on how to prepare and visualize the data as objectively and non-manipulatively as possible. The points, lines and other data consist of a geometric element (spatial reference and identification) and attribute information (tables linked to the geometric information). Particularly, this tabular information can be manipulated usefully, but also in erroneous and misleading ways (Montello & Sutton, 2006). Based on ontological and epistemological pre-assumptions to this study, it was therefore tried to be aware of and minimize the researchers' own biases throughout the mapping process.

Additionally, with GPS as one of the most sophisticated and accurate systems to measure locations today, one can give information about a person's location when using a tracking tool (Montello & Sutton, 2006). Professional platforms of geodata processing (QGIS, ArcGIS, etc.) benefit from today widely available and easy-to-use devices that are equipped with GPS functions, enabling the measurement, localisation, and mapping of spatial information.

Powell (2010, p. 539) calls mapping a "unique contribution [to] encounter[…] and (re)present[…] empirical material, particularly in the ways that the visual evokes multisensory, and thus an embodied, experience". Nevertheless, limits and lack of data due to possible digital divides, especially in countries of the global South, are still of great importance today and need to be considered in an inclusive planning context (Goodchild, 2007). On the other hand, Resch (2013) argues for a continuing decrease in the digital divide on a global scale thanks to ubiquitous sensing and tracking techniques, which are supported by an ever-growing information and communication technologies (ICT) market and increased access to the internet and information. Like this, the imbalance in digital access and resulting societal effects, such as fewer chances for social and economic development without adequate internet connection, could be overcome (Resch, 2013).

In the field of urban planning, the concept of "emotional city mapping" enables the local positioning and visualisation of measured emotions in urban space (Pánek & Benediktsson, 2017; Zeile et al., 2009). Like this, maps can be used to record and evaluate the "socio- and psychogeographic notions of place, social relationships, and/or cognitive processes" (Powell, 2010, p. 540). Additional "emotional layers" of a map can thus help to identify critical spots in urban areas and support a human-centred and participatory urban planning process.

Nold (2018) is considered a pioneer in this research area, having taken a fundamental first step in the direction of emotion mapping with his "BioMapping" project. In this, he asks about the practical use of emotions to articulate cities. With his approach of "participatory urbanism", a new kind of urban body articulation becomes available and enriches urban maps with an additional "emotion layer" to identify problem spots in the environment.

In addition, Zeile et al. (2009) have made important progress in their research "emomap", in which they tried to visualise so-called "feel-good areas" in a small town in Germany with the help of GIS.

Another study into human emotions in public spaces is performed, e.g., by Exner et al. (2012), who discuss two different monitoring systems, one inductive and one deductive, for collecting and analysing spatial sensor data. Subsequently, two maps are produced (skin conductance map and density map) to identify stress-inducing elements.

Aspinall et al. (2015) are likewise analysing the outdoor physical activity of study participants, although with the help of mobile Electroencephalography (EEG) recorders measuring the brain activity of the participants, and find that green spaces are correlated with less negative and more positive human brain reactions.

Kim and Fesenmaier (2015) are using EDA sensing methodologies to investigate how travellers react to touristic places, providing new data to the future planning for cities and their tourist attractions.

Furthermore, Dörrzapf et al. (2016) are analysing both emotions of participants while cycling and walking, developing "heat maps" of sub-areas in the urban environment with measured perceived dangers.

Substantial research on human emotions while walking is also published by Osborne and Jones (2017), who distinguish between three approaches towards human sensing methodologies (biosensing-led, environment-led, and thematic-led) and categorize between different states of arousal of the participants walking in their own neighbourhoods.

Regarding urban walking and pedestrians' emotions during these physical activities, an influential study has been carried out in Vienna and Salzburg by Dörrzapf et al. (2019), in which the researchers adapted a new integrated approach to evaluate the walkability of the two cities. The method is based on the measurements of human emotions through biosensors and additional subjective data. To "improve the conditions for pedestrians and thus to increase the quality of life in urban areas" (Dörrzapf, Zeile, et al., 2019, p. 853), a so-called sensor-fusion method (including 'objective' sensor data, 'subjective' eDiary inputs, integrated walkability index, and paper-based questionnaires) was applied to identify, locate, and visualise triggers of human emotions.

In the previous study "Fühl die Stadt – Methoden zur Erfassung subjektiver Wahrnehmung" [*engl*.: Feel the City – Methods for recording subjective perception], Dörrzapf et al. (2016) analysed the subjective perception of pedestrians in pre-defined sub-areas of the Danube canal, divided and defined by the researchers. By collecting and combining data such as EDA, EEG (which was not recommended by the authors), visual maps and photos, it was possible to create heatmaps and 3D visualization of different areas. Through direct local reference, an unbiased visual evaluation of the measurement results in the study area could be carried out and insight into the perceptions of passers-by in the sub-areas could be provided (Dörrzapf et al., 2016). However, regarding the most useful source of data in ambulatory assessments, Dörrzapf et al. (2016) conclude that although EDA sensing might be more adequate than EEG measurements, the site-specific results are not generalisable, which is why there is a necessity for additional questions and methods to make the collected data usable for planning processes.

Many other examples of emotional (urban) mapping exist (see Annex I) and together they provide an important insight into the potential strengths and weaknesses of the methodology in terms of inclusive and sustainable urban planning. For these studies, it is, therefore, beneficial to "[…] explore the aesthetic aspects of mapping and how the senses are invoked, contributing to an embodied, sensory experience of place as lived" (Powell, 2010, p. 553). If all the challenges described above are considered and incorporated into the study design, it is possible to provide an "extraordinary opportunity to monitor useful behavioural and contextual information related to users" (Kanjo et al., 2015, p. 1210). Participatory sensing of emotion can thus help to identify collective patterns of emotions in a defined area and inform local policies and community planning. In this way, not only can local development strategies be designed in a more participatory way, but emotions can also be included in urban planning processes as an important, objective source of data. According to this, "[e]motional mapping enables the display of subjective, qualitative and bottom-up spatial information about the environment in highly hierarchical, quantitative and top-down GIS settings" (Pánek & Benediktsson, 2017, p. 66).

Walkability

Walking is an emotionally charged activity that can be performed in different ways and can evoke different emotions or be influenced by emotions depending on the person, the context, or the purpose. Especially because of the current importance of walking in the context of sustainable, inclusive urban planning, but also because of the increase of walking activities during the Corona crisis, the focus of this work was set on the walkability of a Berlin neighbourhood. In the following, the discourse on walkability will be set in a context of sustainable urban planning as well as psychophysiological sensing of human emotions.

History and Relevance

In academia, political practice and art, walking as an activity has experienced increasing popularity in recent years, developing "from a mode of transport 'for the poor, the criminal, the young, and above all, the ignorant' ([Ingold,] 2004: 322) to an elite leisure activity strongly influenced by the wanderings of Romantic poets […]" (Forsyth, 2015; Middleton, 2010, p. 578). Today, walking is one of the mainly used and performed mobility options for people in growing and densely populated cities, yet it is often ignored by research and policies and linked to other modes of transport during research data collection processes (Dörrzapf, Zeile, et al., 2019; Sauter & Wedderburn, 2008). With the current focus on planning and designing more sustainable, greener, liveable, or "happy" (Ferdman, 2019) cities in line with global challenges such as urbanisation and climate change, a shift towards more walkable urban environments has been identified in research and urban practice (Annunziata & Garau, 2020). Next to its contributions to people's physical and mental health, the environment or the economy (Annunziata & Garau, 2020; Credit & Mack, 2019; Doyle et al., 2006), it is argued that enhancing local walkability can also improve the objective well-being of people and quality of life in urban areas (Ferdman, 2019). Indeed, Ferdman (2019) argues that walkable neighbourhoods encourage the "knowing, curiosity, meaningful relations, sociability, and imagination" of citizens' and therefore contribute to their objective well-being.

Defining Walkability

Considering that the "walkable place is a complex and contested phenomenon" (Forsyth, 2015, p. 280) and that there is a wide range of sciences and practices dealing with walkability, it is not surprising that a common and overarching definition of the term is still missing. However, this is not only due to the broad number of disciplines concerned with walkability but also due to the different and context-dependent purposes and motivations of the term in different fields. The literature review from Forsyth (2015) identifies nine different themes organized in three clusters (the means, the outcomes, and the proxies), that deal with the definition of walkability based on different approaches. As there are many factors other than simply the physical environment that contribute to the creation of a walkable place, some clarity in the often confusing and unguided processes concerning walkability is needed, to create lively and sociable places with walkability as a holistic solution. Forsyth's framework picturing the state-of-the-art literature in this manner illustrates the interconnectedness among the different definitions (figure 6). Being aware of the link between the built environment and physical

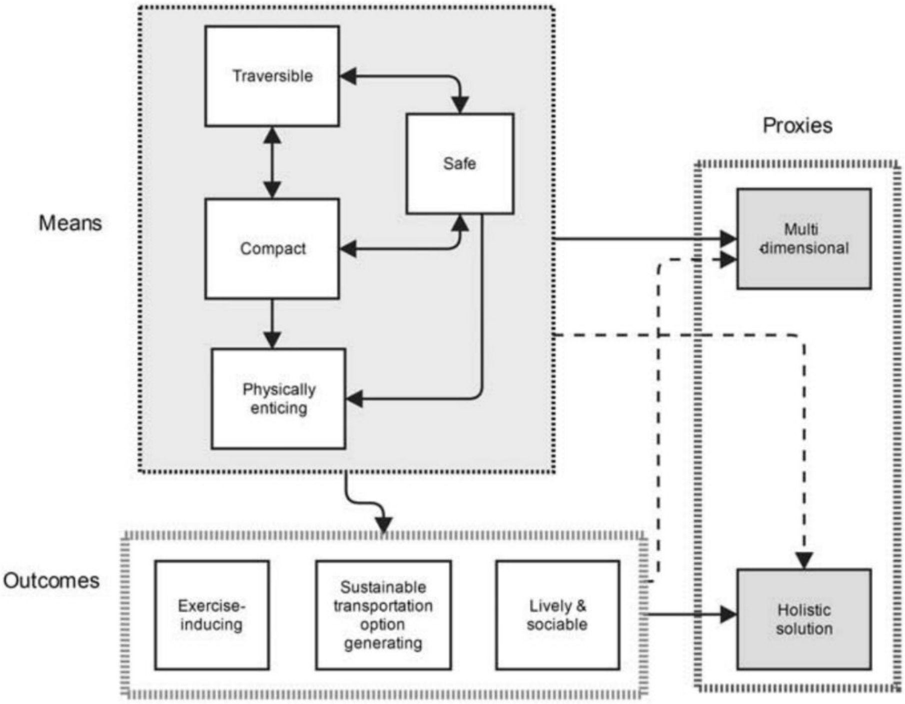

Figure 6: Framework linking definitions of walkability and walkable places (Forsyth, 2015)

activity – e.g., in the form of walking – a more holistic and systematic evaluation is needed (Frank et al., 2010; Sallis et al., 2015). Consequently, when designing a walkable neighbourhood is not only about building the necessary physical structures, but also about other strategies (such as programming, pricing, policy) and the inclusion of other factors (such as income, individual preferences, cultural values, or climate) (see figure 7).

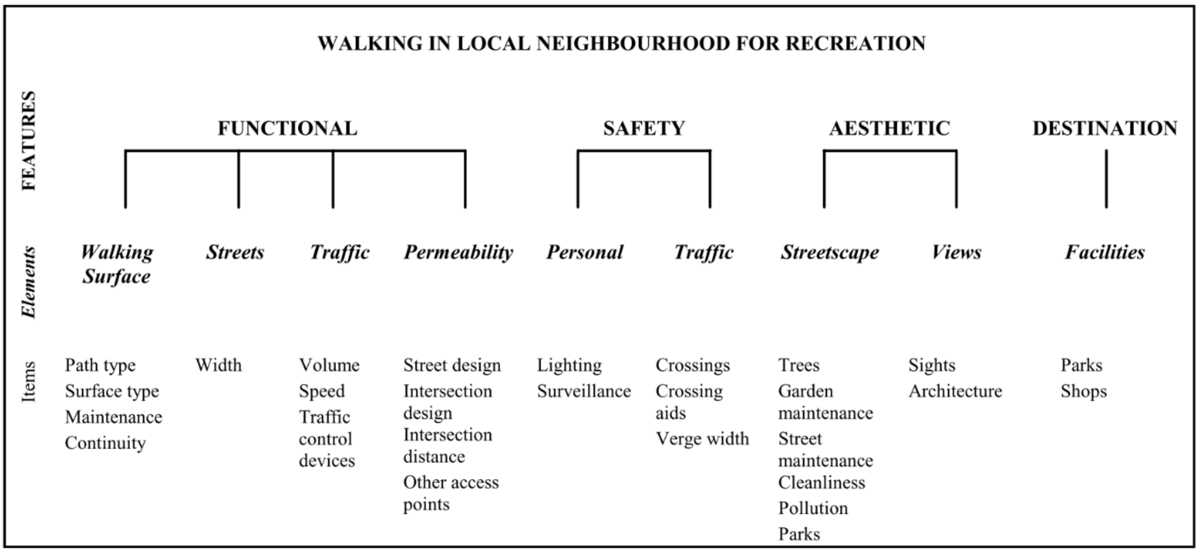

Figure 7: Physical environmental factors that may influence walking (source: Pikora et al., 2003)

Accordingly, it becomes obvious that the walkability of a place is constantly changing and is perceived differently by every individual. In fact, walkability is conceptualised "[…] as a multi-dimensional behavioural category that includes a utilitarian dimension – walking as a necessary activity – a leisure dimension – walking as an optional and recreational activity per se or as a conduit to physical activity – and a social dimension, thus related to walking as a vector to interactions among individuals" (Annunziata & Garau, 2020, p. 423). While accepting that walkability cannot be reduced to one simple definition, all mentioned aspects will be kept in mind to work towards a holistic concept. Nevertheless, the following social relations-oriented definition has been chosen for this work as it is most appropriate to the purpose and themes of the project:

'Walkability is a quantitative and qualitative measurement of how inviting or un-inviting an area is to pedestrians. Walking matters more and more to towns and cities as the connection between walking and socially vibrant neighborhoods is becoming clearer. Built environments that promote and facilitate walking – to stores, work, school and amenities – are better places to live, have higher real estate values, promote healthier lifestyles and have higher levels of social cohesion' (Jane's Walk, 2013 in Forsyth, 2015, p. 285).

Walkability Assessments

Walkability assessments are frequently used forms of transport analysis in the field of transport and urban planning. They help to assess the urban environment for its pedestrian friendliness. Frank et al. (2010) argue, that "active transportation is consistently positively associated with urban form variables of greater mixed land use, street connectivity, residential density and combinations of these variables". But also, various other factors can contribute to supporting or hindering an area's walkability. It is thus of considerable interest to better understand the background of the "built environment potential to affect people's propensity to walk to different destinations and for different purposes" (Annunziata & Garau, 2020, p. 422) to provide information on the human-environment relationship.

An assessment can be carried out on a large scale for a whole city or district, but also for a block or part of a district. There is consensus among walking behaviour research, that the evaluation of different factors of the built environment – usually referred to as the five Ds (density of built environment, diversity of land use, design of street connectivity and built environment, destination accessibility, and distance to transit) – is needed for a comprehensive assessment (Weinberger & Sweet, 2012; Yin, 2017). While previous analyses were primarily based on the evaluation of data such as census data, land-use data, systematic observations or expert opinions, numerous current approaches also incorporate other data into the assessment (Frank et al., 2010). Hence, scholars, today claim that it is important to also include other factors that are not characteristics of the built environment but are as well important aspects – namely crime, transport demand management, demographics, and individual preferences –, into the analysis. So-called walking audits are undertaken to measure and analyse qualities of the urban environment (such as imageability, enclosure, human scale, etc.) concerning citizens' walking behaviour (Ewing & Handy, 2009), but also to find out possible social inequalities that are being reinforced by the local walkability (Su et al., 2019).

For instance, Frank et al. (2010) propose a systematic measurement approach to identify urban forms that enhance the physical activity of citizens through active transportation modes. Walkability indices (WI) or walk scores can thus be generated based on expert opinions about the community, census data, systematic observations, land-use databases using GIS, or a regional 'sprawl index' (Frank et al., 2010). However, it is also argued that due to the compilation of walk scores from merely quantitative data, qualitative and subjective data on pedestrians' senses and feelings are often missing (Kitson & Bratt, 2016).

Weinberger and Sweet (2012) explore the relationship between walkability and actual walking behaviour, arguing that despite the ubiquitous availability of mobility analytics, the results of walking-related research are still not sufficiently incorporated into actual urban planning. Arguing that walking is a self-reinforcing mechanism, which means that people are more likely to walk when others do, more analysis and understanding of walking behaviour is needed. Walk scores can therefore provide very good information about actual walking behaviour in the environment and help to investigate the influence of the built environment on other modes of transport.

Dörrzapf et al. (2019; 2019) are developing an integrated approach that includes statistical data, field observations and sensor data to assess the quality of walking and thereby support any necessary improvements in local conditions. Similar to this thesis, the emotions of the pedestrians are included in the analysis to provide even more precise and clearer information about the individual assessments of walking quality. Accordingly, this innovative and integrative study was taken as a model for the thesis and contributed significantly to the development of the methodology described here.

Site-specific factors cause a great variation among different local walk scores or WI. Still, they can function as important data sources to inform traffic impact assessments in local development projects, property and real estate, routing and navigation or urban planning, and therefore ensure better and more inclusive walking infrastructures due to sufficient information and knowledge about the local walkability behaviour (Dhanani, 2021; Su et al., 2019; Weinberger & Sweet, 2012).

Enhancing Walkability

Practice-informing research on walkability in cities shows that, e.g., more walkable cities and neighbourhoods lead to lower crime rates, healthier citizens, the attraction of economically important facilities such as restaurants, bars, or commercial areas, enhanced social interactions and social capital, or the increase of the general accessibility of the city (Annunziata & Garau, 2020; Doyle et al., 2006; Ferdman, 2019; Frank et al., 2010; Newman & Kenworthy, 2015). Despite the knowledge about these numerous benefits of more walkable urban areas for both the city and its inhabitants and the consensus, that walking – as the most affordable and inclusive mode of urban mobility – should be more investigated and routinised, some authors claim that there is still a lack of adequate strategies to integrate the findings into planning practices (Weinberger & Sweet, 2012). In reality, the focus of research and practice often lies on car infrastructure, partly because it is the easiest mode to analyse, however mainly leading to even more car-focused infrastructures and a car-dependency of citizens (Weinberger & Sweet, 2012). Additionally, the persisting 'gender gap' in urban mobility, which is rooted in fears and insecurities about walking in public spaces, creates gender-specific hotspots of fear (Nasar & Jones, 1997) and thus sheds a divergent light on the walkability of cities, requiring more gender-sensitive analyses and planning (Loukaitou-Sideris, 2014).

An example of a walkability strategy turned into action, is the London-based "Healthy Streets Approach" from the Transport for London, Greater London Authority and Public Health England. Led by Lucy Saunders, it is the aim to improve the health of Londoners by adopting a 'people-first' approach and ensuring healthy streets for active transportation and leisure activities (Papa, 2018; Saunders, 2021). Still, due to the complexity of pedestrian behaviour and the insufficient research on different kinds of walking activities (i.e., utilitarian walking trips, walking for pleasure or walking the dog), people's desires are often unknown and leave open questions about individual priorities regarding the walking environment (Choi, 2013, 2014). Generating these missing data from subjective, personal data in the form of psychophysiological monitoring represents a new approach to urban planning (Bergner, 2010) and can help to overcome knowledge gaps on people's needs in urban spaces.

On the other hand, a focus on planning and designing attractive and accessible neighbourhoods often leads to raises in housing values and therefore rising rents for its inhabitants (Annunziata & Garau, 2020; Cortright, 2009). This form of gentrification associated with walkable neighbourhoods and cities is a notable downside of the above strategies (Annunziata & Garau, 2020) and raises questions about the local relevance and feasibility of international programmes such as "The New Urban Agenda" (United Nations (Habitat III), 2017). At the same time, previous academic research on walking "[…] positions the practice of walking as self-evident and instrumental whilst neglecting the actual experiences of urban pedestrians and the multiplicity associated with those experiences" (Middleton, 2010, p. 578). However, when considering "[…] walking as passing through a series of places, in which intended or non-intended interaction with the material and social environment evoke physical and/or emotional responses" (D. Ettema, I. Smajic (2015)), a deeper and more elaborate analysis of exactly these emotional responses is needed.

8) METHODS

Literature Review

Reading literature is needed and used for a variety of reasons. It helps to gain an overview of the research field in question and topics related to the problem, understand the discipline, set a focus, and frame the project. Reviewing literature does not necessarily mean reading a text from the beginning to the end, but also includes skimming, browsing or only partly an in-depth analysis of relevant passages. It is crucial to decide, whether a topic must be understood in detail or rather an overview of a large topic is needed (Healey & Healey, 2016).

Depending on the aim of the review, different kinds of literature must be considered in the beginning, including e.g., scientific papers, books, journal, magazine or newspaper articles, policies, reports or case studies. In this study, mainly scientific papers and books were used to understand the problem of emotions and walkability in urban planning, but also policies like the *Mobility Act* of Berlin and the Paris Agreement on climate change were considered as legal frameworks, which influence the study site (Healey & Healey, 2016).

To find literature, internet-based search engines were used (internet-based research), as well as library catalogues of the AAU library. Additionally, bibliographies and cross-references in publications lead to further literature ('snowballing' or 'chain search') (Krantz, 2010; Rienecker et al., 2015). It is important to check the reliability of the source by deriving content from scientific platforms of approved author as well as reflecting on the origin and diversity of the used sources.

The process of a literature review is not linear but rather iterative, since finding and refining new keywords while researching will lead to a new starting point for more research. Examples of keywords that were used (individually and in combination) to gather knowledge about the topics of walkability, measuring emotions, and urban planning are the following:

- "walking" + "emotions"
- "emotional mapping" + "urban planning" + "GIS"
- "emotions" + "geography"
- "walkability" + "sustainability"
- "walkability" + "sustainable urban mobility"
- "EDA" + "walkability" + "urban planning"
- "mobile sensing" + "ambulatory assessment"

The findings led further to more specific concepts such as "people as sensors", "psychophysiological sensing", "emotional geography" or "emotional city mapping".

The literature review was mainly used in part one, two and three to frame the problem areas, get an overview of the state-of-the-art knowledge on sensing emotions and walkability, theoretically develop the Urban Sensing Lab, and analyse the context of the study site.

Unstructured Interviews

To collect all available information first-hand and to not risk repeating well-known mistakes from previous studies, three interviews were conducted. With Peter Zeile from the Karlsruhe Institute for Technology (KIT)[1] and Linda Dörrzapf from the Technical University in Vienna[2], both experts in the field of human emotions in urban contexts were consulted before the field studies to get a clearer idea of possible complications and ways to solve them.

[1] https://stqp.iesl.kit.edu/english/209_227.php, 16.04.2021
[2] https://ivs.tuwien.ac.at/research_unit/team/EN/, 16.04.2021

For this, it was decided to conduct unstructured interviews to get a better idea of the research area and identify relevant sources and directions of interest. Interviews in general are defined as ‘a two-way systematic conversation between an investigator and an informant, initiated for obtaining information relevant to a specific study’ (Narayanasamy, 2008). Since unstructured interviews are the least structured version of all interview types, they help to set the research focus and explore new or sensitive topics in depth. The interviewer hereby encourages the interviewee to talk freely about the topic of interest, while giving as minimal guidance as necessary. A detailed pre-planned schedule is thus not needed and standardized, pre-defined questions not useful. Instead, the interview more reminds of a conversation, in which some topics are discussed and maybe even new ones brought up (Narayanasamy, 2008). Interviews are an adequate method to pose questions about facts, behaviour, beliefs, or attitudes to respondents, who are in a good position to know the answers to these very same. Hence, they are perceived as “experts” of their field or own believes and consulted to get a deeper knowledge of the research topic. Farthing (Farthing, 2016b) distinguishes the different types of interviews by their degree of structure, depth, formality, and number of participants to be interviewed. Regarding the structure, the author explains that this depends on the degree to which the interviewer has control over the topic. For this project, experts were consulted to get a better understanding of a relatively new field of research, hence, it was the aim to get as much information as possible but not influence the interview situation with own considerations or believes. Rather open-ended questions can help in an unstructured interview environment to explore the respondents’ experiences and understandings of a field where little research on the topic is done before. In preparation for the conversation, it is thus necessary to prepare a list of topics one wants to talk about while staying open to changes in their order and the emerging of new subjects or angles. Also, this list of subjects can evolve from one interview to the next and therefore be adapted concerning the first given answers and experiences made within the consultation. This kind of flexibility is particularly valuable in a relatively new or unknown research area, in which there might be data or topics one has not thought about in advance (Farthing, 2016b).

Mobile sensing

Study designs to assess human emotions in an ambulatory setting can vary across six rather independent dimensions: naturalness, type and number of channels recorded, degree of situational context awareness, sampling mode, and assessment duration. This large number of choices to be made offer immense flexibility in ambulatory assessment approaches (Wilhelm & Grossman, 2010). Additionally, Exner et al. (2012) are distinguishing between two different monitoring approaches, whereas their combination in a mixed-methods design can be useful to assess phenomena such as walking in urban areas: deductive monitoring as continuous measurement, collection and combination of data after a pre-defined procedure, and inductive monitoring as a dynamic observation and own collection of (un-)consciously similar spatial phenomena through users in real-time. He argues, however, that without contextual information about the type of emotion evoked, interpretation of the physiological data can be difficult.

By sensing emotions through EDA records, real-time data and contexts of the events and behaviour can be captured in ambulatory settings. Nevertheless, the conditions of these experiments are much more uncertain and uncontrollable than in traditional laboratories (movisens, 2021). Hence, several distinct aspects must be considered, and study conditions described as accurately as possible. This includes an explanation of the methods and exact procedure, the used devices, external, environmental conditions, as well as characteristics of the participants and how the data is finally analysed (Boucsein et al., 2012). Environmental conditions, such as humidity and temperature, influence the body temperature and cause bodily reactions (Boucsein et al., 2012). A comfortable temperature is considered to be 25°C to 26°C with 50% humidity[3] (Christopoulos et al., 2019). Since these variables cannot be controlled in a non-laboratory assessment, all weather conditions must be recorded. Furthermore, the location itself and events happening during the measurement influence the results and create uncertainties. If the environment is new, exciting or seems threatening to the participant, this can cause fear or stress-like arousals. Examples include art installations, street performances, traffic, or poor street lighting. Also, engaging conversations and encounters with other people can raise the SCR (Boucsein et al., 2012). Given that not all stimuli can be intentionally set outside of a controllable laboratory environment, it is more difficult to identify and isolate specific events from the EDA signal. Especially, when there is not enough time in between stimulations, as described earlier (Boucsein et al., 2012). For these reasons, it is important to record and describe the test environment with everything that is happening during the

[3] *Although this is estimated the average condition at which a human feels comfortable, it must be recognized, that data is often collected from male persons and the comfortable temperature actually varies for different gender. Studies show that female persons are more sensitive to temperature and tend to feel comfortable at 25°C, while male persons generally do not recognise small temperature changes and feel comfortable around 21°C (Kingma & Lichtenbelt, 2015). Also ethnicity and living environment impact the perception of comfortable conditions (Karjalainen, 2007).*

measurements as precise as possible, to be able to adequately interpret and explain the results and clear artefacts.

Besides external factors, also internal variables, concerning the participants, influence the results of an EDA measurement. These variables are as well biological as societal, cultural, and psychological. Hence, several issues need to be considered throughout the study. First of all, the problem of concurrent metabolic activity variations is a great obstacle to clear interpretation of physiological datasets, since psychophysiological variables such as skin conductance can easily be disturbed by variations in physical activity or social interaction. Also, research has found that gender, age, and ethnicity all influence skin condition. For example, do elderly and biologically male people tend to have dryer skin than young people. Biologically female persons, on the other hand, tend to have less and more delayed sweating. Also, hormones impact the SCR. Due to ethnic differences, there can be differences, e.g., in the number of eccrine sweat glands. Therefore, it is necessary to consider and reflect on demographic data (Boucsein et al., 2012; Christopoulos et al., 2019). Additionally, personal values and perceptions play a role in arousal. Socialisation, including culture and gender roles, influence in which situation someone feels secure or alerted (Boucsein et al., 2012; Christopoulos et al., 2019). Examples are women* walking home at night, BIPOC passing by a police officer or, currently, levels of concern about the COVID-19 pandemic. Chronic and temporary diseases and impairments, mentally as well as physically, impact the way someone interacts with the environment. Not only can an environment be stressful in a different way for a person that is, e.g., visually impaired, or someone who is dealing with anxieties or depression, but also the medication for certain diseases can numb or arouse bodily reaction, just like the consumption of drugs, including alcohol and caffeine. Therefore, the consumption of various substances can influence the recording of EDA data. However, asking for personal details about the medical history of a participant raises questions of ethics and data privacy (Boucsein et al., 2012). All these internal variables make it necessary to include additional measurements of personality, mental condition, and personal values to get a complete understanding of the recorded arousals (Christopoulos et al., 2019).

Likewise, defining the right sampling method is of great importance and has influences on the data collection. Hence, eDiary entries can be prompted at random times or at specific predefined times, depending on the research context and aim of the study. The intervals of entries need to be defined in such a way that meaningful variations of experiences can be captured (Wilhelm & Grossman, 2010). For short-term assessments, sampling intervals of around seven minutes were decided to be appropriate (see chapter 16: eDiary with MovisensXS app).

9) CONCEPTUAL FRAMEWORK

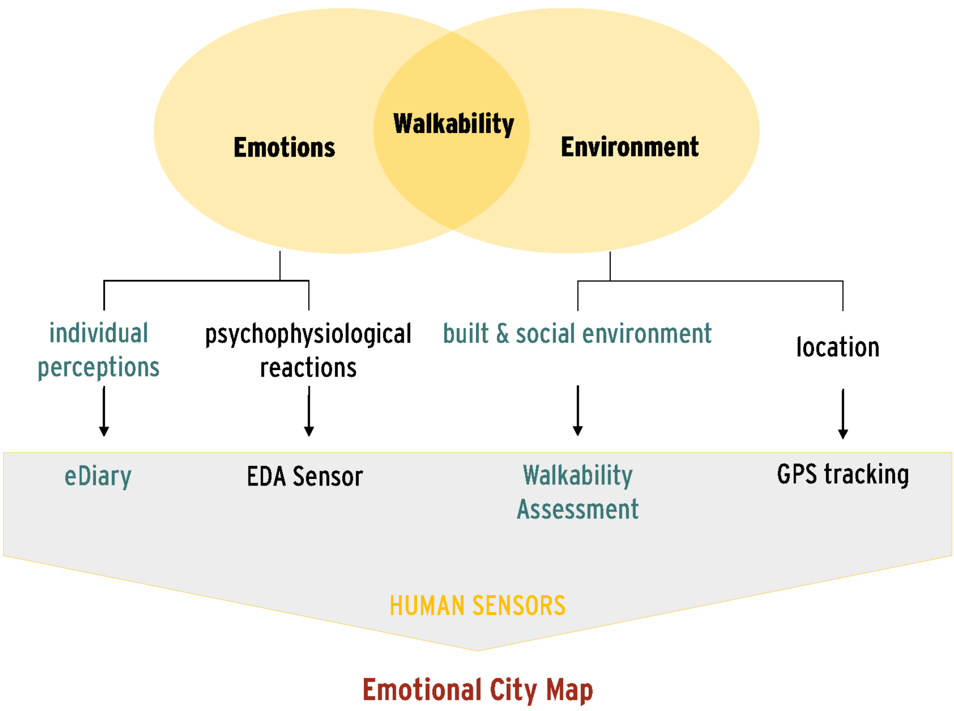

Figure 8: Conceptual Framework, own illustration

Figure 8 illustrates the study's developed conceptual framework, based on the previously introduced theories, concepts, and methods from different disciplines. The framework suggests and illustrates the relationship between the different topics and research areas that are of relevance for this project. It is therefore obvious that walkability, understood as a comfortable walking environment, includes an emotional component in addition to the physical, built environment. Both these parameters can be recorded using people as sensors in an ambulatory assessment. By using their senses and exploring the urban environment, the participants record their perceptions through subjective data collection methods, but also through objective wearable sensing technologies.

Accordingly, the built environment, consisting of a location and its physical qualities, will be recorded firstly with the help of GPS tracking through smartphones and secondly through a paper-based walkability assessment, evaluating the surrounding.

The emotional component consists of a person's subjective, individual perceptions captured by eDiaries and an uncontrollable, psychophysiological response that can be measured by EDA sensors.

All these four methods are brought together to collect the most holistic data possible on walkability, which is then combined and visualised in an emotional city mapping process. Finally, conclusions can be drawn based on the patterns and relationships identified between the emotional component and the built environment of a walkable area.

10) INTERIM CONCLUSION

Based on the above-illustrated theories, which form the theoretical framework for this thesis, SQ1 will be answered in the following.

How can an emotional perspective enrich urban planning research and practice to develop walkable neighbourhoods?

From Romantic-era poets to modern-day walkers during the Corona crisis, walking has traditionally been characterized by a strong emotional component, impacting both the person walking and the area walked through. At the same time, the strong growth of urban dwellers worldwide combined with prevailing crises such as climate change or the Corona pandemic, make innovative and sustainable urban mobility solutions with data inputs from citizens perceptions indispensable. Hence, active forms of mobility such as walking, and cycling are particularly suitable for achieving a strategic change towards a post-car city and making urban landscapes more liveable.

For several years now, researchers and public debates are increasingly engaged in the analysis and application of human emotions as a key aspect of ‘reason’. In the field of urban planning and mobility, especially work on “cycling emotions” as well as the perception of tourist sites while walking has been carried out. However, walking as an active form of mobility has not yet been sufficiently analysed and has been considered only rarely in emotion-based studies. So far, mostly statistical analyses or walking audits were performed to gather information about a city or neighbourhood's "built environment potential to affect people's propensity to walk to different destinations and for different purposes" (Annunziata & Garau, 2020, p. 422). These mostly make use of calculated walk scores or walking indices (WI), based on the "five Ds" or the adjusted "seven Ds", integrating demand management and demographics into the analysis. However, what is missing in many studies so far, is an adequate method to assess human perceptions of an area's walkability.

By conceptualizing emotions from a "Bordieuan perspective" as practices, that are framed by social contexts, their social and historical meaning, as well as their consequences (i.e., human behaviour), are becoming a fundamental part of the analysis. Consequently, the measurement, naming, and cartographic mapping of human emotions can contribute significantly to obtaining a more holistic and transparent picture of the urban areas. Further, with the understanding that urban spaces can be planned accordingly to bring about active forms of mobility, such as walking, a comprehensive understanding of the spaces wanted or not wanted by citizens is necessary. It is thus needed as urban planners and decision-makers to explore how to build an environment that triggers positive emotions and leads to sustainable mobility behaviour.

Emotional sensing techniques can help to fill this gap in planning research on people's perceptions towards certain environments. Since the physiological reactions are mostly uncontrollable, they are considered reliable, objective indicators for human emotions. Hence, using "people as sensors" can help to identify and ground-truth critical spots in the urban area, making future planning and designing processes even more accurate and valid. Like this, more inclusive and community-oriented urban development or planning can be achieved.

As in other cities, Berlin's focus on sustainable future development, which is particularly visible in the newly adjusted *Mobility Act*, calls for innovative and multi-disciplinary assessment tools. In particular, the social component of sustainability, but also the ecological and economic, can benefit in participatory processes of a developing nature by specifically addressing emotions such as stress, fear, anger, surprise, disgust, happiness, or sadness. So by measuring the reactions of citizens as they walk through areas of particular interest using modern sensors, helpful and new kinds of data can be collected and incorporated into the planning of a pedestrian-friendly and sustainable Berlin of the future.

STEP 4: THE CONTEXT OF BERLIN

“Walking slowly down bustling streets is a particular pleasure. Awash in the haste of others, it’s a dip in the surf” (Franz Hessel (1929): Walking in Berlin)

11)GEOGRAPHICAL SETTING: THE WRANGELKIEZ

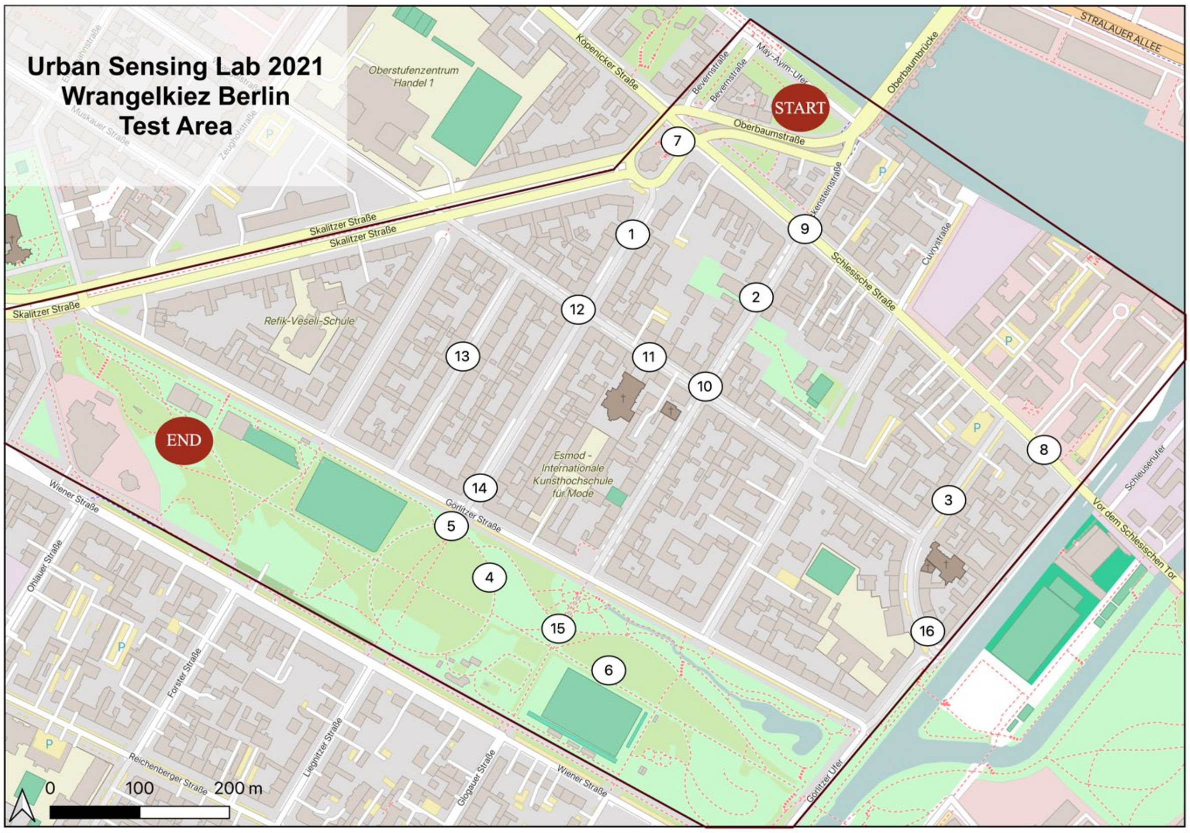

Figure 9: Study area Wrangelkiez with photo spots, own illustration

The city of Berlin was chosen as the general setting for the ambulatory analyses because both researchers have a certain personal closeness to the city and because local proximity helps to carry out the measurement methods on-site cost-effectively and simply. On a smaller scale, the geographical area for the ambulatory assessment was chosen after initial online research, due to its relevance and importance for both the city itself but also the thesis’ topics. A map of the test area can be seen in figure 9 with additional markers, where supporting photographs have been taken during an exploratory walk through the area.

General Information

With the thesis' focus on urban walkability and sustainability, the "Kiez" (Berlin-specific word describing a small neighbourhood) Wrangelkiez was selected. Located within the district of Friedrichshain-Kreuzberg it is bordered at the north-west by the Skalitzer Straße, one of Berlins major traffic roads, in the south-west by the Görlitzer Park, in the north-east by the Spree River and in the south-east by the Landwehr Canal. Wrangelkiez covers an area of 46 hectares (0.46 km^2) and has a population density of 27,556/km^2. The planning area ("Planungsraum" (PLR)) Wrangelkiez lies in the district region ("Bezirksregion" (BZR)) Southern Luisenstadt which is of importance for city and area development projects as well as social space analyses carried out by the local district office (Bezirksamt Friedrichshain-Kreuzberg Sozialraumorientierte Planungskoordination, 2020). Over time, so-called district region profiles ("Bezirksregionenprofile") are created to provide an up-to-date overview of the situation in a particular neighbourhood and to set up a basis for possible development strategies and stakeholder debates. The last assessment in the BZR Southern Luisenstadt was performed in 2020 and gives an overview of the actual state in the PLR, based on pre-defined key indicators to make the outcomes more comparable and useable throughout the whole city. Hence, "the aim was to compile an up-to-date documentation of the socio-demographic development, socio-cultural framework conditions and public infrastructures of the eight district regions, which would be as comprehensive as possible with regard to the municipal fields of action" (Bezirksamt Friedrichshain-Kreuzberg Sozialraumorientierte Planungskoordination, 2020, p. 13).

The neighbourhood's diversity both regarding urban sub-areas (park, river, roads, commercial and housing) but also regarding a social mix of inhabitants was perceived as a useful and relevant setting for the real-life assessments to study as many different settings as possible (see land use plan: Annex II). Besides, the very dense, predominantly perimeter block development in a Wilhelminian style provides a suitable basis for interesting and diverse research results (for some impressions of the area see, e.g., Deutsch bitte!, 2015; Wrangelkiez.de, n.d.). The conditions of buildings and streets are comparably good both because of redevelopment measures due to the International Building Exhibition in the 1980s but also due to a later development program which ended in 2015 (Senatsverwaltung für Stadtentwicklung und Umwelt - Abteilung IV B - Soziale Stadt, 2015; Senatsverwaltung für Stadtentwicklung und Wohnen, 2015). Due to the great mix of social and cultural populations in the neighbourhood, there is an international and vibrant environment which is highly appreciated by the residents, visible, e.g., by a high degree of local initiatives, creativity, and citizen engagement in the Wrangelkiez (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015).

Figure 10: Impressions of the study area; left: Oppelner Straße, middle: Falkensteinstraße, right: Taborstraße (own photographs)

Population

As of 31 December 2018, a total of 26,435 residents lived in Wrangelkiez, of which 47.9% were women. The average age of residents was 38.4 years, which is somewhat younger compared to Berlin as a whole (42.7 years). In addition, compared to the whole city, the neighbourhood has a below-average number of people in the 65-80 age cohort (6.9%, in addition to 13.7% in Berlin) as well as those aged 80 and older (1.6%, in addition to 5.4% in Berlin). The largest share of residents is made up of people in the age group between 25 and 55 (59.5%). It is further noted that the proportion of foreigners who register is higher than the proportion who deregister, which would lead to an increase in the proportion of foreigners if migration behaviour remained the same (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015).

Public Spaces

To determine the attractiveness of a living area, the provision of public green spaces is examined. These should provide opportunities for outdoor recreation and contribute to a healthy living environment. In the BZR Southern Luisenstadt, this proportion of 7.2m^2 per inhabitant is significantly below the Berlin average of 32.2m^2 per inhabitant, showing a clear undersupply of public green spaces (parks, recreation areas, city squares, riverside green spaces, bathing meadows and children's playgrounds) in the area. Nevertheless, there are 13 open green spaces and 17 open children's playgrounds which make a total of 151,957m^2, with the biggest one being the Görlitzer Park (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015).

Figure 11: Impressions of Görlitzer Park; left: park, middle: entrace, right: main traffic route (own photographs)

Traffic Infrastructure

The two bigger streets, Skalitzer and Schlesischer street are main roads with supra-local significance and are burdened by a very high volume of traffic and noise pollution, whereas the riverbank, the Görlitzer park and the close-by Treptower park are offering recreational areas with green and blue spaces. The area is well connected to the public transport system with two metro stations of the U1 inside the area as well as several bus connections. Regarding the biking infrastructure, there are only a few official bike lanes with a lack of the needed infrastructure along main roads such as Görlitzer street (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015).

12)SUSTAINABLE URBAN DEVELOPMENT IN BERLIN

Berlin Mobility Act

With the new *"Berliner Mobilitätsgesetz" ("Berlin Mobility Act"*), Berlin has introduced a specific regulation for more public-, bicycle- and pedestrian-oriented transportation as the first county in Germany. By aiming for an efficient transportation system for Berlin and Brandenburg, climate action, transport safety, mobility for everyone and just public space distribution shall be realised. The act is divided into different sub-parts on the bicycle, public, pedestrian, and economic and "new" mobility (topics of digitalisation and electrification) and contains direct input on the needs of citizens, e.g., more safety in the transportation network, improved accessibility, less congestion or decreases in air pollution. Furthermore, heavily injured or deaths due to traffic accidents shall be limited to a minimum thanks to the "vision zero" approach ("Leitbild"). Increased sustainability in all its forms – socially, economically, and environmentally – in and for Berlin is a main goal of the *Mobility Act*. The introducing paragraph one, which addresses cross-modal mobility assurance and transport design objectives, thus reads as follows (Senatsverwaltung für Umwelt, 2018, para. 1):

(1) The purpose of this act is to preserve and further develop a safe, barrier-free transport system that is geared to the mobility needs of the city and the surrounding area and is designed to be urban, environmentally, socially and climate-friendly, as a contribution to individual lifestyles and inclusive living space design and as an indispensable component of a functioning, sustainable metropolitan region. The purpose of the law is also to guarantee equal mobility opportunities in all parts of Berlin. This is intended to secure participation in social life for all persons.

After the *Mobility Act* was passed in July 2018, it was expanded and partly renewed in 2020, above all the 4th section on pedestrian mobility (Abgeordnetenhaus Berlin, 2020). It is noted that the mobility demands of citizens of Berlin are changing continuously and, at the same time, technical innovations are offering ever new possibilities to improve recent situations. Accordingly, the newly formulated act, even more, attempts to minimise negative traffic impacts such as noise, climate change, air pollution or accidents and contribute to a better quality of life for city residents (Abgeordnetenhaus Berlin, 2020). To reach the climate and environmental goals of the county of Berlin, it is the basic idea to establish and improve an integrated planning approach to optimise the transport system in the interaction of all means of transport. For this, the transport infrastructure shall be both preserved and developed, taking into account all modes of transport and mobility needs as well as wider goals of the urban development and the environment under the umbrella of the Urban Development Plan Mobility and Transport (StEP Mobilität und Verkehr) (Senatsverwaltung für Umwelt; Verkehr und Klimaschutz, 2021). The new section four of the Berlin *Mobility Act* – to promote the development of walking – is a necessary addition to the existing regulations. Furthermore, changes that resulted from the participation procedure were made in sections one to three, particularly promoting pedestrian traffic and having far-reaching effects that are not only relevant for pedestrians themselves, such as the reduction of CO_2 emissions and pollutant emissions (Abgeordnetenhaus Berlin, 2020).

“The aim is to create spaces in the city where motorised private transport plays no or only a subordinate role.” (Abgeordnetenhaus Berlin, 2020, para. 4.3)

For this thesis, the newly supplemented and revised section four (Development of pedestrian traffic) is of particular importance. Since 2020, this section has been concerned, among other things, with setting out the specific goals, tasks, and responsibilities of pedestrian traffic. Accordingly, district pedestrian networks, the implementation of measures and the promotion of pedestrian traffic are targeted. It is stated that footpaths fulfil an important function as protected spaces – especially for vulnerable road users. For this reason, it is important to preserve and strengthen their functions. Expanded and improved pedestrian networks are intended to enable all people to reach their destinations directly throughout Berlin and to encourage them to cover both short and long distances on foot. In addition, priority should be given to pedestrian traffic over motorised individual traffic, which should be done, e.g., through appropriate road space layouts and the switching of traffic lights. Conflicts of use between pedestrian and other modes of transport should be mitigated by measures such as wide pavements and obvious separation of paths and contribute to a harmonious and functioning transport system in urban and green areas (Abgeordnetenhaus Berlin, 2020, p. 8 f.).

A newly set pedestrian traffic plan will be implemented during the next two years to increase the safety and quality of stay for citizens walking through Berlin. Consequently, pedestrian traffic nets with a pedestrian-friendly design and equipment shall be established and developed to give priority to walking activities through adequate infrastructures and traffic regulations. The switching of traffic lights, as well as the barrier-free and comfortable crossing of streets, are key aspects to ensure an inclusive and sustainable traffic planning for Berlin, enabling all citizens regardless of their gender, age, origin, living situation or personal restrictions to be mobile in the same manner. Side-streets are targeted as pedestrian-friendly and traffic-reduced zones to increase safety, especially for playing children on the streets. Adequate signs and digital offers will be provided for the orientation as a pedestrian. But also, temporary or time- and space-restricted projects and efforts are supported by the local government to test developments in the conditions for pedestrian traffic. These targeted ten model projects in the course of five years are meant to assist the re-design of streets and public spaces, enforced by the establishment of citizen initiatives, public campaigns or public relation work (Abgeordnetenhaus Berlin, 2020, p. 10 f.).

Local Development in the Wrangelkiez

Several initiatives have already been carried out to improve the living situation in the neighbourhood and contribute to more liveable and sustainable urban environments. The local instrument used in this neighbourhood is a so-called “urban redevelopment area” (“Stadtumbaugebiet”) (for more information see Senatsverwaltung für Stadtentwicklung und Wohnen, n.d., 2019). Alongside this, some non-political and local initiatives are initiated and supported by motivated and committed citizens or economic organisations. For example, the company infraVelo supports the state of Berlin in creating new routes for cycling and strengthening the environmental alliance. Among other things, new cycle paths are created, old cycle paths are improved, or cycling is generally strengthened and promoted (GB infraVelo GmbH, n.d.). Another project to promote cycling throughout Berlin is the *“FixMyBerlin”* initiative. The interdisciplinary team accompanies Berlin in the implementation of the mobility law and provides digital tools for the mobility turn (FixMyBerlin, n.d.). Their study on the subjective safety of cyclists from 2020 reflects the opinions and feelings of over 21,000 Berliners who took part in the survey via online questionnaires. The aim was to find out how roads and especially cycle paths in Berlin should be designed in the future so that not only planners and politicians feel comfortable with them, but also the people who travel on them (see the full study results here Baaske et al., 2020; FixMyBerlin, 2020). Lastly, there is the vision *“Autofreier Wrangelkiez”* (“Car-free Wrangelkiez”) which imitated in 2018 and serves as a pilot project to demonstrate the opportunities and positive impacts of a car-free neighbourhood in Berlin. The initiative is mainly concerned with returning the space taken up by (private) cars to the citizens of the neighbourhood and freeing the Wrangelkiez from car traffic. Since 2017, volunteers have been engaged in actions, petitions, and events to keep motorised individual traffic to a minimum and thereby reduce potential noise, stress, environmental toxins and sources of danger. For instance, newly installed parklets in former parking spaces and on roadways should contribute to an increased quality of stay and provide visitors with more seating, greenery, outdoor workplaces or similar. Other local initiatives engaged in sustainable and green urban mobility development are, e.g., *“Mobility turn done right”* (“Verkehrswende richtig”) and *“WrangelkiezRat”*.

Feasibility Study "Mobility turn Wrangelkiez" 2020

Fundamental data for the necessity and feasibility of the above-mentioned strategies but also this thesis is provided by the feasibility study *"Mobility turn Wrangelkiez"* ("Verkehrswende Wrangelkiez"), which was carried out in 2020 and is still partly ongoing. The goals hereby are the promotion of the environmental alliance (walking, cycling, public transport), the reorganisation of delivery traffic, the neutralisation of accident sites, the reduction of motor vehicle traffic, the creation of new places to stay and use in public space, and the integration of new and sustainable forms of mobility. An inventory analysis (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020a), discussions with initiatives (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020b), as well as business (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020c) and household surveys (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020d) have already been carried out for this purpose.

Regarding pedestrian friendliness and walking mobility in the area, five intersections were examined, and on-site observations were made. It was determined that after cyclists, pedestrians represent the second-largest share of road users at the intersections. During peak hours (especially in the afternoon), more than twice as many pedestrians as motor vehicle drivers were detected at the intersections along Wrangelstraße. In addition, an accident analysis has shown that especially the intersections around the main road Schlesische Straße pose a risk for accidents with personal injuries. A further conflict analysis revealed that both functional deficits (illegal parking, deficiencies in the road space, difficult road crossings, etc.) and design deficits (lack of recognisability of traffic regulations, design and maintenance deficits or poor condition of the public space) can lead to conflicts among road users and residents, which are displayed in a conflict map (see maps below, figure 12 and 13) (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020a).

Figure 12: Conflict plan Wrangelkiez (source: Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020a)

Figure 13: Traffic accidents analysis Wrangelkiez (source: Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020a)

The discussions and walks around the district with local initiatives *("Mobility turn done right/properly"*, *"WrangelkiezRat"* and *"Car-free Wrangelkiez"*) led to the creation of a list of problem areas and development visions and inspired the "Points of Interest" to be studied in this project (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020b). The business survey conducted in July/August 2020 among 130 local businesses, however, revealed that a large proportion (43%) of local commercial operators are opposed to a shift in transport towards more sustainable forms of mobility. At the same time, 33% of the respondents also support a potential change, 14% are unsure or divided, and 9% do not feel informed enough to make a statement (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020c). In the fourth and so far, last part of the study, resident households were asked to participate. From September/October 2020, a total of 1105 questionnaires were evaluated and included in the analysis. The main findings were that walking, cycling and public transport are the most widespread modes of transport among respondents. The car plays a role as a means of transport for about half of the respondents, of whom about half use the car several times a week. Regarding the non-traffic use of the public street space, almost half of the respondents stated that they often (daily, several times a week) spend time on the public streets in the Wrangelkiez for visits to cafés, pubs or restaurants, for walking, or to meet families, acquaintances and friends. Accordingly, public space in this area plays an important role as a place for everyday activities, leisure activities and social contacts. On the other hand, 46% of the participants rated the co-existence in public space as "rather bad" or "very bad" and 47% find the provision for play and exercise in public space "rather bad" or "very bad". The 55% of people who rated the quality of stay in public space as "rather poor" or "very poor" are compared to 44% who think the quality is "rather good" or "very good". The general conditions for pedestrians are also assessed ambivalently, with 43% of respondents finding the situation "rather poor" or "very poor", whereas 56% of participants indicated "rather good" or "very good". Accordingly, the overall condition of the neighbourhood is perceived and evaluated as very mixed. However, two aspects are rated positively by the majority: the public transport connections in the neighbourhood and the assessment of their housing situation. On the other hand, the general situation of car traffic, as well as the parking space situation for cars and accessibility for people with limited mobility, are mostly rated as negative.

In a subsequent section to evaluate different objectives for the further development of the Wrangelkiez in terms of traffic, strategies for "safe crossing possibilities at the main streets", "more attractive open and green spaces", "safe and comfortable bike routes" and "wider, barrier-free sidewalks" were rated as "rather important" or "very important". The two development goals toward a traffic-calmed, car-free neighbourhood, "car-free streets and more space for other uses" and "fewer car parking spaces in public streets in favour of other uses", were rated rather differently by respondents. Overall, however, the objectives are assigned more relevance than irrelevance. Follow-up surveys of the study with people with a migration background showed that this subgroup, as well as respondents with their cars, are among the two groups with the most negative sentiment toward a change in mobility (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020d).

After all, the study is mainly asking about subjective feelings and perceptions via traditional paper- or online-based questionaries and interviews. It would therefore be interesting and worth it to investigate, to what extent a more objective measurement of emotions aligns or contradicts with the statements about wellbeing in the traffic environment.

13) WALKABILITY ASSESSMENT WRANGELKIEZ

Walkability Assessments were performed in two ways: firstly, the researchers themselves carried out a Walkability Assessment prior to the USL, also considering findings from the study of the municipality and secondly, the lab participants were invited to evaluate the test area for the same factors after their walks (see here chapter 17: Paper-based Questionnaires). The pre-assessments by the researchers should not only provide a better knowledge of the environment but also serve as a basis for the questions posed to the participants via the eDiary application, as well as offer a comparison to the recently conducted local social space analysis (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020c, 2020d, 2020a, 2020b). Furthermore, a walkability assessment can help to define different "Points of Interest" (POI), which ensured their enquiry in the following USL.

For this, a walkability checklist published by the KIT (see Annex III) was used and adapted in accordance with the locality and the thesis' aims of investigation. It was published in 2017 and is based on the *"Neighbourhood Walkability Checklist"* of the Heart Foundation, Australia, as well as the *"Walkability Checklist"* of Safe Routes, National Center for Safe Routes to School, Pedestrian and Bicycle Information Center, U.S. Department of Transportation, Environmental Protection Agency, U.S. and the *"Checklist for Pedestrian Friendliness"* of the Institut für Stadtplanung und Städtebau, University of Duisburg-Essen. The formula is divided into four sections – pedestrian friendliness, comfort, safety, and practicality and connectivity – each of whose sub-questions, e.g., "Are the footpaths free from obstructions such as vegetation, road signs, parked cars?", can be answered with a "yes" or "no". For the local analysis in the Wrangelkiez, most of the questions were included from the checklist, although some of them were adjusted and the answer options were converted into a rating from "fully agree/fully applicable" to "do not agree/does not apply". For later analysis, the scale was then transformed into an inverted number scale to be able to calculate an individual as well as an overall walkability score ("fully agree/fully applicable" = 4; "do not agree/does not apply" = 1). This was decided, among other things, to make the results of the Walkability Assessments more comparable with the scale-based results of the eDiary surveys from the app (read more on the eDiary method in chapter 16: eDiary with MovisensXS App). Besides, the possibility was given to describe additional anomalies, which was also used in some cases.

Before the local on-site analysis, the test area was divided into sub-areas based on land-uses, and critical areas and locations were marked based on the feasibility study. The map can be seen in Annex IV.

Close to the meeting point for the USLs (May-Ayim-Ufer), is the metro station "Schlesisches Tor". It is an up-levelled station under preservation order and is surrounded by the main road Skalitzer Straße (photograph 7). At the time of the first lab, the station was under reconstruction and the trains only passed through without stopping (BVG, 2021).

The Skalitzer Straße is further an important connection between the Eastern district Friedrichshain and the Western part of Kreuzberg and therefore a busy road and intersection.

The Schlesische Straße is a popular address for the club scene. Not only clubs but also the music industry as well as other commercial businesses have settled here. Because it is partly three-lane, there is noise emission through car traffic (photograph 8).

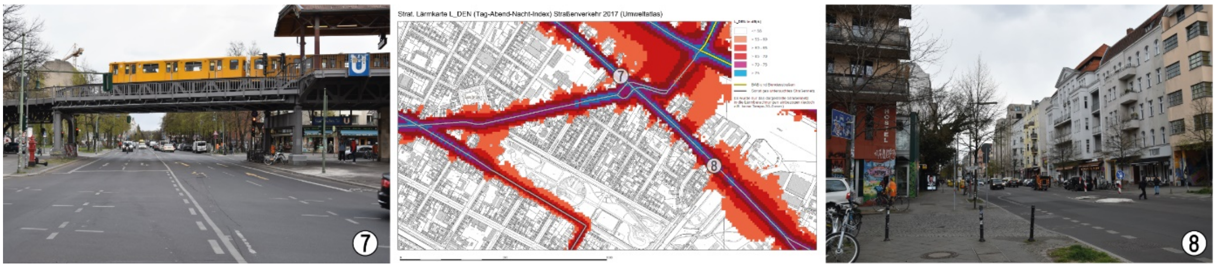

Figure 14: Impressions Wrangelkiez; left: metro Schlesisches Tor (own photograph), middle: noise map (source: Land Berlin, 2017); right: Schlesische Straße (own photograph)

Especially the intersection between Schlesische Straße and Falckensteinstraße was identified as a hotspot for accidents by the feasibility study in Wrangelkiez. Although a traffic light for pedestrians is existing, the traffic flow seems chaotic (photograph 9). But also, the intersection

Falckensteinstraße/Wrangelstraße was identified as a crucial point for further investigations since a diagonal barrier aims to reduce the car traffic here (photograph 10).

The Falckensteinstraße is another popular street with cafes and gastronomy. Here, only one lane limits the car traffic, but the sidewalks seem narrow and crowded with pedestrians (photograph 2).

Figure 15: Impressions of Wrangelkiez; left: Schlesische Straße/Falckensteinstraße, middle: Falckensteinstraße, right: Falckensteinstraße/Wrangelstraße (own photographs)

Also, the Wrangelstraße is a popular commercial street with small shops and cafes, central and name-giving to the Kiez (photograph 11). The street's intersection with the Oppelner Straße is another point of interest, identified as a hotspot for pedestrian accidents despite the physical barriers on each corner (photograph 12).

In the residential street Sorauer Straße, big trees are giving the impression of a small green oasis. A bench to sit down and a narrowed road both aim to create a peaceful roadway. However, this location is criticised for not meeting its goals of a quiet oasis with accidents being still reported regularly here (photograph 13) in chapter 12).

Figure 16: Impressions of Wrangelkiez; left: Wrangelstraße, middle: Oppelner Straße/Wrangelstraße, right: Sorauer Straße (own photographs)

Another critique of previous neighbourhood investigation is the non-existing pedestrian crossings at all entrances of the Görlitzer Park towards the Görlitzer Straße, which serve as a direct connection to the residential area (photograph 14).

The Görlitzer Park itself is rather busy. It is identified with a high level of crime due to the present scene of drug dealers and often listed as a “crime hotspot” by the police or the media (Polizei Berlin, 2020). In the East, trees and tall vegetation give the impression of a hiding place in a piece of nature, while in the West the lack of tree planting makes the park look more like a meadow. There is also a petting zoo and a paved plaza at the entrance to the North, where outdoor cultural events take place while spectators can linger in an arena-like arrangement. This very busy and popular place was also the endpoint of the Urban Sensing Labs (see pictures USL in Step 5). The path leading directly through the park as extension of the Falckensteinstraße is the main traffic route for people crossing on the quickest way, hence it is busy with pedestrians and bikers (photograph 15)

Finally, the test area is bordered to the East by the channel, which is followed along by the Heckmannufer. The narrow sidewalk and many parking cars are already criticised in the feasibility study and prevent an enjoyable view of the water (photograph 16).

Figure 17: Impressions of Wrangelkiez; left: Görlitzer Straße/Oppelner Straße, middle: Görlitzer Park, right: Heckmannufer (own photographs)

In general, the researchers perceived the area as attractive and vibrant with street life in the centric parts and quiet side streets in the residential areas. Pedestrian traffic is concentrated on Wrangelstraße and Falckensteinstraße. Drug dealers offering their “goods” were identified throughout the area and apart from Görlitzer Park, few green spaces were identified. Accordingly, the walkability assessment checklist was completed in the course of the site visit and can be found in Annex XI.

STEP 5: THE URBAN SENSING LAB

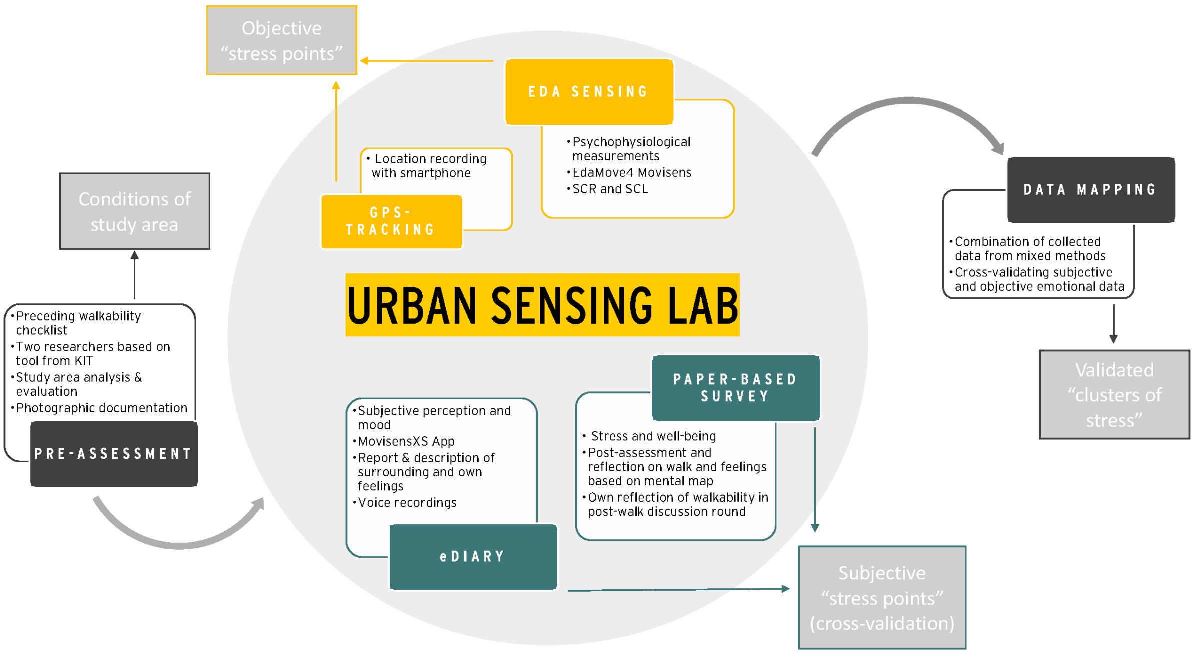

Figure 18: Workflow Urban Sensing Lab (own illustration)

Based on the theory described above and state-of-the-art knowledge on ambulatory assessments of emotions, basic study design decisions could be made according to context and research questions. As mentioned above, there are many different approaches and methods to assess people's emotions in a "real-life" context and to relate them to other parameters (e.g., Dörrzapf et al., 2015, 2016; Mavros, 2019; Nold, 2018; Pánek & Benediktsson, 2017; Zeile et al., 2016). For this urban laboratory, which was outside a controllable traditional setting, a variety of assumptions and decisions were made. The design of the USL was largely oriented toward pioneering studies in the field, although some contextual changes and adaptations were made. They are illustrated in the practical workflow of the lab in figure 18. Additionally, each step and needed technologies of the USLs will be explained in the following chapters. By this, SQ2 shall be answered and give information on the practicability of designing a sensing lab for urban research projects.

How can subjective and objective emotional data be collected through a mixed-methods approach applied in an Urban Sensing Lab to create a more holistic picture of an urban environment?

Figure 19: Impressions of the USL (own photographs)

14)PARTICIPANTS

Participant	Age	Gender	Education	Occupation
1	28	m	master	part-time job
2	27	f	master	unemployed
3	25	w	higher education	student
4	26	w	master	full-time job
5	28	m	higher education	student
6	26	w	Bachelor	student
7	30	w	Master	full-time job
8	23	m	Master	part-time job
9	26	m	Bachelor	student

Figure 20: Demographics of USL participants

First, two days were determined for the workshops. Weather and time were of particular importance, as rain, cold or snow were considered to hinder the measurements and the time of day, and the weekday had to be suitable for all participants. Therefore, as well as due to the current corona situation (see chapter: Preface), it was important to find a suitable time window for the measurements, which could finally take place on two Saturdays in April (11th and 24th) and lasted about two to three hours. Subsequently, five participants were invited for the first USL and four for the second USL. All of them were acquaintances of the researchers, which resulted in a homogeneous group of people that are predominantly white, European citizens, in the age between 23 and 30 and with an academic background. Some are working or studying in the field of urbanism or architecture while others do not have additional background knowledge in urban planning.

Since the primary purpose of the research was to establish and test a methodology for analysing the walkability of urban space using emotions, the homogeneity of the participant group was considered acceptable. To carry out a representative study of people walking in Berlin, more diversity and a larger number of participants would be needed.

Further, when working in a study environment in which the participants have a personal relationship with the researchers, emotional attachment and study biases must be considered. A benefit of this emotional attachment is however that the motivation to participate and produce valuable results is also driven by personal interest. Furthermore, the researchers have an expansive knowledge of the participants' backgrounds, which can influence the data analysis either in a supportive or a distorting way. To stay as objective as possible, the two researchers were cross-validating their interpretations through various datasets, to make sure that personal opinions are left out and involved emotions are recognized.

15)EDA SENSING WITH EDAMOVE4

The EdaMove 4 is the latest model of Movisens brand EDA and activity sensors. It allows measurements and analysis of EDA and general physical activity (for more information see Movisens, n.d.-a). By storing and processing the data in the proprietary DataAnalyzer program, insights into the emotional effects of selected research participants can be provided. For the USL, the sensors were attached to the participant's non-dominant wrist with a band and connected to the skin through two electrodes attached to the inner surface of the hand. Once the sensors were activated, physiological data recording started and continued until the end of the walk. Afterwards, the recording of further data can be stopped manually and stored in the DataAnalyzer program. For the analysis, all collected physiological parameters were subsequently downloaded and checked for their usefulness for the study. Concerning the research question of this thesis and the use of the data for urban planning purposes, especially the data SCR was considered important and hence used for the visualisation in QGIS.

16)EDIARY WITH MOVISENSXS APP

A crucial requirement for interpreting the results of the EDA measurement and linking them to the urban environment is to understand the context in which the data is recorded. Knowledge about the subjective perception of the environment is needed, to describe circumstances, that cause certain mental states. The crux, however, is to ask the participants to report their perspective during the walk without having them constantly thinking about the laboratory situation. In this study, it was therefore chosen to work with a survey app, which triggers an alarm and reminds the user to fill out a short questionnaire. Thus, the participants were not asked to describe the environment on their own but instead were able to focus on their walk with automated notification triggers through the app. After researching and testing several potential survey apps (see Annex V), it was decided to use the MovisensXS app provided by the same producer as the EDA sensors. This brings the advantage of compatibility between the app and sensors. With MovisensXS, survey forms can be created with a variety of question types and including multimedia such as voice memos or photos. It is further possible to create a sampling scheme to trigger an alarm and define when the survey should be filled out (for more information see Movisens, n.d.-b). However, it must be added that MovisensXS can only be set up on a Windows operating system and the app is programmed for an Android environment, which required the additional organisation of compatible smartphones for each USL participant.

In this research, three types of alarm triggers to start the surveys were considered: a trigger based on SCL values, a time-based trigger, and a geofence trigger. Sjoerd Halem, who conducted a similar study using MovisensXS and EDA sensors (Halem et al., 2020), was consulted to get advice on how to define an EDA threshold that automatically triggers a survey when a certain level of arousal is reached. Although this approach is promising to obtain subjective perceptions in moments of stress, it became evident that the definition of individual thresholds per participant would require more time and previous tests.

A suggestion was instead to define geofences around crucial areas and points of interest in the neighbourhood, to make sure that stress level and subjective perception are recorded at these locations. An alarm would be triggered either when entering, exiting, or staying in a geofence for a certain amount of time.

Based on the feasibility study *"Verkehrswende im Wrangelkiez"* (Mobility turn in Wrangelkiez) (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020a, 2020c, 2020b, 2020d) and the vision of a car free Wrangelkiez (Stangenberg et al., 2018), geofences were identified and given as input in the MovisensXS app (see Annex VI). Because the accuracy of the GPS location was not always reliable with the collected Android phones, a combination of geofence triggers and time triggers (set in a seven-minute-interval) were used to ensure, that the survey will be filled out during the walk.

If participants did not want to answer one of the triggered surveys, they were able to dismiss the alarm. At the same time, it was always possible to fill out the survey manually and report on the current environment and perception. A picture of the sampling scheme can be found in Annex VII. Accordingly, the brief survey in the eDiary aimed to explore the participant's current location, general emotional state, perception of the built environment, role as a pedestrian in traffic, and social environment. The complete survey questions can be seen below in figure 21. With the option to write a comment or record a voice message, a more accurate reporting on the situation was possible, often used by the participants. The feature of uploading a photo of the environment did not work properly in the current version of the MovisensXS app.

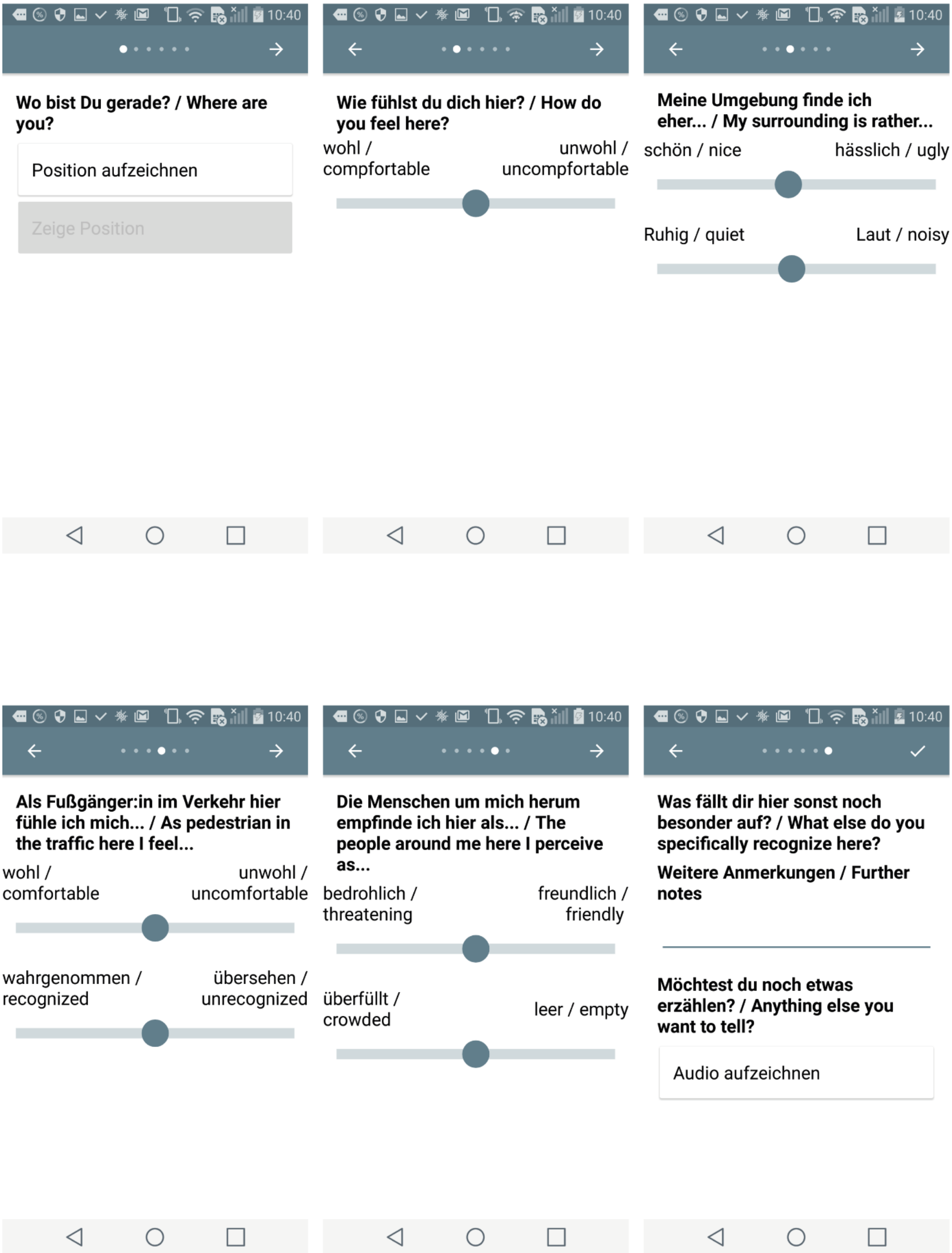

Figure 21: MovisensXS app Questionnaire

17)PAPER-BASED QUESTIONNAIRES

Inspired by the research of Dörrzapf et al. (2019) and Zeile et al. (2015), a paper-based questionnaire to fill out before and after the walk was developed (see Annex VIII). The first survey aimed to get an insight into the participants' general personal context, including their current state of well-being and general attitudes towards walking as well as current emotional states and daily feelings. Also, with relevant questions about one's walking habits and feelings in an urban environment, sensitivity towards the topic shall be given and stimulate a more intense experience while walking in the test area. After the walk, a reflection of the route should reveal how the participants perceived the environment in relation to the general walkability, as well as the existence of significant locations along the way. With the help of a map, people were engaged to report on their walks and draw their routes out of their memories into the map layer. With these mental maps, it was possible to trigger some important events, revealing valuable information about the city environment but also the people's feelings during these walks.

18)DATA PREPARATION AND COMBINATION

After carrying out the first USL, several adjustments were made, and data was prepared accordingly to make a comparison and analysis feasible.

Adjustments for the USL 2.0

A research design should be a reflexive process and researchers should often reconsider or modify their design decisions during a study (Bickman et al., 2014; Farthing, 2016c). As such, modern methodologies such as collage promise openness to spontaneity and shifts in the research framework. This was also implemented in this study, where constructive feedback from participants as well as technical difficulties led to several adjustments in the USL design. First, the frequency of alarms from the eDiary app was reported to be too high and thus disturbing the peoples' individual experience. Therefore, the time trigger was set up to remind the app users in a twelve-minutes-frequency to fill out the survey.

Furthermore, the geofence trigger did not work as intended and was not a reliable technique to secure data collection at pre-defined points of interest. To tackle this problem, the participants received a map with the important areas and points of interest (see Annex IV) before the workshop to ensure broad orientation in the study area and give some inspiration for interesting spots to walk through. During the lab, the researchers made clear that this map only serves as an inspiration, and that all participants are free to use it – or any other tool to orientate themselves – or not.

Finally, to make sure that the people are exploring as much of the Wrangelkiez as possible, and not only walk from the starting to the endpoint in a straight direction, the whole research area was shown again at the beginning of the lab and, also, people were encouraged to walk for a longer period than in the first lab.

Data Processing

For further analysis and visualisation of the different data sets collected it was necessary to process the data in a way to make it comparable and usable. Already when retrieving the data from the sensors, it became evident, that not all measurements worked out properly. For participant three and four, the GPS tracking failed, so that the EDA data could not be linked to a specific location and is thus not comparable. For participant five, the sensor did not record the EDA signals for uncertain reasons. Eventually, six complete data sets (P1, P2, P6, P7, P8, P9) could be obtained from the USLs and used for the analysis, while from P3-P6 only the answers to the walkability assessment and the mental map were considered in the results. To display the collected data from EDA measurements, the eDiary app and the GPS tracking in QGIS, the common parameter "time" was defined, and data accordingly prepared.

First of all, the EDA data from the sensors had to be processed. Therefore, the Movisens software DataAnalyzer was used to retrieve the wanted measurements from the raw data (see visualisation in Annex IX). After consulting Peter Zeile, it was decided to specifically look at the SCR amplitudes [in µS] to identify at which points the arousal increased. With the DataAnalyzer, the output rate of 32Hz could also be sampled down to 1Hz, to match the GPS output rate. Eventually, the values of EdaScrAmplitudesMean.csv are used for further analysis and visualisation, which are calculated as means in an interval of 1s.

In an Excel sheet, the datasets were combined per participant (see Annex X). However, since the time frequencies of the output data were not the same, adjustments had to be made to merge the datasets. Since all GPS data was recorded with a two-hour delay, it had to be adjusted using an Excel formula. Furthermore, the EDA data was calculated in intervals of one second and the survey data was recorded whenever participants felt the need to report on their surroundings. Thus, using the "VLOOKUP" formula, timestamps present in all three data sets were searched for and merged into a new data series. This allowed contemporaneous statements obtained from GPS (longitude and latitude), EDA (SCR amplitude), and the eDiary (answer to "how do you feel here?") to be identified and processed into a new table. Even though the GPS and the EDA data both have an output rate of 1Hz, they sometimes recorded different milliseconds (e.g., GPS location at 12:31:30, 12:32:30 and EDA at 12:31:18, 12:32:18). Since there was in some cases no exact accordance of the times, the "VLOOKUP" formula was used to search for the closest but still smaller value that is looked for. To give a practical example: if GPS data is recorded at 12:31:30 and the related EDA was only measured for 12:31:18 and 12:32:18, the EDA data at 12:31:18 will be associated due to its proximity to the GPS recording. Hence, an inaccuracy of maximum 1s must be considered. Because the distance a human can travel by foot in one second is not big enough to change the circumstances and environment significantly, this inaccuracy was accepted.

To standardize the identification of peaks, the mean, as well as the standard deviation of the SCR amplitudes during the walks, were calculated per participant. All amplitudes, that were higher than the mean plus the standard deviation, were considered as "significant peaks" and used as the objective data set for the subsequent mapping.

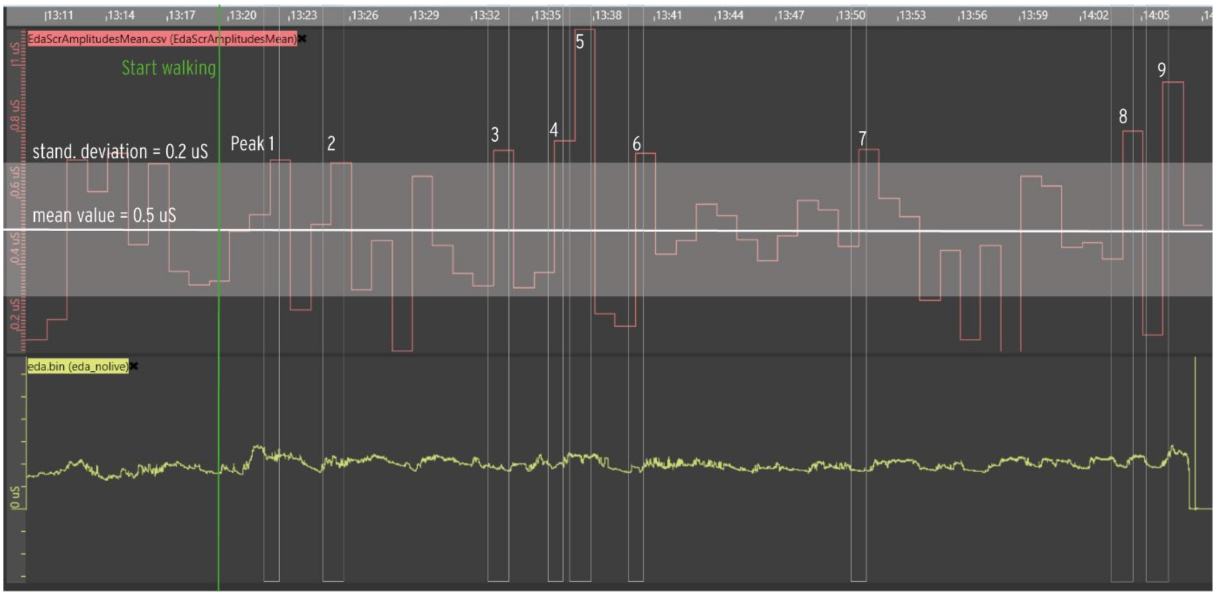

Figure 22: Visualisation of Peak identification in DataAnalyzer

Furthermore, the results of the paper-based walkability surveys were transferred to an Excel spreadsheet and converted into an inverted scale of 4-1, with 4 indicating good and 1 displaying poor performance. Like this, "scores" for pedestrian friendliness could be assigned to each participant, and an overall grade could be calculated. If further walkability assessments are carried out in other areas in the future, these final grades can be compared with each other and provide an initial indication of the suitability of walking. While the researchers before the study rated the walkability with 2.17 and 2.28 based on their knowledge, findings of the Wrangelkiez study and own observations, the participants' grades are in a range of 2.28 to 3.28. Overall, a grade of 2.62 can be given to the area. Most criticised were the low clarity and amount of street crossings as well as the conditions of playgrounds and parks. Also littering and damages were seen as negative, as well as a lack of shelter possibilities. This aligns with the findings in the Wrangelkiez study, in which also a deficit in the maintenance of green spaces and playgrounds, as well as littering and spraying was identified. On the other hand, all participants agreed, that the area is aesthetically rather pleasant, no odour nuisance was recognized, they felt safe and had enough space for walking (see Annex XI). This is a contradiction to the Wrangelkiez study, which criticises the lack of space for pedestrians in Wrangelstraße and Falckensteinstraße.

19) INTERIM CONCLUSION 2.0

The USL, which was developed in this project and is described in the previous chapters works as an example of how to combine methods to collect subjective as well as objective emotional data. Wilhelm and Grossman (2010) state that "naturalistic studies employing ambulatory monitoring techniques can address essential and often ignored issues in emotion research". Since the methodology is based on previous research projects on emotional mapping and EDA sensing, recommendations from practices were considered and adopted. By this, and with the help of various data, it was possible to provide a more holistic analysis of the local walkability conditions in Wrangelkiez'.

One challenge was to take subjective perceptions and feelings into consideration, while also making emotions objectively measurable and comparable. To do so, different qualitative and quantitative methods were chosen to gather different kinds of emotional data. Paper-based surveys including a mental map were handed out in the beginning and in the end, to learn more about the participants' backgrounds, attitudes towards walking and perceptions of walkability and reflect on the own routes and individual experiences as a pedestrian. Physiological measurements of emotions in the form of EDA were carried out with mobile and easy-to-use biosensors, i.e., EdaMove4 Sensors. Through these modern, mobile, and easy-to-use devices, people were transformed into "sensors" themselves and contributed to the participatory recording and reporting of the local walkability. Hence, emotional responses to external stimuli could be recorded and further analysed in a data programme. Additionally, all the participants were equipped with an Android smartphone for both tracking GPS signals and recording subjective perceptions during the walk with the help of an eDiary app. With this additional use of eDiaries, it was the aim to overcome biases and measurement errors that occurred with traditional methods using retrospective questionnaires. Thus, it was possible to put certain experiences that the participants had during the ambulatory assessment into a temporal and local context and to compare them with the EDA data to obtain cross-validation of the data sets. A geofence trigger and an additional time trigger were set as the sampling method for the first USL (see more on this choice in chapter 18: Adjustments for USL 2.0).

Challenges related to misinterpretation of data due to "normal" physical activity, consumption of alcohol, drugs, or caffeine, as well as social interaction, all of which can automatically lead to physiological variations (Wilhelm & Grossman, 2010), were addressed by attaching the sensors to the subjects' arm wrists early on, giving the participants time to familiarise themselves, hence taking measurements during social interaction. In addition, the consumption of the above-mentioned items was queried beforehand and recorded in a questionnaire. Nevertheless, these variations and possible influences on the emotional experience need to be critically considered and their effect remains uncertain. After the real-life recording of the emotional data, the data was processed and adjusted to each other for further analysis. For the analysis method, mainly the "detection of abrupt changes" methodology proposed by Wilhelm and Grossman (Wilhelm & Grossman, 2010) was used. Based on the parameter "SCRamplitudesMean", specific points in time when sudden changes occurred in the measurements could be identified in the DataVisualizer program and compared with temporal and local events.

To summarising, it can be said that measuring emotions with the help of psychophysiological sensors in an ambulatory assessment is still a challenge. Large sample sizes, time-consuming field tests, the consideration of many parameters, and other steps are necessary to be able to make valid statements for urban planning (Dörrzapf et al., 2016). Nevertheless, naturalistic studies with ambulatory psychophysiological assessments have the potential to address some essential issues and data gaps in emotion research and go beyond traditional laboratory settings. Still, they incorporate some limits of data generation such as technical difficulties or sophisticated analysis software. Even though it is mentioned that urban sensing methods cannot yet be seen as an immediate solution for inclusive and objectively based planning issues, they offer a "new anthropocentric approach to analyse and survey interactions between the dynamics in time, space, and humans' perceptions and emotions" (Resch et al., 2015, p. 521) and a fresh perspective on the psychological and biological bases of emotions (Wilhelm & Grossman, 2010).

STEP 6: THE EMOTIONAL MAPS

In the following, the results from the USLs in form of different maps will be presented. The chapter will therefore help to answer SQ3.

Which conclusions about an urban environment can be drawn from mapping pedestrians' emotions in a GIS?

After processing the data, obtained through the Walkability Assessments and the USLs, the results are displayed through:

(1) two different kinds of maps per participant (see all maps in Annex XII)
   a. one with extraordinary EDA peaks
   b. one with the subjective perception of the surrounding according to the eDiary entries + EDA peaks

(2) one overall map displaying EDA peaks from all participants and additional comments from the mental maps

Creation of the maps

With mapping the results from the objective and subjective measurements of emotions it was aimed to conclude correlations and patterns between emotions and the walkability of the environment. For this, it was decided upon a particular style for the map visualization, which allows a good overview of the research area and the displayed topics. This style was adapted to all maps to ensure a common style and make the maps comparable. By adding a base map as well as the processing of the raw data, a clear and appealing presentation could be achieved. The colour of the stress points was chosen to be red due to their role as "stress triggers/stress points". The walking route was equipped with arrows to indicate the direction and the study area was illustrated with the help of a red marker line. In addition, the title of the map refers to the location, date, participant number (P1-9), and data presented. Finally, an additional legend, as well as a north arrow and a scale, round out the cartographic representation. Also, there was no distinction made between the intensity of the peaks due to the complexity of interpretation. Hence, all peaks "above average" were treated and visualized in the same manner which goes the same for different peaks of different people. To put it more clearly, the aim was neither to make a difference between the individual selected peaks of a single participant, nor between the peaks of the different participants among themselves. Each statistically calculated peak was thus mapped in the same way. A critical reflection on this method can be found in step 6: The Emotional Maps.

Figure 23 shows an example of how the representation of the "objective stress points" of the USL participants can look like. For the geographic mapping of the stress points, i.e., the measured sensor data, the two data sets GPS and EDA were combined as described previously. Thus, due to the common parameter "timestamp", EDA data, which do not have georeferencing by themselves, could be linked to a specific location in the research area. Since the GPS data have a clear spatial reference due to the specifications of the longitude and latitude during the recording while walking, it was possible to load and visualize the merged data sets into QGIS.

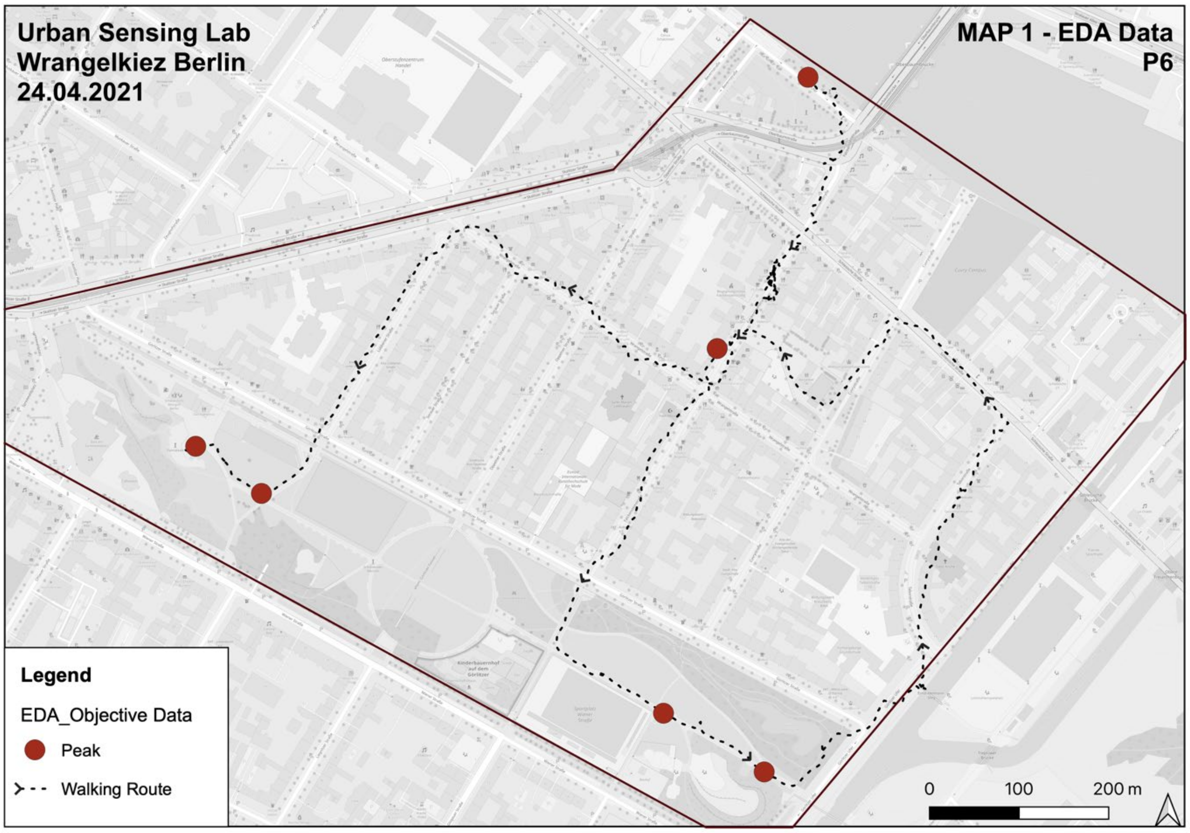

Figure 23: Map 1, participant 6: Objective Emotional Data (own illustration)

In a second map (see figure 24), subjective data from the eDiary were visualised. As explained before, it was chosen to map the general feeling at a certain location, resulting from the question "how do you feel here?". While the answers were given based on a scale from 0 ("I felt comfortable") to 100 ("I felt uncomfortable"), there were three states of the mood defined: feeling "good" (0-33), feeling "mixed" (33-66), and feeling "bad" (66-100). Thus, for this second map, the results of the eDiary surveys were added to the EDA data presented in map 1. Labelling the three mood states in the attribute table (good = 1, mixed = 2, bad = 3) helped to distinguish and adjust the representation of the respective attributes accordingly. An SVG vector representation was created to quickly and graphically illustrate where participants made which statements about how they felt. By overlaying the two sets of data (objective EDA data and subjective eDiary data), it is now possible to see both at which locations multiple data sets were measured and whether subjective and objective data match or differ. These spots are of particular interest since they provide the opportunity to further understand the circumstances under which emotional stress can appear.

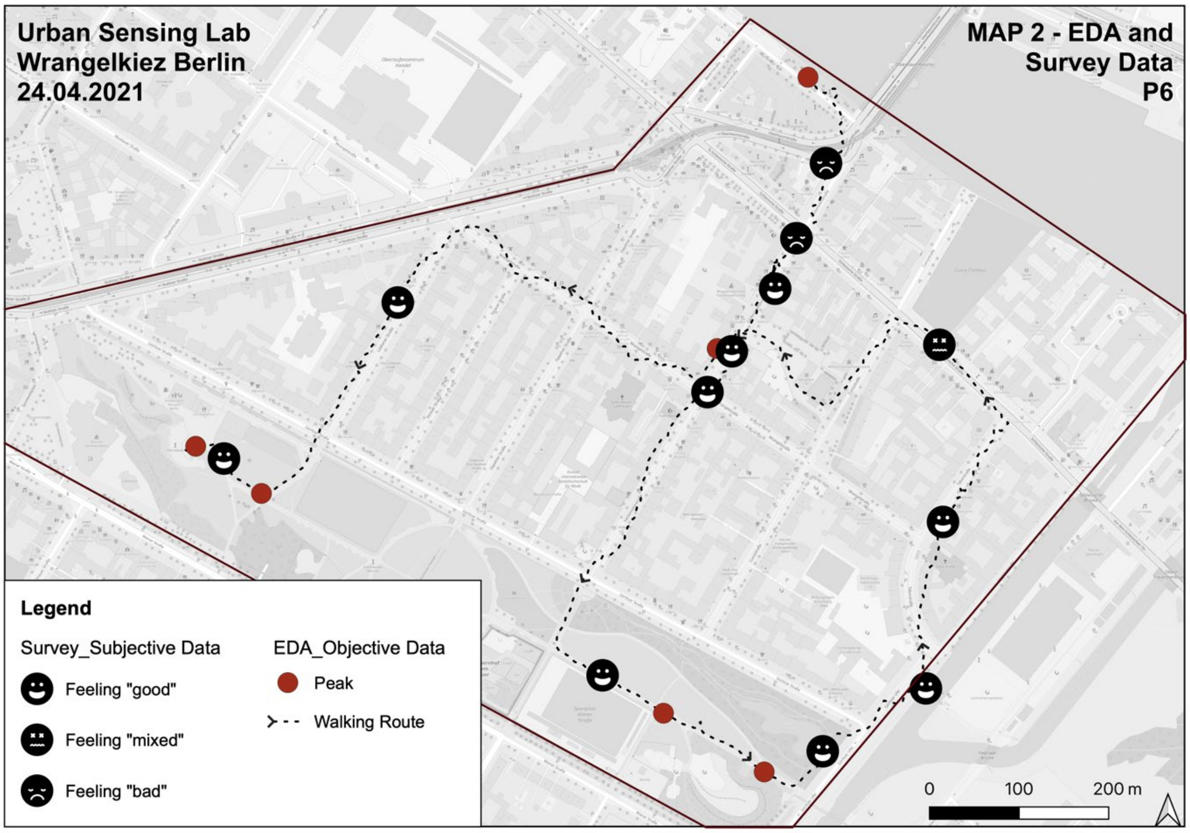

Figure 24: Map 2, participant 6: Subjective Emotional Data (own illustration)

Finally, the peaks of all participants were overlayed and combined in one map (see figure 25 and 26) to display the so-called "Cluster of Peaks". These clusters show locations where measurements of above-average stress responses from multiple participants matched, identifying overlapping stress points. Here, additional subjective data from both the eDiary app (through voice recordings or notes) and the paper-based questionnaire (through entries in a mental map or notes at the end) were included in the visualization (see Annex XII). This should help to cross-validate the collected measurement data once again and to compare statements of the different participants to check them for similarities and divergences and thus to be able to make assumptions about the environment and possible causes for the stress reactions.

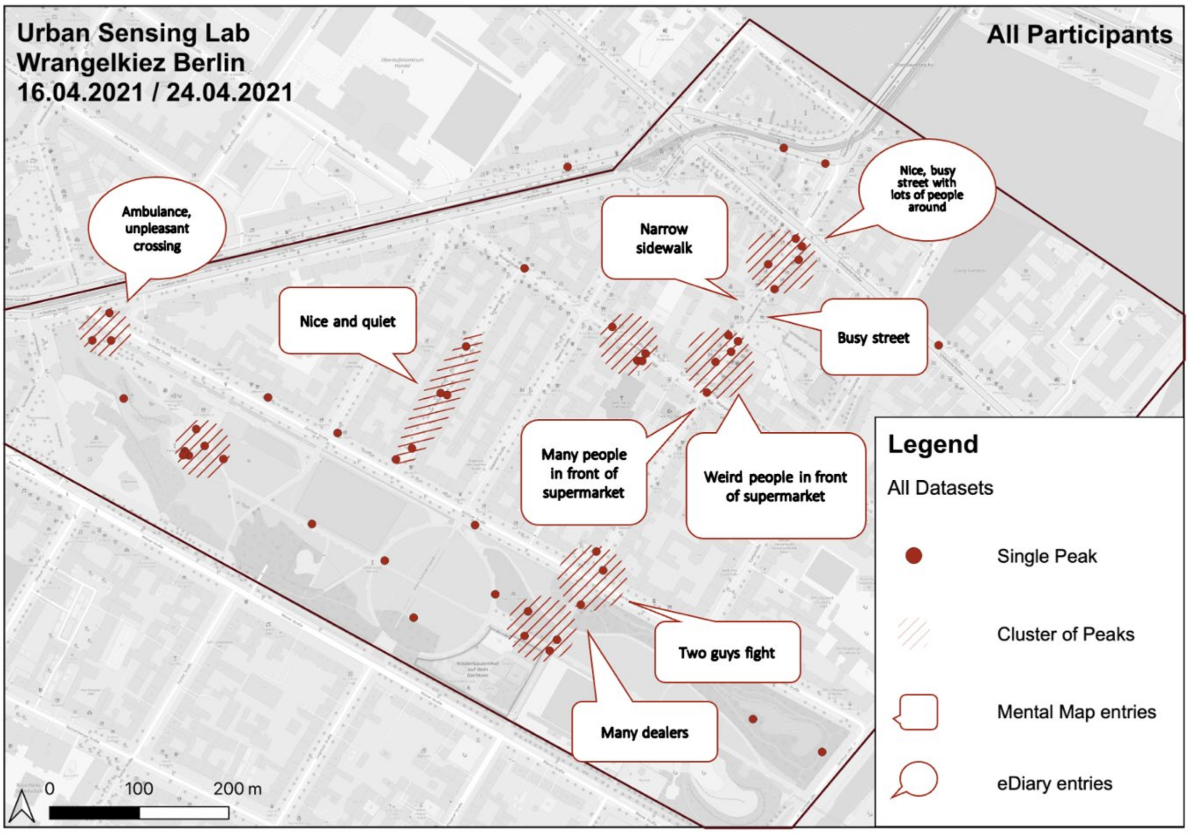

Figure 25: Map 3, all participants: Clusters of peaks + subjective perceptions (own illustration)

Interpretation of the maps

Looking at the land use plan, it is possible to identify in which kind of urban areas exciting moments appear. Additionally, the maps could be compared with information already collected as part of the Wrangelkiez study. This helped to cross-validate the data once again and to examine the hotspots found more closely for their significance. Resulting of the EDA measurements it can be seen on the maps that stressful moments appear when crossing the Görlitzer Straße at the entrances of the Görlitzer Park. This finding matches with data from the Wrangelkiez study, in which the absence of appropriate street crossing possibilities was also criticised and marked as spots with accidents (see picture below, figure 26).

Figure 26: Left: map of EDA peaks P9, middle: visualised EDA signal and ScrAmplitudes mean with marked identified peaks right: picture of surrounding at peak nr. six, street crossing to Görlitzer Park at Oppelner Straße

Furthermore, the Wrangelstraße and Falckensteinstraße were identified as streets, with a high conflict potential between different traffic participants and too little space on the sidewalks, also matching the findings from the Wrangelkiez study in which participants reported on several conflict areas throughout the neighbourhood. At the intersection Falckensteinstraße/Schlesische Straße, which is an identified accident hotspot, an additional cluster of stress reactions could be detected, and matched with overall negative perceptions based on eDiary and mental map data.

However, there are areas identified where the occurrence of arousal clusters is unclear and cannot be explained with the additional comments given. For instance, in the Sorauer Straße where the street was reported as “nice and quiet” (P9) or “quite empty” (P6), a cluster of peaks was identified. Hence, it became obvious from EDA measurements that participants were aroused, however, it remains uncertain if positively or negatively due to a lack of additional data, e.g., the skin temperature. After all, the area is considerably interesting since there is already a discussion if the installed parklets and planned obstacles on the street calm down the area or instead do not reach the intended goal (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2020c).

Also, from the results of the USLs, it seems like more stress points are detected in the Görlitzer Park than in the residential areas. Explanations can be found in the reported events happening at the park (drug dealers, people loudly screaming at each other) and especially the path complementing the Falckensteinstraße is busy with bikers and pedestrians quickly passing through the park on the shortest way (see photograph 15). It also needs to be considered, that more participants have visited the park than the residential areas during the walks. Other research suggests a tendency of people to be more relaxed in (urban) green areas (Mennis et al., 2018; Roe et al., 2013), hence, the extent to which the park can be regarded as a rest and recreation zone for the city's residents remains open at this point.

Summarising, it can be said that the maps revealed spots and clusters, at which data is overlapping and where stressful moments appear to pedestrians, but additional data such as skin temperatures, pictures of the environment, personal comments and descriptions are needed for interpreting the local findings. In general, mapping emotional data offers a suitable possibility to visualise not only "hard information" (i.e., facts) in the cartographic representation of urban spaces, but also "soft information" (i.e., emotions, feelings, impressions or moods) and to represent them graphically (Höffken et al., 2008). Hence, through this new type of psychogeography, an individual's objective biodata can be linked to georeferenced locations and contribute to improved information collection and representation. The specificity of real-time measurement of individuals in urban space also offers the possibility to draw conclusions about individual experiences and potential stress situations in urban space. The bottom-up approach of mapping emotions in urban space offers valuable input for a new form of participatory urbanism (Höffken et al., 2008; Nold, 2018; Zeile et al., 2009). Bergner (2010) further reports on the potential of Emotional City Mapping to foster identity building and engage with one's living environment through these participatory study designs. However, since the participants of the workshops in Berlin were not selected because of their (personal or physical) proximity to the study area and therefore often reported some distance or unfamiliarity with the area, connecting them to the Kiez was not the primary goal.

STEP 7: THE OUTCOME

Throughout this research, knowledge was gained about the connection of emotions and urban planning, methods of measuring emotions in an Urban Sensing Lab, and visualising the results through emotional maps to draw conclusions about the urban environment and especially its walkability. Hence, with the help of the three sub-questions it was possible to answer the main research question (RQ) throughout this thesis:

How can emotional data be measured, combined, and applied in urban research to investigate the walkability of an urban area using EDA sensors, questionnaires, eDiary, and emotional city mapping?

Conclusion

Through a methodological collage using different methods, it was possible to conduct an investigation from different angles and with information from different sources, which were finally put together to explain the overall research problem. First, it was investigated which role emotions play in urban planning processes. Through a literature review, it was found that urban planning can benefit from an emotional perspective when methods are combined in an integrated approach to link different types of data (both subjective self-assessments and objective physiological measurement data). Especially for the planning of sustainable, inclusive, and walkable cities of the future, a human perspective is indispensable. Hence, it can help to close the gap in walkability research by collecting important data on the subjective perception of pedestrians and incorporating it into future decision-making processes. This will help to design desired and appropriate places for pedestrians and support overarching efforts to promote sustainable urban mobility.

With the establishment of an Urban Sensing Lab, a possibility was shown how such methods for collecting emotional data can be put together and successfully combined. It was crucial to add a new component of sensing technologies to the existing standard methods for collecting subjective data (surveys, walk-throughs, interviews, diaries), thereby adding an objective perspective on emotions. A central point was thereby to find a way to connect the methods and allow for measurements of subjective and objective emotional data at the same time and location. Therefore, different combinations of methods were considered for this project, resulting in some overlapping EDA and eDiary data, but also leaving some locations where subjective data complementary to measured EDA peaks is not available.

Walkability Assessments were designed to help establish a link between walking behaviour and emotions. Since walkability can be defined as a quantitative and qualitative measure of how inviting or uninviting an area is for pedestrians, indices were calculated that overall resulted in good ratings of the area's walkability. However, the small number of participants as well as the short duration of the study has only little significance on the overall picture in the neighbourhood and would have to be improved by analyses accompanied by researchers. Also, the measured emotional data are recorded punctually and show specific moments of arousal, but the assessments are describing the area as a whole, complicating the connection between the two datasets. Instead, it was found to be more helpful to have a direct, informal conversation with the participants after their walks to get an idea of their current feeling and mood about walking in the area.

The MovisensXS app was found a helpful tool to use for the eDiaries. The setup and creation of questions are intuitive and provide a lot of possibilities for individual preferences. Especially the possibility to include free input, not only in the form of text but also as voice recording, was a useful feature to gain helpful data. Theoretically, also the advantage of installing geofences to set trigger at specific locations or setting trigger according to the measured EDA level are perfect, to ensure collecting data at points of interest. In practice, the technology needs further development, to make these features work properly. They are crucial to overcome the challenge of gathering subjective and objective data for the same location and improve the quality of the outcome from the USL. Defining alarm triggers was effective to remind the participants to fill out an eDiary entry while taking the burden from them to remember constantly. However, it is crucial to find the right number of notifications to collect enough data on the one hand, but also not to stress and stop the participant too much.

During the data processing, a mean value and standard deviation were used to find extraordinary peaks instead of calculating individual thresholds per participant, for which more tests would be needed. It must be clear that the peaks identified by this method indicate exceptional moments of stress, while lower levels of arousal are neglected, as causes and triggers for these less "extreme" stress points can often be less obvious and numerous.

Further, the presentation of collected emotion data in a map with an additional "emotional layer" was already successfully implemented in several other examples and has shown the significance of the results. In the own survey and presentation in QGIS, the advantages and difficulties of the methodology used could be recognised quickly. Particularly the combination of the different, incoherent data was a challenge. Since the EDA sensors do not record a GPS signal, the common parameter to compare the measurements was the time. Also, due to the different frequencies of the collected datasets, a sampling process was necessary to make the data comparable. For the visualisation, the open-source programme QGIS was suitable and provided many opportunities for individual adjustments. By presenting so-called stress hotspots/clusters, i.e., places where data from different participants overlap, a valid statement on local conditions can be made and used in future urban planning processes. Nevertheless, it is important to reflect on one's own biases when creating a map. Deciding upon which data is displayed and highlighted influences how the result interpreted by the readers of the maps and constructs a certain perspective on reality. In the mapping of the identified EDA peaks, e.g., it was decided to map the quantity but not the quality of stress points. Thus, there is no differentiation between more and less stressful environments or positive and negative stress nor between different participants' EDA data.

To conclude, EDA sensors are a promising approach to measure the objective aspects of emotions and make them tangible for research. However, to better understand human emotions, it is not enough to only integrate these objective components, but subjective perceptions must be captured as well. A mixed-methods approach of EDA sensors, GPS tracking, eDiaries and mapping was deemed suitable for this purpose. Statements about individual feelings in a certain area can thus be collected and compared with each other. Since built environments that promote and facilitate walking are perceived as better places to live due to their promotion of healthier lifestyles and increased social cohesion, the approach of emotional sensors can help to detect stressful environments which require further development. In addition, the complexity of the walkability topic due to the difficulties in collecting sufficient data on people's perceptions can be overcome by adopting a sensing approach with suitable technologies. However, precise identification of causes for arousal cannot be determined yet. Hence, few limitations of the methodology could be detected and will be presented in the following.

Limitations

First of all, the participants selected for the study were, for practical reasons (see chapter: Preface), exclusively friends and colleagues of the researchers. Therefore, they had some personal connection to the study, came from similar social environments and were biased accordingly. Thus, the group of participants is not diverse enough to represent the whole society.

Second, due to the limited time, only two USLs could be carried out as pilot studies. For future assessments to make valid statements about the emotional characteristics of an urban neighbourhood, a larger and diverse sample is necessary, which is however difficult to implement due to the effort involved in measuring and mapping so far (see similar limitations in, e.g., Dörrzapf, Zeile, et al., 2019).

Concerning the utilised methods and technology, it was found that the EdaMove4 Sensors are not suitable for measuring body temperature, thus, an objective distinction between positive and negative moments of stress could not be made. An additional statement about the rise/decline of the temperature would be of immense advantage for urban planning since it can give further information on the quality of stress points. Setting up location-based alarms for the eDiaries has proven to be challenging and difficult to implement, as the technique is still in the development stages. In addition, participants reported a constant awareness of the lab-like situation, especially by wearing a sensor, even though the gadgets were comparatively small, and attempts were made to keep the walks as natural as possible (e.g., by not giving a predefined route to follow). Also, the local context of the lab environment in Berlin needs to be reflected and has influences on the outcomes of the measurements, hence an equal study in a different area would lead to different results and conclusions based on the data's highly context-depended character.

All obtained data (eDiary entries, mental maps, EDA peaks) are abstract from the situation and can only describe some parts of the lab environment. Thus, the whole situation at which emotion was measured, cannot fully be understood. Especially because of the unknown and varying latency of an EDA peak, identifying the exact spot of the stress trigger is not precise. The maps produced during this project, though, can only provide a small glimpse of possible representation and application options, as the limited sample size and diversity allow limited conclusions to be drawn about the population.

Nevertheless, further development and investigation of the sensor approach seems promising for the future of inclusive and participatory urban planning processes due to its objectivity and high acceptance among the participants. Particularly, in times of increasing digital literacy and the collection and use of sensor data in cities, it is crucial to not neglect the gathering of people-centred data too, giving adequate input on behaviour and life in public spaces.

Reflection

Despite the above-mentioned limitations of the sensing approach in general but also the own implementations during the USLs in Berlin, a method was explored that can provide a different and useful perspective on urban research and planning and support an optimised understanding of feelings towards walkable spaces. A particular challenge was the aim to collect subjective and objective emotional data at the same time and location. The goals of capturing holistic datasets of an urban environment and closing the gap in data collection in future assessment processes can thus be achieved with further research into the methodology as well as optimisations of the technique. Particularly the use of mental maps with additional comments and reflections on the walks was perceived as a useful step in the process towards a better understanding of the local urban conditions.

In terms of lab participants, it was recognised that those with a background and understanding of urban planning recognised and reported more moments of interest, which in turn led to valuable results, while other participants without an urban planning background took the straightest route from the starting point to the endpoint and reported at the end that nothing caught their eye. Therefore, the researchers would recommend either inviting participants to the USL who are sensitive to the urban environment or giving an introduction on what aspects to look out for during the lab to gain more valuable data.

Concerning the general constitution of the labs, choosing a different start and endpoint worked as a compromise, between predefining a route and not giving any guidance at all. Additionally, choosing a small test area assures that the participants pass the same locations.

Although the method needs further development, eventually the results, visualised in maps, can be compared with other studies. Hence, "[e]motional mapping enables the display of subjective, qualitative and bottom-up spatial information about the environment in highly hierarchical, quantitative and top-down GIS settings" (Pánek & Benediktsson, 2017, p. 66). The procedure can contribute to a clearer understanding of local conditions and provide insight into feelings about, e.g., walking. This in turn can help to add an emotional and participatory component to future strategies of the city of Berlin, but also other places, towards an accessible and inclusive urban environment.

STEP 8: THE FUTURE OF URBAN SENSING (METHODS)

A growing number of contemporary development processes are steering towards more sustainable urban and transport planning, with greener and more inclusive urban mobility for all citizens. The city of Berlin is also pushing for pedestrian-friendly environments and driving change towards more walkability with laws and initiatives advocating for car-free zones and "superblocks" / "Kiezblocks". The newly adopted Berlin *Mobility Act*, therefore, includes a separate paragraph on the importance of and possible developments in the field of pedestrian traffic. The definition of walking paths as "protected areas" highlights their importance, especially for vulnerable groups, but also for all other residents of the city. With the aim of the law to ensure the maintenance and optimisation of these paths, the city sets a clear focus on sustainable and inclusive mobility of the future. With an understanding of how people feel when walking, what makes them feel delighted, relaxed, anxious or uncomfortable in a pedestrian environment, this shift can be further advanced.

Measuring emotions reveals the importance of stressful urban places to citizens' wellbeing and highlights "zones of stress". So far, many ideas and proposals to close streets, slow down or reduce traffic or install parklets in places of stress have already been proposed by initiatives such as "*Wrangelkiez Autofrei"* and been discussed with residents and local actors (see Wrangelkiez study). However, these are based on subjective perceptions of local actors (collected through interviews or questionnaires) as well as quantitative data collection such as traffic monitoring and counts. Transformation agendas such as the Berlin *Mobility Act* support a human-centred perspective and build on the 'needs of citizens'. Intending to create equal mobility opportunities for all residents of Berlin, participation in social life is to be guaranteed for all. By measuring emotions, psychophysiological data can be included in the surveys and support the subjective perceptions and opinions as well as statistical measurements with objective "human data", giving a glimpse on "true" feelings and wishes of Berlin residents. In addition, concepts such as the "vision zero" approach can benefit from measuring human emotions by identifying and remedying potential danger and accident points early on when walking, cycling, or driving through the city.

The necessary technology is available but requires extensive preparation and introduction for project workers on site. In addition, the existing technology that makes it possible to collect such emotional data is a financial aspect that can be remedied in the future through broad availability and optimisation. It is expected that the development of sensing methods and technology will improve the quality and possibilities of measurements further so that e.g., more precise location-based data can be collected and extended psychophysiological parameters can complement the analysis and interpretation of emotions. In any case, further experiments in this interdisciplinary field between geography, urban planning and design, GIScience, computational linguistics, sociology, computer science, neuroscience, and psychology promise an exciting perspective on the city, by using modern technologies as well as human data for a more inclusive and sustainable urban future.

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ANNEX

I. Studies on human emotions
II. Land use plan
III. KIT walkabilty checklist
IV. Points of interest
V. App comparison
VI. Geofences
VII. Sampling schemes
VIII. Paper-based questionnaires
IX. Visualisation of EDA Signals
X. Combined data per participant
XI. Evualations of Walkability Assessment
XII. Maps per participant
XIII. Mental maps

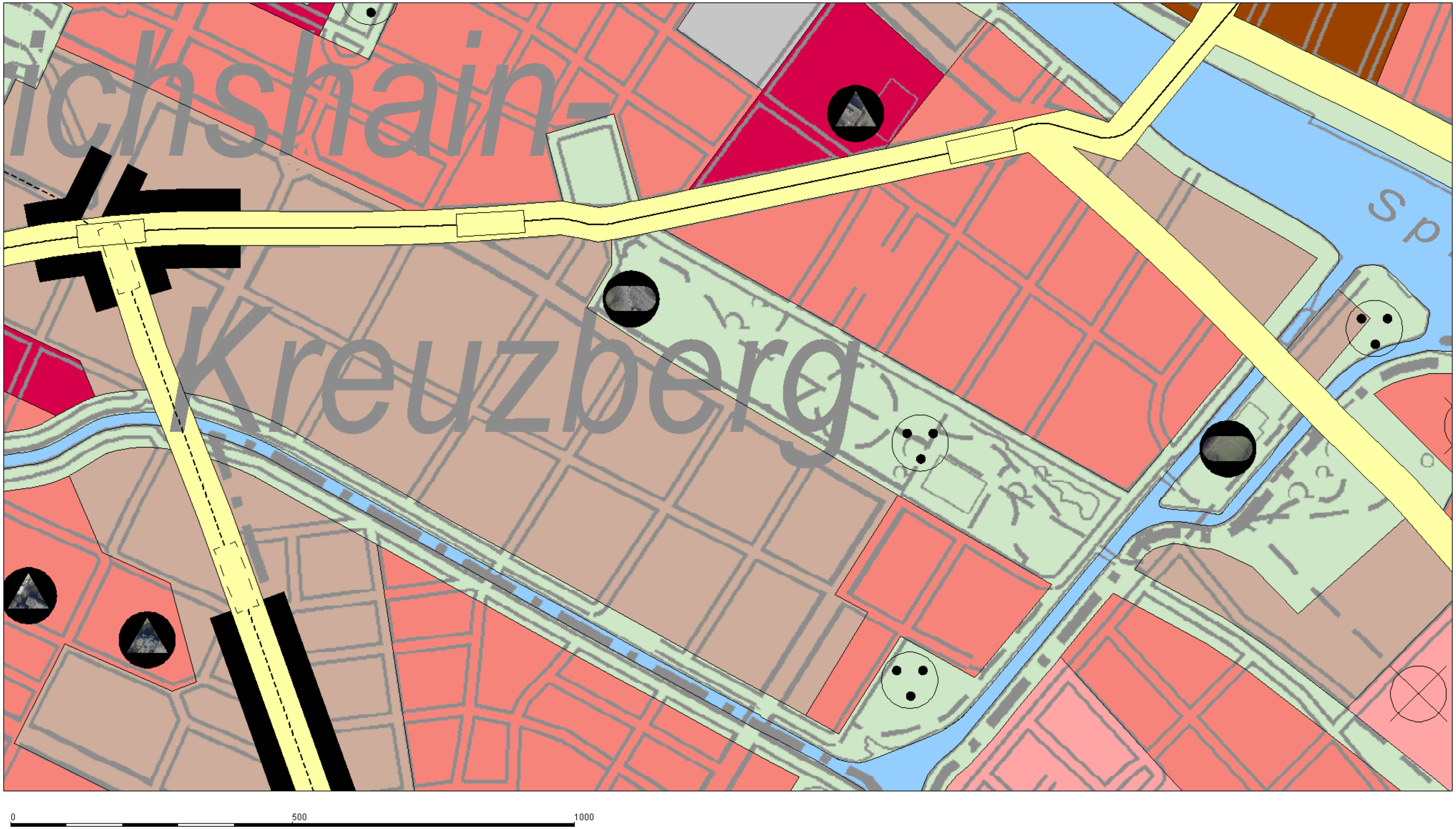
ANNEX I – STUDIES ON HUMAN EMOTIONS

Year	AUTHOR(S)	STUDY TITLE	METHODOLOGY	SOFTWARE / HARDWARE	PARTICIPANTS
2004	Nold	Bio-Mapping: How can we use emotion to articulate cities?	Biosensing + GPS + GoPro Camera + "People as Sensors" App	"People as Sensors" App	
2011	Zeile et al.	Mapping people? - The measurement of physiological data in city areas and the potential benefit for urban planning	Smartband (skin conductance level measures) + GPS		
2012	Exner et al.	Humansensorik in der räumlichen Planung	Mix of methods from deductively and inductively collected spatial data; SMART bands: collect stress signals with their measurement parameters skin conductivity (electrodermal) and skin temperature (cardiovascular) + geo position by GPS logger & tagging + camera + questionnaires	SMART-Band + GPS Visualizer	22 Studierende der Raum- und Umweltplanung an der TU Kaiserslautern auf eine ihnen unbekannte Route durch den Pfälzer Wald geschickt → möglichst unbeeinflusste Erfahrungen mit dem Untersuchungsgebiet gewinnen
2014	Höffken et al.	EmoCycling - Analysen von Radwegen mittels Humansensorik und Wearable Computing	Smartband + Video Recording + GPS		6 participants
2015	Aspinall et al.	The urban brain: Analysing outdoor physical activity with mobile EEG	individually walked 25 minutes through three different urban areas (urban shopping street, ptath through green space, street in busy commercial district) on different days in Edinburgh with Emotiv EPOC (low-cost mobile EEG recorder); same route for everybody; EEG measurement (brain activtiy) + GPS	Emotiv EPOC (EEG recorder)	12 students from University of Edinburgh (mean age 30.5, 8 male, four female)
2015	Kim and Fesenmaier	Measuring Emotions in Real Time: Implications for Tourism Experience Design	EDA x diary with photos and describtion x follow up Interviews 4-day trip; 15 min warm-up period (sitting relaxed),	Affectiva Q-sensor - EDA MATLAB - eliminating measurement errors through pressure, motion and electrical noise SPSS 19.0 - calculation of mean and standard deviation of EDA	2 female students 23y
2015	Groß, Holderle and Wilhelm	EmoCycling – Analyse von Radwegen mittels Humansensorik für Kommunen	Smartband + Video Recording + GPS		
2015	Daniel, Leszczynski and Reinhart	bike emotions	SCL + Brain activity + Eye tracking + GPS		
2016	Dörrzapf et al.	Fühl die stadt - Methoden zur Erfassung subjektiver Wahrnehmung	a) Eyetracker, GPS, EEG (heatmap), EDA, subjective mapping of hotspots b) visual mapping, photography, EEG (heatmap), EDA,	MindCap XL (NeuroSky) - EEG eSense Skin Response (Mindfield) - EDA Tobii Glasses - Eyetracking Endomondo App - GPS tracking QGIS - visualising heat map	a) 8 cyclists b) 5-40 people (5 EEG and EDA, 10 Photography, 40 visual mapping)
2017	Osborne and Jones	Biosensing and geography: A mixed methods approach	walk around their neighbourhood for around 45 min with Empatica E4 + GPS + GoPro; afterwards, participants watched video footage while undertaking qualitative interview about their emotional responses		participants who worked or lived in the area of study were asked to take a unaccompanied walk
2019	Dörrzapf et al.	Defining and assessing walkability: a concept for an integrated approach using surveys, biosensors and geospatial analysis	comprehensive methodology that combines existing qualitative and GIS-based methods with biosensor technologies and thus captures the perceptions and emotions of pedestrians.		
2019	Pykett et al.	Detecting moments of stress from measurements of wearable physiological sensors	GSR + ST + geo-located questionnaires + video with algorithm	Empatica E4 + eDiary + GoPro	19 participants for laboratory; 12 participants for real-world cycling study; 56 participants for real-world walkability study; 31 participants for real-world wellbeing study
2019	Mavros	Measuring the emotional experience of pedestrian navigation: the development of a research approach for mobile psychophysiological experiments			
2019	Birenboim et al.	Wearables and Location Tracking Technologies for Mental-State Sensing in Outdoor Environments	heart rate, heart rate variability, and skin conductance + GPS	Empatica E4 wristband + Microsoft Band 2 (MS Band)	15 participants in controlled outdoor walk in diverse urban setting
2019	Dörrzapf et al.	Walk & Feel - a New Integrated Walkability Research Approach	a) bio-sensors collecting physiological parameters and stress-indicators; b) integrated walkability index (IWI) through GIS; c) eDiary app; d) traditional paper-based questionnaire		60 participants in Vienna and Salzburg

Year	AUTHOR(S)	RESEARCH QUESTION	MAIN OUTCOMES	STUDY DESIGN / APPROACH	SPECIALTIES
2004	Nold		detectors made people feel awkward and more aware of themselves, environment and technology; mundane aspects can transform into new significance; surprise, how physical responses and personal memories are related to urban environment; foster discussions about broader political/societal issues with a low key incipit and example of the well-known neighbourhood; by visualising GSR and GPS together, people can reflect on their body-data in relation to their environment	Bruno Latour: "How to talk about the body?" --> overcoming modern dualism, which creates artifical hierarchy between "science & people"	new kind of urban body articulation that becomes participatory urbanism; emotion layer in maps identifies urban problem spots and enables feedback loop to let authorities experiment with interventions
2011	Zeile et al.		Geolocalising and visualising emotional reactions; develop new methods for urban planning practices		
2012	Exner et al.		Two maps with a) skin conductivity curve (physical stress and arousal level) and b) density map (overlay of equal stress signals of individuals in heat maps); supplementary to this, a qualitative analysis is also possible so that the respective stress-triggering elements can also be described precisely	real-world assessment	Various monitoring systems for the collection and analysis of room sensor data: Deductive monitoring & Inductive monitoring
2014	Höffken et al.		Identification + geolocalising hotspots of emotional reactions and their triggers	real-world assessment	exploring triggers of emotional reactions through video records
2015	Aspinall et al.	1. Can the emotional impact of different urban environments be detected by cortical EEG signals while participants are walking through them? 2. Is there any evidence that urban green space can modify EEG signals in a restorative way, that is, reduction of stress, arousal and frus- tration and increase in meditation?	new form of high-dimensional correlated component logistic regression analysis showed evidence of lower frustration, engagement and arousal, and higher meditation when moving into the green space zone; and higher engagement when moving out of it; shared patterns of emotional activity, even though the experiment was performed on different days	real-world assessment	researcher followed the participatns with around 10-30 m distance while walking trips; positive connotation towards emotion with five channels from the sensors: excitement (short-term), frustration, engagement, long-term excitement (or arousal) and meditation
2015	Kim and Fesenmaier	How do travellers react to touristic places? - in order to plan better touristic places	reveal the distinct reactions to touristic attractions but also identify the continous emotions "in between" that create the setting for meaningful events; show, how travellers experience activities; help understand value of places and draw emotion maps for planning; contribution of the research about underlying structure (is it a reaction to triggers or has everyone developed internalised patterns?)	real-world assessment	
2015	Groß, Holderle and Wilhelm		Identification + geolocalising hotspots of emotional reactions and their triggers	real-world assessment	exploring triggers of emotional reactions through video records
2015	Daniel, Leszczynski and Reinhart		successful identification of triggers for stress	developing measurement methods to collect subjective perception and emotions during cycling; focus on traffic safety	
2016	Dörrzapf et al.	Comparision of different methods for: a) bike emotions - Identifying hot spots to improve them (and security); b) identifying sections in a defined space and how people relate and feel in these sections	a) potential perceived dangers can be indicated and identified throug EDA, EEG did not give satisfying results, due to problems with connection and recording b) EEG didnt bring significant results, EDA can be used to indicate changes in bodily reactions to environment, EDA supports subjective perception	real-world assessment	Comparision of Methods; Division of the study area in "Sub areas" to make conclusions about these classified envirionments
2017	Osborne and Jones			real-world assessment	discussion of three approaches: biosensing-led, environment-led, thematic-led; circumplex model of affect (fig.) --> categorizing different states of arousal
2019	Dörrzapf et al.				Definition of walkability
2019	Pykett et al.		algorithm that detects MOS and associates them with time and space	laboratory + real-world assessment	develop algorithm to detect moments of stress (MOS)
2019	Mavros				
2019	Birenboim et al.	adequacy of using current off-the-shelf wearables in combination with location tracking technologies to serve as a marker for mental state in outdoor environments; impact of environmental factors (e.g., green spaces) on our daily well-being		real-world assessment	
2019	Dörrzapf et al.		integrated approach to assess and visualise walakbility; need for further methodological considerations to link diverese data; holistic understanding of walkability needed	real-world assessment	develop integrated approach for assessing walkability

ANNEX II – LAND USE PLAN WRANGELKIEZ

FNP (Flächennutzungsplan Berlin), aktuelle Arbeitskarte



Geoportal Berlin, PDF erstellt am 13.04.2021

Baufläche

- Wohnbaufläche, W1 (GFZ über 1,5)
- Wohnbaufläche, W2 (GFZ bis 1,5)
- Wohnbaufläche, W3 (GFZ bis 0,8)
- Wohnbaufläche, W4 (GFZ bis 0,4)
- Sonderbaufläche Hauptstadtfunktion (H)
- Sonderbaufläche mit gewerblichem Charakter
- Gemischte Baufläche, M1
- Gemischte Baufläche, M2
- Gewerbliche Baufläche
- Einzelhandelskonzentration
- Sonderbaufläche
- Sonderbaufläche mit hohem Grünanteil

Gemeinbedarfsflächen

- Gemeinbedarfsfläche / Gemeinbedarfsfläche mit hohem Grünanteil
- Hochschule und Forschung
- Schule
- Krankenhaus
- Sport
- Kultur
- Verwaltung
- Post
- Sicherheit und Ordnung

Ver- und Entsorgungsanlagen

- Fläche mit gewerblichem Charakter / Fläche mit Mischnutzungscharakter
- Fläche mit hohem Grünanteil / Fläche mit landwirtschaftlicher Nutzung
- Wasser
- Abfall, Abwasser
- Energie
- Betriebshof (Bahn und Bus)

Verkehr

- Autobahn mit Anschlußstelle
- Übergeordnete Hauptverkehrsstraße
- Trassenfreihaltung
- Tunnellage
- Bahnfläche
- U-, S-, R-Bahn; Bahnhof ober-/unterirdisch
- Fernbahnhof (ICE/IC/IR) ober-/unterirdisch
- Kleinbahn

Freiflächen, Wasserflächen

- Grünfläche
- Parkanlage
- Friedhof
- Kleingarten
- Wald
- Wasserfläche
- Feld, Flur und Wiese
- Sport
- Wassersport
- Camping
- Landwirtschaftsfläche

Nutzungsbeschränkungen zum Schutz der Umwelt (Darstellungen(D), nachrichtliche Übernahmen(N) und Kennzeichnungen(K))

- Landschaftliche Prägung von Wohnbauflächen(D)
- Vorranggebiet für Luftreinhaltung(D)
- Planungszone Siedlungsbeschränkung gem. LEP FS(N)
- Geltungsbereich ThF-Gesetz (N)
  Nutzung entspr. Gesetz zum Erhalt des Tempelhofer Feldes (ThF-Gesetz)
- Weltkulturerbe(N)
- Wasserschutzgebiet(N)
- FFH-* /Landschaftsschutz- /Naturschutzgebiet (N)
  * Flora-, Fauna-, Habitat einschl. Vogelschutz
- Schadstoffbelastete Böden(K)

ANNEX III – KIT WALKABILITY CHECKLIST

Karlsruher Institut für Technologie

Checkliste für Fußgängerfreundlichkeit

Wie gehfreundlich ist Ihr Wohnumfeld/Ihre Nachbarschaft?

Wie Sie die Checkliste benutzen

1. Benutzen Sie diese Liste, um Ihren alltäglichen Fußweg zu beurteilen. Wenn Sie keinen bestimmten Weg haben, suchen Sie sich ein Ziel aus, das es zu erreichen gilt, wie z. B. ein Geschäft oder einen Park.
2. Lesen Sie die Liste, bevor Sie beginnen. Füllen Sie diese während des Laufens aus, indem Sie die entsprechenden Felder ankreuzen. Wenn Sie Kommentare hinzufügen möchten, ist es hilfreich, wenn Sie dabei einzelne Straßennamen oder Orte benennen. Fotografieren oder skizzieren Sie gegebenenfalls relevante Stellen.
3. Summieren Sie alle Punkte zusammen, um Ihre gelaufene Strecke bewerten zu können.
4. Wenn Sie problematische Stellen entdeckt haben, bietet Ihnen die Liste am Ende des Bogens (S. 6) sofortige Lösungsvorschläge und zeigt Möglichkeiten auf, was Sie und Ihre Mitbürger langfristig dagegen tun können.

Wie fußgängerfreundlich ist Ihr Weg?

Die Liste ist in vier verschiedene Abschnitte unterteilt:

- A Fußgängerfreundlichkeit
- B Komfort
- C Sicherheit
- D Zweckmäßigkeit und Vernetzung

Zählen Sie nach jedem Abschnitt die mit Ja und Nein beantworteten Fragen zusammen. Falls Sie bei einer Frage unsicher sein sollten oder diese für Sie nicht relevant ist, so lassen Sie dort eine Lücke. Wenn Sie die Liste bearbeitet haben, tragen Sie Teilsummen in die dafür vorgesehenen Kästchen, um Ihren Weg bewerten zu können.

Über Ihren Fußweg

Wenn möglich, führen Sie einen Stadtplan mit sich, um eventuell auftretende Probleme zu markieren.

Stadtteil: ______________________________

Name der Straße am Startpunkt: ______________________________

Name der Straße am Endpunkt: ______________________________

Gelaufene Strecke: ______ km

Tageszeit: ______ Uhr

Grund des Fußweges:
- ☐ Zum Zwecke der Fortbewegung – um einen bestimmten Ort zu erreichen (Schule, Bahnhaltestelle, etc.)
- ☐ Zur Erholung – in der Freizeit, zum Sporttreiben
- ☐ Fortbewegung und Erholung

Ich gehe ohne Spazierstock oder Hilfsmittel: ja ☐ nein ☐

wenn ja, welche: ________________

A	**Fußgängerfreundlichkeit** Eine attraktive Nachbarschaft fördert das Laufen		
		JA	NEIN
1.	Sind die Gehwege frei von Behinderungen, wie z. B. Vegetation, Straßenschildern, parkenden Autos?	☐	☐
2.	Gibt es Bäume entlang des Gehweges, die Schatten spenden, für eine angenehme Atmosphäre und Klima sorgen?	☐	☐
3.	Gibt es irgendwelche schönen Orte und Gebäude, wie z. B. historische Sehenswürdigkeiten, öffentliche Kunst, Parks?	☐	☐
4.	Sind die Straßenfronten attraktiv gestaltet?	☐	☐
5.	Ist das Quartier frei von Abfall und zerbrochenem Glas?	☐	☐
6.	Gibt es in den Parks und in den öffentlichen Räumen genug Abfalleimer und Hundekotbeutel?	☐	☐
7.	Ist die Nachbarschaft frei von Graffiti und Beschädigungen?	☐	☐
8.	Sind Spielplätze und Parks in einem guten Zustand?	☐	☐
	Zwischensumme	/8	/8

Kommentare/Vorschläge:

____

____

____

Orte der aufgefallenen Probleme und/oder positive Besonderheiten:

____

____

____

B	**Komfort** Eine ansprechende und facettenreiche Straßengestaltung unterstützt das Laufen		
		JA	NEIN
1.	Haben Leute nebeneinander auf dem Gehweg Platz, insbesondere Leute mit Kinderwägen oder Rollstühlen?	☐	☐
2.	Gibt es ausreichend Sitzmöglichkeiten entlang der Weges?	☐	☐
3.	Gibt es die Möglichkeit Erfrischungsgetränke zu bekommen?	☐	☐
4.	Hat man entlang des Weges die Möglichkeit Toiletten zu benutzen?	☐	☐
5.	Gibt es Unterstellmöglichkeiten, um sich vor Regen oder vor der Hitze der Sonne zu schützen?	☐	☐
6.	Sind die Gehwege in gutem Zustand und für Kinderwägen, Rollstuhlfahrer oder Radfahranfänger geeignet?	☐	☐
7.	Verlaufen die Gehwege entlang ruhiger Straßen mit wenig Verkehr?	☐	☐
	Zwischensumme	/7	/7

Kommentare/Vorschläge:

____

____

____

Orte der aufgefallenen Probleme und/oder positive Besonderheiten:

____

____

____

C	**Sicherheit** Beleuchtung, Sicherheitsmaßnahmen und gepflegte Wege unterstützen das Gehen		
		JA	NEIN
1.	Fühlen Sie sich sicher auf Ihrem Weg?	☐	☐
2.	Sehen Sie andere Menschen während des Laufens?	☐	☐
3.	Ist die Strecke bei Nacht ausreichend beleuchtet?	☐	☐
4.	Gibt es ausreichend Fußgängerampeln und Zebrastreifen, besonders in der Nähe von Schulen, Altenheimen, Geschäften?	☐	☐
5.	Erlaubt die Zeit der Ampelschaltung älteren Menschen und Kindern die Straßen sicher zu überqueren?	☐	☐
6.	Sind abgesenkte Bordsteine entlang des Weges vorhanden?	☐	☐
7.	Sind Bremsschwellen vorhanden, um den Verkehr zu entschleunigen?	☐	☐
8.	Besteht ein ausreichender Abstand zum Straßenverkehr?	☐	☐
9.	Halten sich die Autofahrer an die Geschwindigkeitsbegrenzungen?	☐	☐
10.	Sind die Straßenübergänge frei von Hindernissen, welche die Sicht auf den Verkehr behindern?	☐	☐
	Zwischensumme	/10	/10

Kommentare/Vorschläge:

____

____

____

Orte der aufgefallenen Probleme und/oder positive Besonderheiten:

____

____

____

D	**Zweckmäßigkeit und Vernetzung** Eine gut vernetzte Nachbarschaft sorgt für kürzere Wege zwischen den Zielen und fördert somit das Gehen		
		JA	NEIN
1.	Gibt es Fußgängerbeschilderung und Pläne entlang der Wege?	☐	☐
2.	Gibt es Anbindungen an den öffentlichen Verkehr? Wenn ja, bitte markieren Sie an welche: Bus/Zug/Straßenbahn/andere	☐	☐
3.	Sind die Gehwege ohne Unterbrechungen miteinander verbunden?	☐	☐
4.	Wenn Ihr Weg in eine Sackgasse führte, gab es eine Verbindung zu einem weiteren Weg?	☐	☐
	Zwischensumme	/4	/4

Kommentare/Vorschläge:

____

____

____

Orte der aufgefallenen Probleme und/oder positive Besonderheiten:

____

____

____

Wie hat Ihre Strecke bei der Bewertung abgeschnitten?

Zählen Sie Ihre mit Ja beantwortete Fragen zusammen:

A	Fußgängerfreundlichkeit	_____
B	Komfort	_____
C	Sicherheit	_____
D	Zweckmäßigkeit und Vernetzung	_____
	Gesamt	___/29

Auswertung	
22-29	Gute Nachrichten! Ihre Route ist extrem fußgängerfreundlich.
15-21	Ihre Route ist fußgängerfreundlich, aber es gibt Platz für Verbesserungen.
8-14	Es braucht etwas Arbeit, um Ihre Route fußgängerfreundlich zu machen.
0-7	Ihre Route ist nicht fußgängerfreundlich.

Die Prüfliste wurde auf Basis der „Neighbourhood Walkability Checklist" der Heart Foundation, Australien, sowie der „Walkability Checklist" der Safe Routes, National Center for Safe Routes to School, Pedestrian and Bicycle Information Center, U.S. Department of Transportation, Environmental Protection Agency, U.S. und der „Prüfliste für Fußgängerfreundlichkeit" des Insitituts für Stadtplanung und Städtebau, Universität Duisburg-Essen entwickelt.

Institut für Sport und Sportwissenschaft, Karlsruher Institut für Technologie (2017)

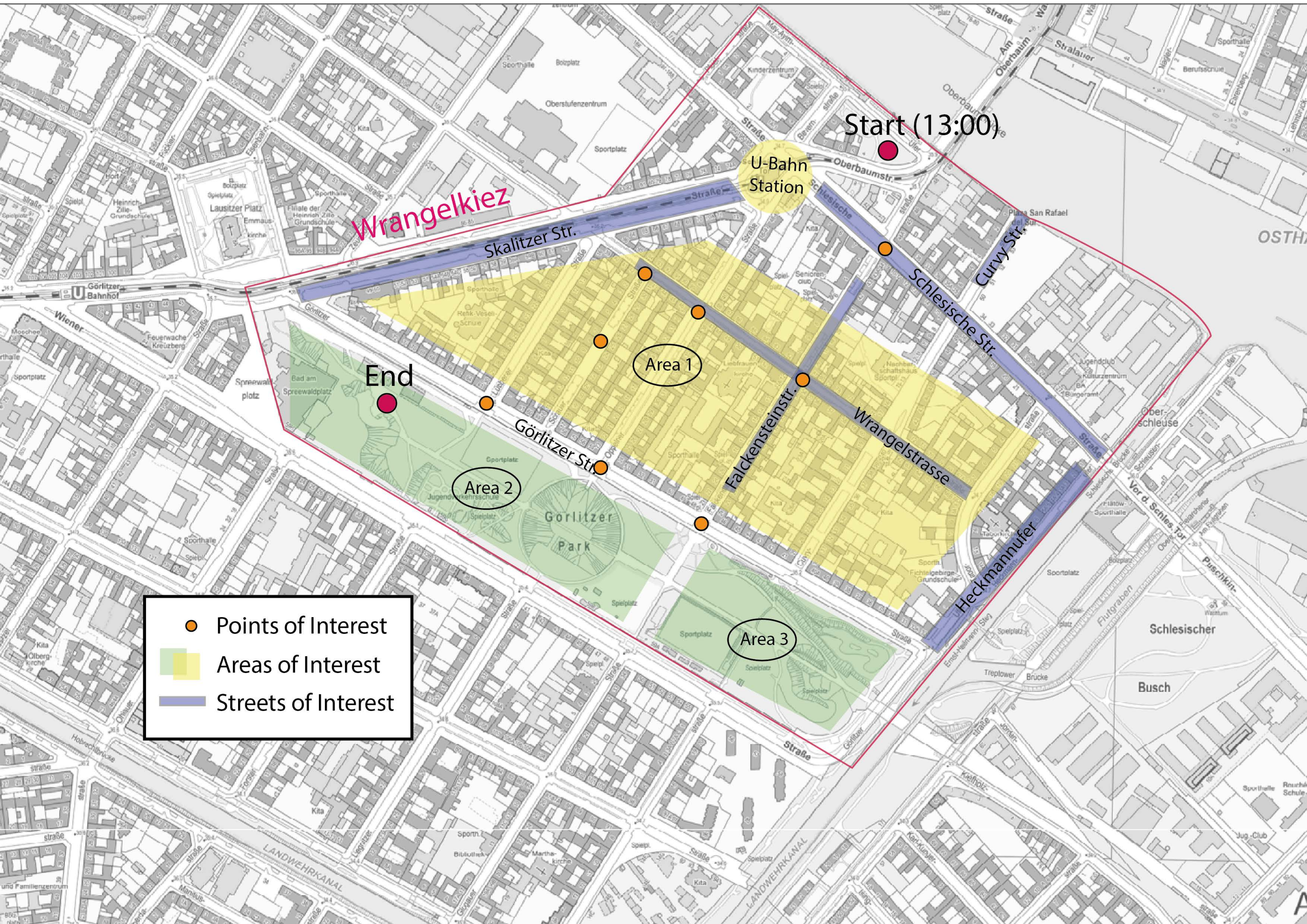
Verbessern Sie Ihre Bewertung

Nachdem Sie nun mögliche Problemstellen identifiziert haben, finden Sie in dieser Liste beispielhafte Möglichkeiten, diese direkt oder auch gemeinsam mit Ihrer Mitbürger zu begegnen.

Was Sie direkt tun können...	**Was Sie und Ihre Mitbürger langfristig tun können...**
▪ Wählen Sie vorerst eine andere Strecke, um an Ihr Ziel zu gelangen. ▪ Informieren Sie das Gartenbauamt oder Stadtplanungsamt über Problemstellen und senden Sie eine Kopie der Checkliste mit. ▪ Hinterlassen Sie falschparkenden/ behindernden Autos eine nette Notiz mit der Bitte des Umparkens. ▪ Seien Sie Vorbild und halten Sie sich selbst an Geschwindigkeitsbegrenzungen. ▪ Organisieren Sie die Begleitung des Schulwegs von Kindern durch Eltern aus Ihrer Nachbarschaft. ▪ Nehmen Sie auf Ihrem nächsten Spaziergang eine Mülltüte mit und sammeln Sie den auf der Strecke liegenden Müll ein. ▪ Weitere Ideen: ____________________ ____________________ ____________________	▪ Wenden Sie sich mit den aufgefallenen Problemen in Ihrer Nachbarschaft an einen Gemeinderatsvertreter (sammeln Sie evtl. Unterschriften dafür). ▪ Schalten Sie die Presse ein, um auf die Probleme aufmerksam zu machen. ▪ Arbeiten Sie mit dem kommunalen Stadtplanungsamt zusammen, um fußgängerfreundliche Wege zu gestalten. ▪ Ermutigen Sie Schulen, Verkehrssicherheitsprogramme und -maßnahmen[1] wie LaufBus, Schülerlotsen, Schulwegpläne, aufgepasst mit ADACUS, etc. durchzuführen. ▪ Organisieren Sie einen regelmäßigen „Säuberungstag“ in Ihrer Nachbarschaft. ▪ Weitere Ideen: ____________________ ____________________ ____________________

[1] Eine ausführliche Liste mit Verkehrssicherheitsprogammen und -maßnahmen für jedes Alter finden Sie unter: http://www.verkehrssicherheitsprogramme.de

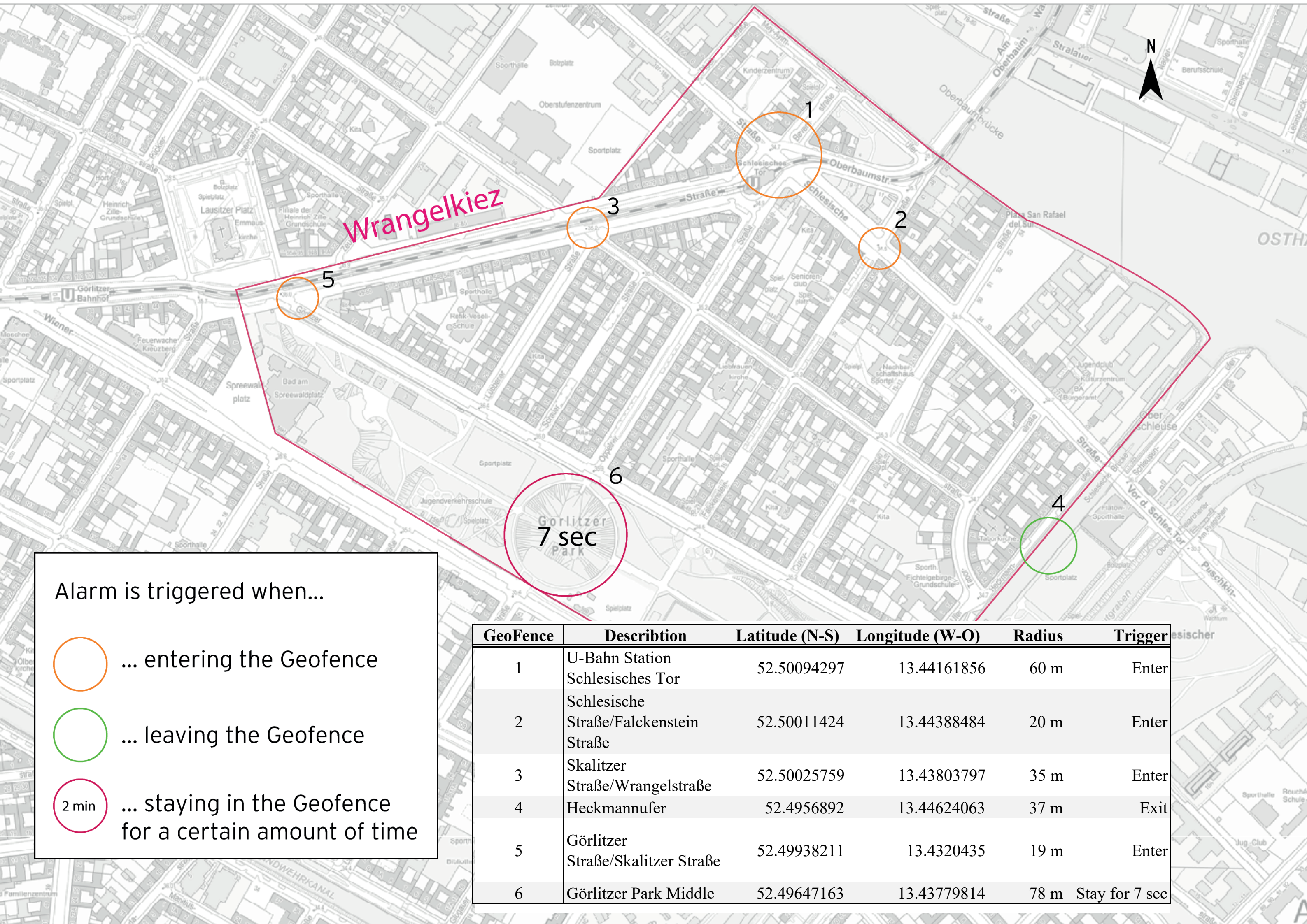
ANNEX IV – POINTS OF INTEREST IN TESTAREA


Start (13:00)
U-Bahn Station
Wrangelkiez
Skalitzer Str.
Schlesische Str.
Curvy Str.
Area 1
Falckensteinstr.
Wrangelstrasse
End
Görlitzer Str.
Area 2
Heckmannufer
Area 3
Points of Interest
Areas of Interest
Streets of Interest

ANNEX V – APP COMPARISION

Name	Original Purpose	GPS Tracking	eDiary Tracking	Photo Uploading	Supporting System	Data Visualisation (QGIS)	Anonymous	Free of charge	Comments
MovisensXS	Survey in connection with EDA	yes		yes	Android		no	trial/student version	crashes for some features (e.g. uploading pictures) many possibilities easy setup link to sensors multimedia uploads
AthenaCX	Survey	no		no	iOS + Android		yes	trial	
PIEL Survey	Survey	no	yes	no			no	trial	no photo/video option complicated setup basic questions data upload didnt work
Murmuras	Survey	no			iOS		no		
Polarsteps	Travel Planner & Tracker	yes	yes	yes	iOS + Android	no	no	yes	
Komoot	Activity Guide & Mapping Software	yes	yes	yes	iOS + Android	no	no	yes	only some routes useable in QGIS
Mappiness	Happiness Mapping App for Research	yes	yes	yes	iOS	yes	no	yes	only in UK App Store
LifeData	Experience Sampling App for Research	yes	yes	yes	iOS + Android	yes	yes	no	
MetricWire		yes	yes	yes	iOS + Android	?	yes	no/student version	

ANNEX VI – GEOFENCES



Alarm is triggered when...

... entering the Geofence

... leaving the Geofence

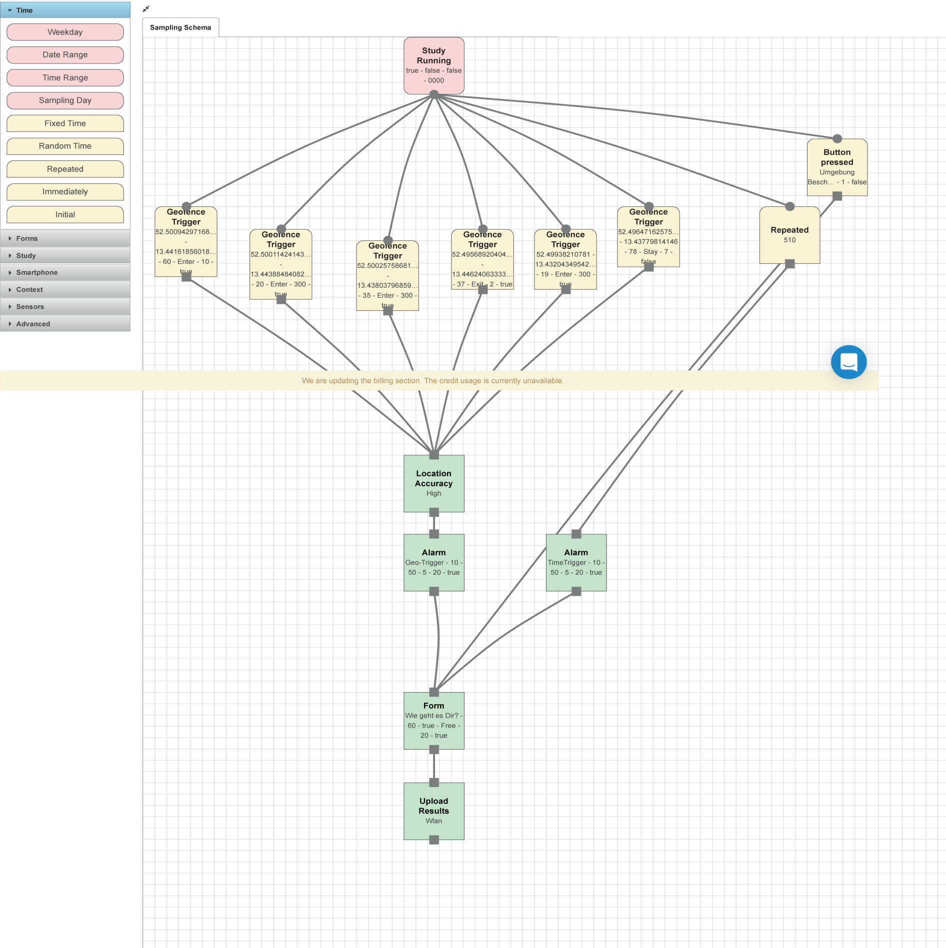
2 min ... staying in the Geofence for a certain amount of time

GeoFence	Describtion	Latitude (N-S)	Longitude (W-O)	Radius	Trigger
1	U-Bahn Station Schlesisches Tor	52.50094297	13.44161856	60 m	Enter
2	Schlesische Straße/Falckenstein Straße	52.50011424	13.44388484	20 m	Enter
3	Skalitzer Straße/Wrangelstraße	52.50025759	13.43803797	35 m	Enter
4	Heckmannufer	52.4956892	13.44624063	37 m	Exit
5	Görlitzer Straße/Skalitzer Straße	52.49938211	13.4320435	19 m	Enter
6	Görlitzer Park Middle	52.49647163	13.43779814	78 m	Stay for 7 sec

ANNEX VII – SAMPLING SCHEMES

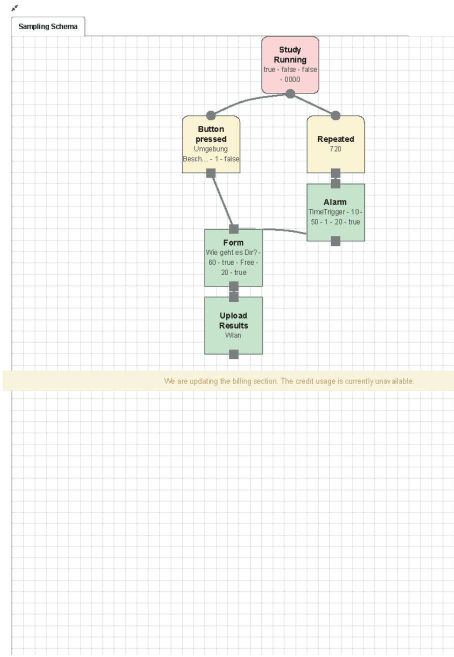
Sampling Scheme USL1

With geofence trigger, time trigger and button initiated start



Sampling Scheme USL1

With time trigger and button initiated start



ANNEX VIII – PAPER-BASED QUESTIONNAIRES

1. About the Test person

a) demographic data

Age: __________

Gender: ☐ female ☐ male ☐ divers/non-binary ☐ prefer not to day

Education:
☐ High school ☐ Bachelor ☐ Master ☐ PhD ☐ vocational training

Current occupation:
☐ full-time employed ☐ part-time employed ☐ unemployed ☐ in School

In the past 5h I consumed: ☐ Caffeine ☐ Alcohol

b) General walking behaviour

Why and how often do you walk:	*Every day*	*At least 3 days per week*	*1-2 days per week*	*never*
To work/school	o	o	o	o
For staying healthy	o	o	o	o
As leasure activity	o	o	o	o
Social reasons (e.g. meeting friends)	o	o	o	o
running errands like shopping groceries or visiting the doctor	o	o	o	o
To reach public transport	o	o	o	o
Care-work related (going for a walk with the dog, elderly, children..)	o	o	o	o
Other reasons or comments				

Please note, how much you agree with the following statements:

When I walk …	*Agree completely*	*Rather agree*	*Rather disagree*	*disagree*
… I stay in my neighbourhood	o	o	o	o
… I got to a special place	o	o	o	o
… I'm seeking for green areas	o	o	o	o
… I prefer walking in an urban environment	o	o	o	o

comments:

To what extend do you agree with the following:	*Agree completely*	*Rather agree*	*Rather disagree*	*disagree*
I walk because it's priceless/cheap	o	o	o	o
I feel free and independent when I walk	o	o	o	o
I walk for sustainability reasons	o	o	o	o
I feel as part of the city when I walk	o	o	o	o
I spare time when I walk	o	o	o	o

Other reasons and comments:

2. Mood and emotions

a) Basic mood

In the past two weeks…	*All the time*	*Most oft he time*	*Less than half oft he time*	*From time to time*	*never*
I have been happy	o	o	o	o	o
I felt relaxed	o	o	o	o	o
I have been active and energetic	o	o	o	o	o
My everyday life was exciting	o	o	o	o	o
I have been in homeoffice	o	o	o	o	o
I went for a walk on a regular basis	o	o	o	o	o
I missed social interactions	o	o	o	o	o
Encounters with people made me nervous	o	o	o	o	o

b) Mood today

Please mark on the scale, how you rather feel today

energetic						**tired**
happy						**sad**
calm						**annoyed**
In a good mood						**In a bad mood**
relaxed						**Stressed out**

The temperature today I perceive as:	**Too hot**						**Too cold**

The weather today I peceive as:	o *pleasent*	o *Rather pleasent*	o *Rather unpleasent*	o *unpleasent*

REFLECTION

Welcome back from your walk!

1. The walk

a) Dates:

Distance: ______ km

Time: ______ min

b) Orientation in the test area

mark with a cross, to what extend the following statement applied to you.

	Agree completely	*Rather agree*	*Rather disagree*	*disagree*
I knew the test area Wrangelkiez before the walk	o	o	o	o
The orientation in the area was easy	o	o	o	o
I used supporting apps for orientation (like google maps)	o	o	o	o

c) General feeling

How did you feel during the walk?	o *comfortable*	o *Mostly comfortable*	o *Rather uncomfortable*	o *uncomfortable*

d) Walkability

mark with a cross, to what extend the following statement applied to you.:

	Agree completely	*Rather agree*	*Rather disagree*	*disagree*
The sidewalks were free of obstacles (e.g. parking cars)	o	o	o	o
Greenery along the way created a nice atmosphere	o	o	o	o
Art and impressive buildings were seen	o	o	o	o
The facades look generally pleasant	o	o	o	o
The neighbourhood was free of waste and littering	o	o	o	o
The neighbourhood is free of damage	o	o	o	o
Parks and playgrounds are well-kept	o	o	o	o
Green phases of traffic lights were long enough	o	o	o	o

e) Comfort

mark with a cross, to what extend the following statement applied to you.:

	Agree completely	*Rather agree*	*Rather disagree*	*disagree*
The sidewalks were wide enough for strollers and wheelchairs or to walk next to each other	o	o	o	o
Enough possibilites to sit down existed	o	o	o	o
Shelters from sun and rain exist	o	o	o	o
There is a high noise pollution in the area	o	o	o	o
There is a high odour nuisance/bad smell in the area	o	o	o	o

f) Safety

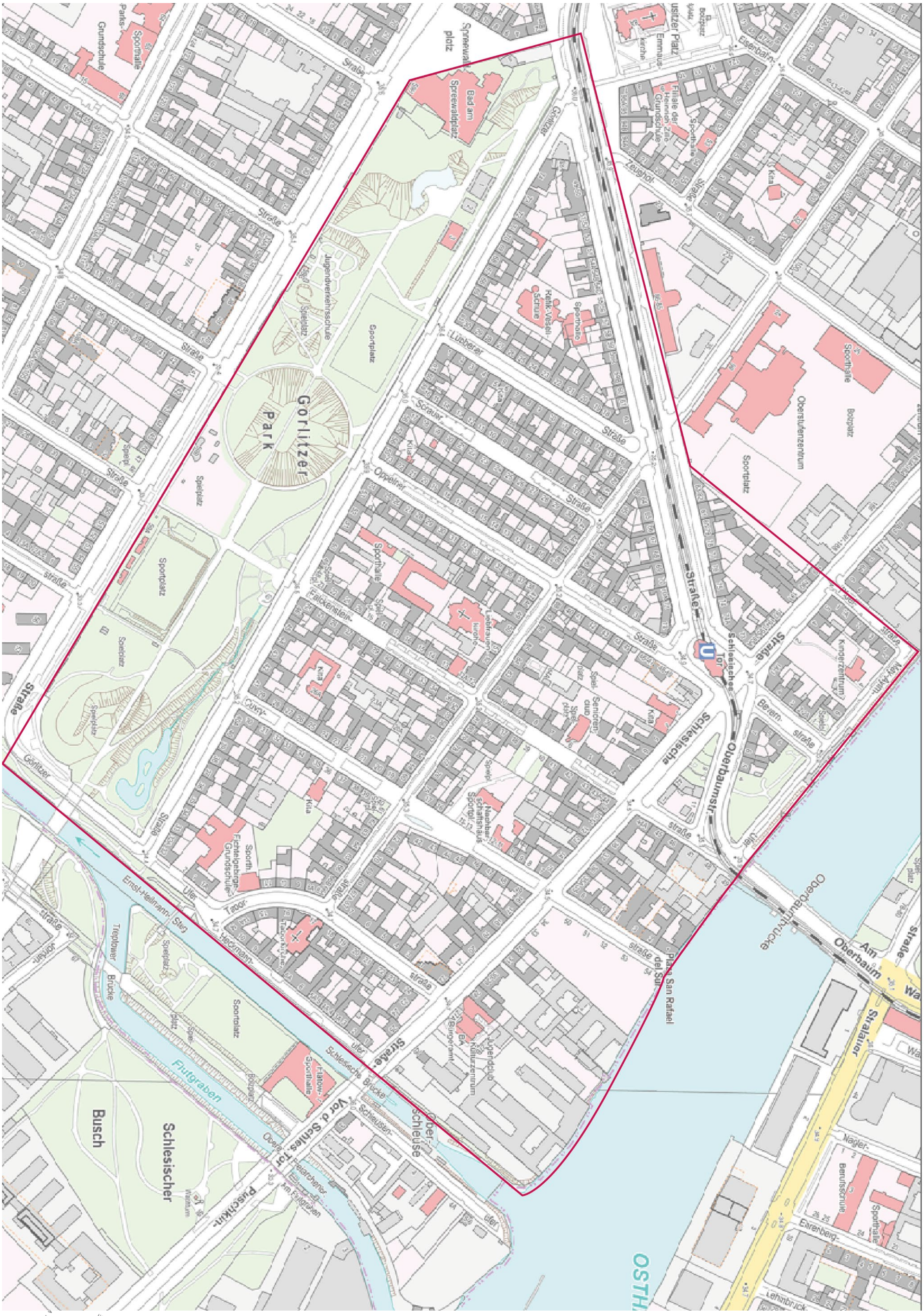
mark with a cross, to what extend the following statement applied to you.

	Completely agree	*rather agree*	*Rather disagree*	*disagree*
I felt safe on the way	o	o	o	o
There is a demand for more pedestrian crossings	o	o	o	o
There is enough space between the sidewalk and the road	o	o	o	o
Cars kept to the speed limit	o	o	o	o
Street crossings were open and easy to overlook	o	o	o	o

g) Striking experiences

Draw in the map on the next page your way and mark points, where you recognised something extraordinary or important.

Participant Nr.: Sensor Nr: Date: Time:



2. Stimmung und Emotionen

a) Mood after the walk

Please mark on the scale, how you rather feel today

energetic						**tired**
happy						**sad**
calm						**annoyed**
In a good mood						**In a bad mood**
relaxed						**Stressed out**

The temperature today I perceive as: **Too hot**						**Too cold**

The weather today I peceive as:

o	o	o	o
pleasent	*Rather pleasent*	*Rather unpleasent*	*unpleasent*

3. Methods

mark with a cross, to what extend the following statement applied to you.

a) EDA Sensors

	Agree completely	*Rather agree*	*Rather disagree*	*disagree*
The application was comfortable	o	o	o	o
The wearing was comfortable	o	o	o	o
I felt hindered while walking by the sensor	o	o	o	o
I was aware of and recognised the sensor constantly	o	o	o	o

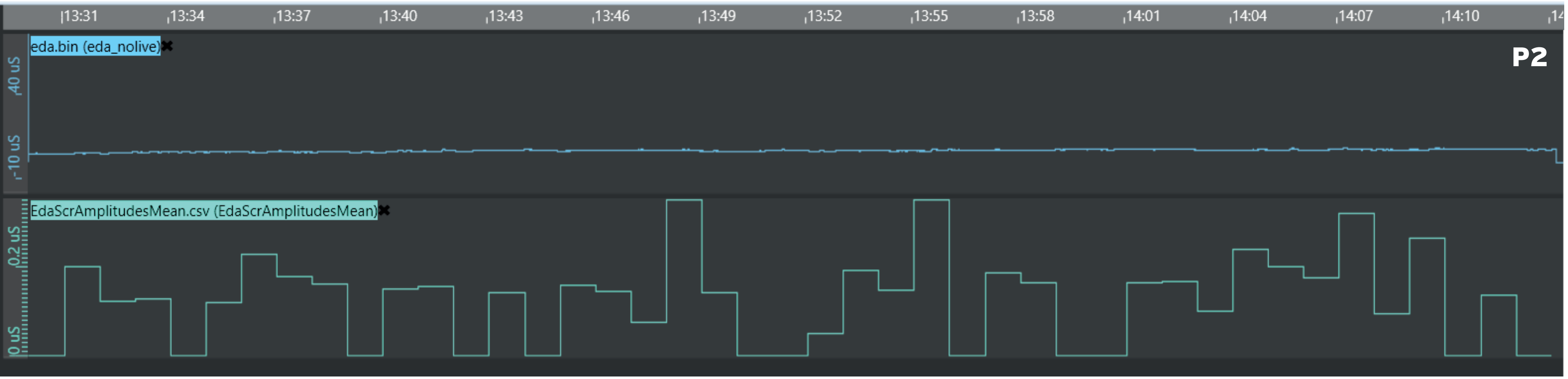
c) Supporting App

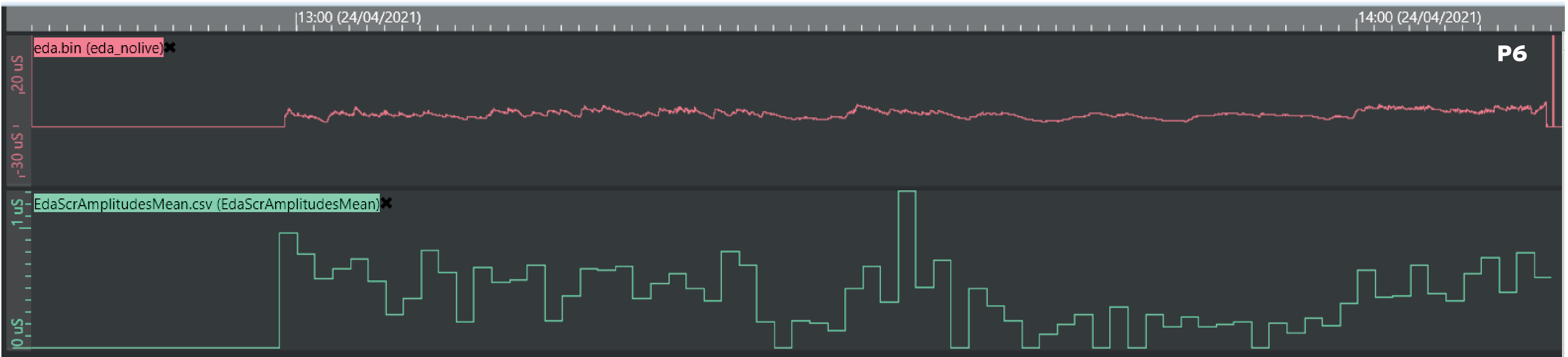
	Agree completely	*Rather agree*	*Rather disagree*	*disagree*
The set up and installation was easy	o	o	o	o
The use was intuitive and easy	o	o	o	o
The use has bothered and hindered me during the walk	o	o	o	o
Filling out the surveys distractad me from the walk	o	o	o	o

4. Other comments, feedback or critique:

ANNEX IX – VISUALISATION OF EDA SIGNALS


13:39
13:42
13:45
13:48
13:51
13:54
13:57
14:00
14:03
14:06
14:09
14:12
14:15
14:18
14:21
14:24
14:27
14:30
14:33
14:36
eda.bin (eda_nolive)
P1
40 uS
20 uS
-10 uS
-40 uS
EdaScrAmplitudesMean.csv (EdaScrAmplitudesMean)
0.2 uS
0 uS


13:31
13:34
13:37
13:40
13:43
13:46
13:49
13:52
13:55
13:58
14:01
14:04
14:07
14:10
eda.bin (eda_nolive)
P2
40 uS
-10 uS
EdaScrAmplitudesMean.csv (EdaScrAmplitudesMean)
0.2 uS
0 uS


13:00 (24/04/2021)
14:00 (24/04/2021)
eda.bin (eda_nolive)
P6
20 uS
-30 uS
EdaScrAmplitudesMean.csv (EdaScrAmplitudesMean)
1 uS
0 uS

14:00 (24/04/2021)
eda.bin (eda_nolive)
P7
50
20 uS
0 uS
-30 uS
EdaScrAmplitudesMean.csv (EdaScrAmplitudesMean)
0.2 uS
0 uS
14:00 (24/04/2021)
eda.bin (eda_nolive)
P8
30 uS
0 uS
-30 uS
EdaScrAmplitudesMean.csv (EdaScrAmplitudesMean)
0.3 uS
0 uS
13:11
13:14
13:17
13:20
13:23
13:26
13:29
13:32
13:35
13:38
13:41
13:44
13:47
13:50
13:53
13:56
13:59
14:02
14:05
eda.bin (eda_nolive)
P9
0 uS
EdaScrAmplitudesMean.csv (EdaScrAmplitudesMean)
0.7 uS
0.2 uS

ANNEX X – COMBINED DATA PER PARTICIPANT

RESULTS PARTICIPANT 1

Results GPS tracking			Sensors	Results eDiary (MovisensXS)								
Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudesMean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:38:03			0.151086224									
13:40:03	13.4436229	52.5014540	0.232579989									
13:42:03	13.4442429	52.5004920	0.204402418									
13:43:03	13.4442318	52.5004775	0.144095389	21	76	74	47	68	64	50		
13:45:03	13.4432577	52.5006161	0.163524493									
13:46:03	13.4424661	52.5009956	0.195942333									
13:49:03	13.4415202	52.5003137	0.249763651	37	56	70	43	45	67	44		
13:52:03	13.4395450	52.4996648	0.184037786									
13:54:03	13.4384668	52.4989686	0.162519708									
13:55:03	13.4385328	52.4989034	0.149197339	23	12	12	12	13	65	88		
13:56:03	13.4385331	52.4989036	0.178544632									
14:03:03	13.4330828	52.4991088	0.157465576									
14:04:03	13.4319798	52.4992080	0.16317513									
14:05:03	13.4322509	52.4985760	0.157020172									
14:06:03	13.4327356	52.4983899	0.301028102									
14:07:03	13.4333224	52.4980249	0.141565669									
14:08:03	13.4335184	52.4980257	0.285085392	11	7	21	8	9	82	72		
14:09:03	13.4338061	52.4978211	0.443693657									
14:12:03	13.4371034	52.4975953	0.141414808									
14:13:03	13.4382740	52.4972372	0.14174427									
14:15:03	13.4405019	52.4968164	0.210206128									
14:16:03	13.4412792	52.4973700	0.231521704	24	29	66	29	30	54	23		
14:17:03	13.4417117	52.4978649	0.185324409									
14:18:03	13.4427927	52.4982129	0.141012739									
14:19:03	13.4440035	52.4977814	0.15938481									
14:20:03	13.4436295	52.4973669	0.243666396									
14:21:03	13.4427691	52.4965830	0.222550637									
14:22:03	13.4422012	52.4959837	0.283759589									
14:23:03	13.4413094	52.4961157	0.216884631									
14:24:03	13.4406035	52.4957792	0.23983382									
14:25:03	13.4396702	52.4959498	0.214487189									
14:26:03	13.4391220	52.4960949	0.252566381	31	22	44	12	11	57	30		
14:28:03	13.4376577	52.4961366	0.244961697									
14:29:03	13.4374801	52.4961953	0.197021858									
14:30:03	13.4375027	52.4961984	0.33292613									
14:31:03	13.4374952	52.4962101	0.201142061									
14:32:03	13.4368570	52.4967459	0.16805317									
14:33:03	13.4358304	52.4971354	0.388834528									
14:36:03	10:25:33	52.4978671	0.327400447									

Mean value	0.215626284
Standart deviation	0.070899267
SUM	0.286525551

0.327	= above mean value + standard deviation
0.444	= more than 2 times above mean value + standard deviation
	= data for mapping

RESULTS PARTICIPANT 2

Results GPS tracking			Sensors	Results eDiary (MovisensXS)								
Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudesMean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestrian I feel comfortable/uncomfortable	As pedestrian I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:30:01	52.5014181	13.44369348	0									
13:31:01	52.5014223	13.443691	0.201675508									
13:32:01	52.5012108	13.44374798	0.122537087	25	84	80	79	77	81	62	TrAshin the small park where ww met	1618572786522.3gpp
13:33:01	52.5009957	13.44293622	0.1301345									
13:34:01	52.501371	13.44186796	0	13	81	77	81	80	82	69	Flowershop at corner	
13:35:01	52.5010181	13.44105593	0.121394003									
13:36:01	52.5007063	13.44003524	0.230891212									
13:37:01	52.5005706	13.43890152	0.180432996	10	15	67	23	20	86	76	Duo Cafe	
13:38:01	52.5003987	13.43794113	0.16405279	12	8	9	12	10	86	81	Ruhige Seitenstrasse und Sonne kommt raus	1618573221654.3gpp
13:39:01	52.5001795	13.43839032	0									
13:40:01	52.4997202	13.43908502	0.151168822									
13:41:01	52.4994339	13.44013449	0.156891489									
13:42:01	52.4990098	13.44103266	0	14	9	13	12	10	82	73	Wrangelstrasse wird zum Ende hin jetzt voller undbeim Rewe stehen viele unangenehme Leute	
13:43:01	52.4986778	13.44195148	0.142774938									
13:44:01	52.4981981	13.44200174	0									
13:45:01	52.4978171	13.44130643	0.160016801	3	1	0	0	0	100	100	Leckerer Brownieladen	
13:46:01	52.4971879	13.44069725	0.146269438									
13:47:01	52.4965431	13.44033464	0.077610774	25	34	35	8	13	15	44	Two guys having an argument inGörli	1618573677204.3gpp
13:48:01	52.4959782	13.43985908	0.353322506									
13:49:01	52.4955782	13.44071811	0.143970772									
13:50:01	52.4954616	13.44109066	0	7	13	8	9	7	88	83	Habe mich auf eine Bank gesetzt und beobachte Leute. Görli kommt mir heute sehr leer vor. Sonne scheint jetzt immer mehr	
13:52:01	52.4954633	13.44108843	0.051220003									
13:53:01	52.4954637	13.44108725	0.193870297	8	10	5	3	8	88	83	Viele Familien mit Kindern sind unterwegs	
13:54:01	52.4957439	13.44027157	0.148166038									
13:55:01	52.4960169	13.43932706	0.353386685									
13:56:01	52.4959773	13.43837445	0									
13:57:01	52.4959153	13.43739026	0.188558324	10	6	5	10	13	81	76	Laufe an Streichelzoo vorbei	
13:58:01	52.4964672	13.4367393	0.166329694	14	13	14	14	12	85	80	Schild Stop Racial Profiling fällt mir auf	
13:59:01	52.4970154	13.43726058	0									
14:00:01	52.4972173	13.43821001	0									
14:01:01	52.4975408	13.43759273	0.166889276	23	28	74	68	66	83	56	Viele Leute vor Mugrabi, Baustelle	
14:02:01	52.4978364	13.43679133	0.168735003									
14:03:01	52.4981713	13.43596019	0.102629502	21	19	55	15	49	68	57	Polizeiauto am Eingang Görli,Leute sitzen auf dem Fußweg in derSonne. Annelies- gutes Cafe	
14:04:01	52.4984008	13.43510736	0.24074655									
14:05:01	52.498683	13.43413913	0.201363492									
14:06:01	52.4989518	13.43321295	0.17745531	12	38	62	57	75	73	37	Shell Tanke, Kirche	
14:07:01	52.4992459	13.43249986	0.321947952									
14:08:01	52.4992125	13.43192801	0.095690465	82	32	75	85	84	64	21	Krankenwagen, unangenehme Kreuzung wo mich Auto fast anfährt	
14:09:01	52.4989709	13.43222029	0.266495197	8	7	4	7	2	89	83	Im Görli	
14:10:01	52.4985573	13.43299727	0									
14:11:01	52.4981114	13.4338572	0.138009945									
14:12:01	52.4979037	13.43372777	0									
14:13:01	52.4979037	13.43372777										

Mean value	0.130110414
Standart deviation	0.099457566
SUM	0.22956798

0.24	= above mean value + standard deviation
0.3	= more than 2 times above mean value + standard deviation
	= data for mapping

RESULTS PARTICIPANT 6

Results GPS tracking			Sensors	Results eDiary (MovisensXS)								
Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudes Mean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
12:59:02			0.95938821									
13:00:02			0.789715923									
13:01:02			0.57714958									
13:02:02			0.660158266									
13:03:02			0.742973838									
13:04:02			0.556907627									
13:05:02			0.28131248									
13:06:02			0.414103013									
13:07:02	52.5015982	13.44397614	0.817273352									
13:08:02	52.5016896	13.44397114	0.62926515									
13:09:02	52.5016769	13.44399495	0.225744985									
13:10:02	52.5017079	13.44398611	0.674976297									
13:11:02	52.5015648	13.44413593	0.55221258									
13:12:02	52.5015107	13.44404617	0.575342852									
13:13:02	52.5014851	13.4443936	0.691945837									
13:14:02	52.5014851	13.4443936	0.236087635									
13:15:02	52.5010742	13.44450368	0.440911725									
13:16:02	52.5007391	13.44427154	0.662524145	71	73	83	74	72	38	45		many bikers and cars, no traffic lights, participant is unsure if they can cross the street (voice recording)
13:17:02	52.5003922	13.44418102	0.656182372									
13:18:02	52.4999885	13.44378529	0.687934779	74	65	95	65	68	41	38	Große Straße, viel los	
13:19:02	52.4998714	13.4436693	0.419659803									
13:20:02	52.4994837	13.44343568	0.536765835	31	26	35	34	43	69	63		pleasant small street with options to sit down, relaxing (voice recording)
13:21:02	52.4994716	13.44342994	0.623982363									
13:22:02	52.4995319	13.44333489	0.500630325									
13:23:02	52.4991906	13.44308408	0.396163193									
13:24:02	52.4988848	13.44248289	0.804547317									
13:25:02	52.4984492	13.44232389	0.694672353	16	20	17	33	30	76	51		pleasent, a lot of people, small shops, bike traffic, less cars, nice people, bought drink at späti and didnt have enough money so the drink was just given as a present. (voice recording)
13:26:02	52.498016	13.4416741	0.218372372									
13:27:02	52.4974866	13.44123483	0									
13:28:02	52.4969142	13.4408841	0.230630664									
13:29:02	52.4964185	13.44015004	0.214906842									
13:30:02	52.4958354	13.43997926	0.148589197									
13:31:02	52.495616	13.44059955	0.497411311									
13:32:02	52.495616	13.44059955	0.681735745	25	25	38	40	45	58	47		green, many pedestriants, many bikes, street doenst feel dangerous, no cars (voice recording)
13:33:02	52.4955976	13.44068048	0.388294151									
13:34:02	52.4952367	13.44160048	1.308498105									
13:35:02	52.4950235	13.44231473	0.507173732									
13:36:02	52.4946495	13.44325562	0.740929508									
13:37:02	52.4946718	13.44404952	0									

Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudes Mean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:38:02	52.4948557	13.44421859	0.496053335	**10**	10	14	8	45	89	100		small fountain, bird tweeting, very small pond, cant hear the noisy street, feels like being in the nature (voice recording)
13:39:02	52.4948607	13.4441912	0.357987998									
13:40:02	52.4948658	13.44422098	0.233032147									
13:41:02	52.4951563	13.44505467	0									
13:42:02	52.4955123	13.44573946	0.115756453									
13:43:02	52.4954854	13.44591423	0.196978197	**24**	8	17	20	39	74	62		pleasend athmosphere, people around are concentrated on doing their things, being on the bridge feels uncomfortable (voice recording)
13:44:02	52.4955235	13.44581336	0.283019891									
13:45:02	52.4960511	13.44578213	0									
13:46:02	52.4966589	13.44595585	0.349900262									
13:47:02	52.4971503	13.44619527	0	**28**	17	22	17	45	68	71		pleasent, empty street, flowers on the street, possibilities to sit down. Relaxing (voice recording)
13:48:02	52.4974975	13.44663344	0.287292333									
13:49:02	52.4980682	13.44711446	0.181863483									
13:50:02	52.4984835	13.44679222	0.261723142									
13:51:02	52.4989223	13.44613525	0.178919854	**36**	38	41	41	41	61	60		big street, but not stressful if I dont have to cross it (voice recording)
13:52:02	52.4991452	13.44526609	0.202559972									
13:53:02	52.4986766	13.44480412	0.222269041									
13:54:02	52.4983988	13.44404275	0									
13:55:02	52.4989229	13.44345991	0.215997594									
13:56:02	52.4988569	13.442724	0.124599296	**9**	29	39	4	45	68	45		busy street but still nice, lively feeling, exciting surounding (voice recording)
13:57:02	52.4987166	13.44186784	0.247290811									
13:58:02	52.498908	13.44096605	0.18891522									
13:59:02	52.4993696	13.44034848	0.380148388									
14:00:02	52.4995932	13.43937738	0.658219751									
14:01:02	52.5000128	13.43882686	0.422459493									
14:02:02	52.4998301	13.43780825	0.44215184									
14:03:02	52.4993454	13.43723292	0.697439096	**19**	35	23	0	43	64	86		walkable place, big sidewalk and small street (voice recording)
14:04:02	52.4988224	13.43668947	0.454846601									
14:05:02	52.4982938	13.43622994	0.396223681									
14:06:02	52.4978074	13.43577607	0.621771245									
14:07:02	52.4974355	13.43499128	0.756720023									
14:08:02	52.4977844	13.43437513	0.467102652	**15**	29	68	0	29	86	40		walkable environment, many people, lively, participant is in sight of end-point (voice recoding)
14:09:02	52.497907	13.43391081	0.802801666									
14:10:02	52.4978624	13.43377083	0.596480193									
14:11:02	52.4978324	13.43374534										

Mean value	0.438688849
Standart deviation	0.263178989
SUM	0.701867837

0.76 = above mean value + standard deviation

0.30 = more than 2 times above mean value + standard deviation

= data for mapping

RESULTS PARTICIPANT 7

Results GPS tracking			Sensors	Results eDiary (MovisensXS)								
Time [hh:mm:ss]	**Latitude**	**Longitude**	**EdaScrAmplitudesMean [uS]**	How do you feel here?	**My surrounding is rather nice/ugly**	**My surrounding is rather quite/noisy**	**As pedestriant I feel comfortable/uncomfortable**	**As pedestriant I feel recognized/unrecognized**	**People around me I perceive as threatening/friendly**	**People around me I perceive as crowded/empty**	**Free Text input**	**Voice record**
13:10:02			0.24246189									
13:11:02			0.30610613									
13:12:02			0.16883498									
13:13:02			0.22048422									
13:14:02			0.253434									
13:15:02			0.16153866									
13:16:02			0.18584167									
13:17:02			0.15377826									
13:18:02			0.24390191									
13:19:02			0.25773083									
13:20:02			0.21938052									
13:21:02			0.22167574									
13:22:02			0.16116834									
13:23:02			0.19233944									
13:24:02			0.17586727									
13:25:02			0.20177076									
13:26:02			0									
13:27:02			0.24179798									
13:28:02	52.5016572	13.4440398	0.19781515									
13:29:02	52.5013731	13.4441427	0.13320563									
13:30:02	52.5009491	13.443466	0.1475171									
13:31:02	52.5008619	13.4432236	0.17478936	40	35	67	60	81	60	59	Fußgänger*innenweg direkt über Straße. Im Nirgendwo sein	
13:32:02	52.5008619	13.4432236	0.14770995									
13:33:02	52.5009161	13.4425039	0.13344334									
13:34:02	52.5009144	13.4422336	0	74	59	85	75	75	60	30		many different traffic participants, chaotic and participant feels watched (voice recording)
13:35:02	52.5008532	13.4420384	0.1464315									
13:36:02	52.5006047	13.4417837	0.1857482									
13:37:02	52.5001175	13.4411957	0.11943935									
13:38:02	52.4998329	13.4409028	0.12338412	10	12	17	10	5	82	42		suffen change and contrast to skalitzer str, suddenly feeling like in a village, everyone knows each other, big graffities (voice recording)
13:39:02	52.4998319	13.4408863	0.11046771									
13:40:02	52.4994256	13.4404066	0.14782044									
13:41:02	52.4993406	13.4400078	0.11768108									
13:42:02	52.4997269	13.4394102	0									
13:43:02	52.4996913	13.4393265	0	67	24	20	24	18	31	30	Altes Cafè aus ersten Berlin-Tagen wiederentdeckt. Etwas unwohlfühlen, da Männergruppen vor Cafè sitzen	
13:44:02	52.4996913	13.4393265	0.22291635									
13:45:02	52.4995507	13.4391589	0.20294173									
13:46:02	52.4989931	13.4385156	0	9	8	0	0	1	76	75		discovered new and unknown street, green oasis with trees, different athmoshohere, no bars/cafes/shops in basement, instead, graffities. green Housing street (voice recording)
13:47:02	52.498722	13.4381427	0.13803132									

Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudesMean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:49:02	52.498469	13.4380267	0									
13:50:02	52.4984819	13.4380332	0									
13:51:02	52.4982338	13.4377397	0									
13:52:02	52.4977805	13.4372118	0.21931348									
13:53:02	52.4976032	13.437662	0	45	19	18	16	8	61	41		was annoyed at the corner, because the new cafe Mugabi reminds of gentrification and the "new hipster Kreuzberg" in contrast to the street before, that more looks like the "old kreuzberg" (voice recording)
13:54:02	52.4975219	13.4376399	0.11654974									
13:55:02	52.4975284	13.4378307	0									
13:56:02	52.4973587	13.438747	0									
13:57:02	52.4970493	13.4396954	0									
13:58:02	52.4966712	13.440619	0.2905715	18	13	22	38	16	75	62		changing street side to side where no restaurants are. On one side, there are bikes while the other street side is almost empty. (voice recording)
13:59:02	52.496527	13.4406142	0									
14:00:02	52.496627	13.4406537	0.10596285									
14:01:02	52.4965794	13.440873	0									
14:02:02	52.4961027	13.4416717	0									
14:03:02	52.4958771	13.4418642	0.08426139									
14:04:02	52.4955615	13.4423717	0									
14:05:02	52.4951846	13.4430821	0.22872368									
14:06:02	52.4951726	13.4430909	0	8	23	12	10	12	67	40		never been to this side of the park, recognized, there is water. Everything is quite, cars seem very distant, there is a bird and nature in the city. (voice recording)
14:07:02	52.4951835	13.4430932	0.11664055									
14:08:02	52.4950053	13.4432233	0.12247125									
14:09:02	52.4946948	13.4438579	0									
14:10:02	52.4944912	13.4439201	0	16	46	30	17	13	83	26		interesting mix of green, street and channel, a bit industrial and an old bridge. Feels uncompfortable because of a lot people passing. No space to hide and find private peace. (voice recording)
14:11:02	52.4944933	13.4439018	0									
14:12:02	52.4944667	13.443846	0.17194381									
14:13:02	52.4944667	13.443846	0									
14:14:02	52.494562	13.4434152	0									
14:15:02	52.4946185	13.4427201	0.19981703									
14:16:02	52.4946884	13.4421149	0									
14:17:02	52.4952832	13.4418171	0.15448603									
14:18:02	52.49563	13.4409689	0									
14:19:02	52.4959431	13.4400844	0									
14:20:02	52.4962509	13.4393431	0	58	40	58	32	33	74	27		many people on the cross section in the park, a lot of impressions and taking care of all the traffic, rather ugly environment (voice recording)
14:21:02	52.4962614	13.4393833	0.29753713									
14:22:02	52.4963267	13.4387405	0									
14:23:02	52.4965777	13.4377315	0	29	42	23	60	35	72	34		last part of the park is not so exciting anymore, known place and less details to discover, feeling watched but also watching other people (voice recording)

Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudesMean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
14:25:02	52.4967689	13.4370268	0.46634063									
14:26:02	52.4970615	13.4360738	0									
14:27:02	52.4974361	13.4348287	0.11473735									
14:28:02	52.4979159	13.4340664	0.28960214									
14:29:02	52.4978633	13.4337402	0.23305536									
14:30:02	52.4978652	13.4337478										

Mean value	0.09764601
Standart deviation	0.10638637
SUM	0.20403238

0.22	= above mean value + standard deviation
0.42	= more than 2 times above mean value + standard deviation
	= data for mapping

RESULTS PARTICIPANT 8

Results GPS tracking			Sensors	Results eDiary (MovisensXS)								
Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudes Mean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:14:02			0.319745435									
13:15:02			0.336608798									
13:16:02			0.348745451									
13:17:02			0.528632192									
13:18:02			0.502618695									
13:19:02			0.542958964									
13:20:02			0.461373448									
13:21:02			0.514315501									
13:22:02			0.536694861									
13:23:02			0.558645253									
13:24:02			0.342380881									
13:25:02			0.397562133									
13:26:02			0.292352949									
13:27:02			0.330621092									
13:28:02			0.38305036									
13:29:02			0.387881076									
13:30:02			0.672472989									
13:31:02	52.5016082	13.4440125	0.328461043									
13:32:02	52.5013827	13.4441588	0.241277639									
13:33:02	52.5009136	13.4445095	0.22648897									
13:34:02	52.5004944	13.4441714	0.312271602									
13:35:02	52.4999123	13.4438858	0.653256051									
13:36:02	52.4997104	13.4433924	0.31047667	0	65	71	13	15	100	31	Nice library with beautiful postcards	
13:37:02	52.4997004	13.443338	0.17167367									
13:38:02	52.4997315	13.4433317	0.475179765									
13:39:02	52.4993573	13.4431639	0.381932363									
13:40:02	52.4989625	13.4428363	0.62333208									
13:41:02	52.4989351	13.4427423	0.424510996									
13:42:02	52.4989925	13.4426876	0.397117567									
13:43:02	52.4988821	13.4426526	0.274959027									
13:44:02	52.4990074	13.4426407	0.346261038									
13:45:02	52.4990244	13.4426765	0.492024332									
13:46:02	52.4990245	13.4427117	0.175103196	0	0	41	0	0	100	19	Beautiful library with amazing stuff. Got a really nice book from an author i like a lot	
13:47:02	52.4987555	13.4424675	0.47006346									
13:48:02	52.4984566	13.4423233	0.18587284									
13:49:02	52.4981813	13.4432784	0.278854328	0	0	33	25	22	100	40	Kid playing with her grandpa with a ball. Super sweet	
13:50:02	52.4980832	13.4435928	0.339542813									

Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudes Mean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:52:02	52.4980183	13.4443637	0.15808389	22	18	20	0	0	100	77	Nice memories in this square. Kinda sad that it is a little bit empty today	
13:53:02	52.4980097	13.4442507	0.340656177									
13:54:02	52.497708	13.4442921	0.137044532									
13:55:02	52.4974396	13.445222	0.132041885	18	1	18	18	17	100	65	Cute kiosk with very smiley people	
13:56:02	52.4973688	13.4453874	0.361927349									
13:57:02	52.4971985	13.4456395	0									
13:58:02	52.496963	13.4457783	0.206581704	73	29	29	29	33	61	83	The church has a gloomy vibe today	
13:59:02	52.4967498	13.4455913	0.1997739									
14:00:02	52.4965496	13.4456347	0.3062243									
14:01:02	52.4960555	13.445798	0.124328986									
14:02:02	52.4956161	13.4455531	0.127046389									
14:03:02	52.4952327	13.4450142	0.087933706	0	0	19	20	20	60	86	You can hear the sound of a fountain inside görli and it's really peaceful. Also this part of the street looks like the neighbours are taking good care of it	
14:04:02	52.4953209	13.4446072	0.254173933									
14:05:02	52.4953185	13.444604	0.178699829									
14:06:02	52.4953265	13.4445573	0.172210214									
14:07:02	52.4955553	13.4438115	0.174007523									
14:08:02	52.4958493	13.4429926	0.103538054									
14:09:02	52.4961003	13.4422755	0.226052058									
14:10:02	52.4962801	13.4417086	0.148853771									
14:11:02	52.4965447	13.4408574	0.132651147									
14:12:02	52.4968598	13.4405068	0.516902456									
14:13:02	52.4971642	13.4409654	0.356294704									
14:14:02	52.4974546	13.4412121	0.288733797									
14:15:02	52.4978644	13.4417291	0.37567107									
14:16:02	52.4980572	13.4418171	0.305316192	0	37	66	34	1	68	35	Cozy music coming out an apartment	
14:17:02	52.4982651	13.4420471	0.179838327									
14:18:02	52.498647	13.4419651	0									
14:19:02	52.4987729	13.4414174	0.282209953									
14:20:02	52.4987794	13.4413203	0.309630974									
14:21:02	52.4987917	13.4413262	0.363628225									
14:22:02	52.4987875	13.4412977	0.31066851									
14:23:02	52.498745	13.4412464	0.317620406									
14:24:02	52.4988034	13.4412494	0.428512835									
14:25:02	52.4988292	13.4412879	0.292556569									
14:26:02	52.498811	13.4413409	0.391114207									

Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudes Mean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
14:28:02	52.4988206	13.441231	0.132088452									
14:29:02	52.4987797	13.4412846	0.162890612									
14:30:02	52.4987797	13.4412846	0.242492568									
14:31:02	52.4987677	13.4411836	0.457493573	0	0	65	0	0	100	23	Reading in the sun. There's a busy market next to me that radiates good mood	
14:32:02	52.498765	13.4412615	0.456455517									
14:33:02	52.4987685	13.4413084	0.260312607									
14:34:02	52.4988386	13.4413162	0.535441392									
14:35:02	52.4991058	13.440769	0.615482617	0	15	85	15	66	99	33	Nice smell from a café	
14:36:02	52.4992397	13.4403742	0.283274209									
14:37:02	52.499387	13.4399696	0.394049753									
14:38:02	52.499687	13.4391266	0.273412994									
14:39:02	52.4992928	13.4386987	0.270447436									
14:40:02	52.4989784	13.4383643	0.183190769									
14:41:02	52.4986289	13.4381567	0.227239678									
14:42:02	52.498186	13.4378376	0.282197094									
14:43:02	52.4977612	13.4372949	0.168741871									
14:44:02	52.4979951	13.4363926	0.307133872									
14:45:02	52.498185	13.4359465	0.190579556	4	31	67	44	30	82	59		
14:46:02	52.4980456	13.4362528	0.44647214									
14:47:02	52.4978872	13.4365756	0.08719304	0	21	38	16	2	100	36	The leaves are back in the trees and the view from the middle of the street is really nice. I feel safe walking in the middle because there almost no cars	
14:48:02	52.497892	13.437476	0.713422422									
14:49:02	52.4984247	13.4380537	0.467399503									
14:50:02	52.4984525	13.4381491	0.233507548									
14:51:02	52.4984354	13.4381612	0.380143426									
14:52:02	52.4983458	13.4380154	0.369322126									
14:53:02	52.4978891	13.4373568	0.206563563									
14:54:02	52.4976626	13.4366546	0.305277453									
14:55:02	52.4977286	13.4358843	0.206892816									
14:56:02	52.4973931	13.4350359	0.209426179									
14:57:02	52.4977802	13.4343546	0.332085144									
14:58:02	52.4978458	13.4337367	0.480592523									
14:59:02	52.4978235	13.4337122	0.453309573									
15:00:02	52.4978171	13.4337301										

Mean value	0.295638172
Standart deviation	0.141472014
SUM	0.437110187

0.52	= above mean value + standard deviation
0.75	= more than 2 times above mean value + standard deviation
	= data for mapping

RESULTS PARTICIPANT 9

Results GPS tracking			Sensors	Results eDiary (MovisensXS)								
Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudesMean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:10:01			0.173515998	4	26	30	5	19	100	90		
13:11:01			0.234420778									
13:12:01			0.714685146									
13:13:01			0.619914362									
13:14:01			0.735308286									
13:15:01			0.459867931									
13:16:01			0.702826697									
13:17:01			0.380001697									
13:18:01			0.339281069									
13:19:01	52.501554	13.44403358	0.350881638									
13:20:01	52.5015778	13.44404651	0.501661657									
13:21:01	52.5015447	13.44399804	0.550650475									
13:22:01	52.5008948	13.4435895	0.713513998									
13:23:01	52.5001488	13.44376339	0.2619381									
13:24:01	52.499839	13.44394297	0.521736611	71	76	86	67	35	42	45		
13:25:01	52.4997764	13.44383304	0.705021766									
13:26:01	52.4994632	13.44350777	0.323169524									
13:27:01	52.4987376	13.44270275	0.471674879	65	94	43	70	74	27	35		
13:28:01	52.4982666	13.4422149	0.136688141									
13:29:01	52.4982973	13.44217247	0.66580877									
13:30:01	52.4978438	13.44172883	0.456228135									
13:31:01	52.4971419	13.44109726	0.371543816									
13:32:01	52.4964695	13.44039546	0.33648671	65	77	22	34	34	23	62	Aug den weg Dutch due falckensteinstr wurde ich drei Mal Von deallern angequatscht	
13:33:01	52.4963281	13.44025234	0.742784248									
13:34:01	52.4963777	13.44028208	0.329757587									
13:35:01	52.4964313	13.44024877	0.377164864									
13:36:01	52.4958684	13.43973948	0.772246898									
13:37:01	52.4964325	13.43884491	1.107573113									
13:38:01	52.4970753	13.43831771	0.25096518									
13:39:01	52.4971543	13.43836295	0.214247235	24	70	24	27	28	41	73		
13:40:01	52.4971241	13.43851167	0.734755587									
13:41:01	52.4975483	13.43892494	0.430279817									
13:42:01	52.4981462	13.43957278	0.472617031									
13:43:01	52.4987	13.44013974	0.58225514									
13:44:01	52.4990668	13.44043373	0.547138092	15	26	22	25	21	66	68		
13:45:01	52.4991266	13.4404125	0.473935876									
13:46:01	52.499223	13.44029739	0.410342455									
13:47:01	52.4997246	13.43921409	0.486767268									
13:48:01	52.4997174	13.4391719	0.59192137	57	68	40	62	64	44	36		

Time [hh:mm:ss]	Latitude	Longitude	EdaScrAmplitudesMean [uS]	How do you feel here?	My surrounding is rather nice/ugly	My surrounding is rather quite/noisy	As pedestriant I feel comfortable/uncomfortable	As pedestriant I feel recognized/unrecognized	People around me I perceive as threatening/friendly	People around me I perceive as crowded/empty	Free Text input	Voice record
13:50:01	52.4988837	13.43843534	0.45538677									
13:51:01	52.4989104	13.43836429	0.746219124	14	14	14	11	17	81	82	Viel grün	
13:52:01	52.4986359	13.43818239	0.599841094									
13:53:01	52.4978896	13.43768991	0.543632666									
13:54:01	52.4977622	13.43716029	0.2910195									
13:55:01	52.497817	13.43698495	0.443851215	45	58	68	40	42	44	37		
13:56:01	52.4981623	13.43627104	0.172117505	62	70	62	58	36	22	35		
13:57:01	52.4981345	13.43621461	0.455687003									
13:58:01	52.498292	13.43571359	0									
13:59:01	52.4987328	13.43457381	0.666713886									
14:00:01	52.4990627	13.43346017	0.637662923									
14:01:01	52.4993214	13.43260071	0.450937979	56	66	88	63	73	48	67		
14:02:01	52.4993391	13.43251599	0.464944726									
14:03:01	52.4992029	13.43201182	0.415266051									
14:04:01	52.4989698	13.43252796	0.802716018	42	33	37	22	20	34	59		
14:05:01	52.4985258	13.43313943	0.187789677									
14:06:01	52.4980838	13.43392795	0.949819542									
14:07:01	52.4978732	13.43377868	0.517977128	82	98	100	99	95	100	95		
14:08:01	52.4978599	13.43375042										

Mean value	0.495037671
Standart deviation	0.209971764
SUM	0.705009

0.757	= above mean value + standard deviation
1.40	= more than 2 times above mean value + standard deviation
	= data for mapping

ANNEX XI – EVALUATIONS OF WALKABILITY ASSESSMENT

OVERVIEW OF WALKABILITY RATING

	4	3	2	1
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)	1	8	2	0
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen	1	6	4	0
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.	4	3	4	0
Die Straßenfronten sind insgesamt attraktiv gestaltet	0	11	0	0
Das Quartier ist frei von Abfall und zerbrochenem Glas	0	4	5	2
Die Nachbarschaft ist frei von Beschädigung	0	3	6	2
Parks und Spielplätze sind in einem guten Zustand	0	6	5	0
Grünphasen von Ampeln waren ausreichend lang	0	5	6	0
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander	2	5	4	0
Es gab genügend Sitzmöglichkeiten entlang des Weges	2	4	5	0
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden	0	3	3	5
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg	1	4	5	1
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	6	3	2	0
Sie haben sich sicher gefühlt auf dem Weg	4	6	1	0
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht	1	3	6	2
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend	1	6	4	0
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten	1	4	5	0
Straßenübergänge sind frei einsichtig gewesen	1	1	8	1

OVERALL GRADES FOR WALKABILITY PER PARTICIPANT

R1	**2.17**
R2	**2.28**
P1	**2.72**
P2	**2.28**
P3	**2.72**
P4	**2.61**
P5	**3.28**
P6	**2.50**
P7	**3.06**
P8	**2.83**
P9	**2.33**
	2.62

	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen	1				
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.		1			
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas		1			
Die Nachbarschaft ist frei von Beschädigung		1			
Parks und Spielplätze sind in einem guten Zustand			1		
Grünphasen von Ampeln waren ausreichend lang			1		
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander			1		
Es gab genügend Sitzmöglichkeiten entlang des Weges			1		
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden		1			
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg		1			
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	1				
Sie haben sich sicher gefühlt auf dem Weg	1				
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht				1	
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend		1			
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten			1		
Straßenübergänge sind frei einsichtig gewesen			1		
SUMME	12	24	12	1	**2.72**

	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)			1		
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen		1			
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.			1		
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas			1		
Die Nachbarschaft ist frei von Beschädigung			1		
Parks und Spielplätze sind in einem guten Zustand			1		
Grünphasen von Ampeln waren ausreichend lang			1		
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander			1		
Es gab genügend Sitzmöglichkeiten entlang des Weges	1				
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden		1			
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg				1	
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg		1			
Sie haben sich sicher gefühlt auf dem Weg			1		
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht			1		
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend			1		
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten			1		
Straßenübergänge sind frei einsichtig gewesen			1		
SUMME	4	12	24	1	**2.28**

	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen		1			
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.			1		
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas		1			
Die Nachbarschaft ist frei von Beschädigung		1			
Parks und Spielplätze sind in einem guten Zustand		1			
Grünphasen von Ampeln waren ausreichend lang		1			
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander		1			
Es gab genügend Sitzmöglichkeiten entlang des Weges		1			
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden				1	
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg		1			
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	1				
Sie haben sich sicher gefühlt auf dem Weg		1			
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht			1		
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend			1		
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten		1			
Straßenübergänge sind frei einsichtig gewesen			1		
SUMME	4	36	8	1	**2.72**

	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen			1		
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.	1				
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas				1	
Die Nachbarschaft ist frei von Beschädigung			1		
Parks und Spielplätze sind in einem guten Zustand			1		
Grünphasen von Ampeln waren ausreichend lang		1			
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander	1				
Es gab genügend Sitzmöglichkeiten entlang des Weges		1			
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden			1		
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg			1		
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg		1			
Sie haben sich sicher gefühlt auf dem Weg		1			
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht			1		
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend		1			
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten		1			
Straßenübergänge sind frei einsichtig gewesen			1		
SUMME	8	24	14	1	**2.61**

	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)	1				
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen		1			
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.	**1**				
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas		1			
Die Nachbarschaft ist frei von Beschädigung		1			
Parks und Spielplätze sind in einem guten Zustand		1			
Grünphasen von Ampeln waren ausreichend lang		1			
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander	1				
Es gab genügend Sitzmöglichkeiten entlang des Weges			1		
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden		1			
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg		1			
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	1				
Sie haben sich sicher gefühlt auf dem Weg	1				
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht		1			
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend		1			
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten	1				
Straßenübergänge sind frei einsichtig gewesen		1			
SUMME	24	33	2	0	**3.28**

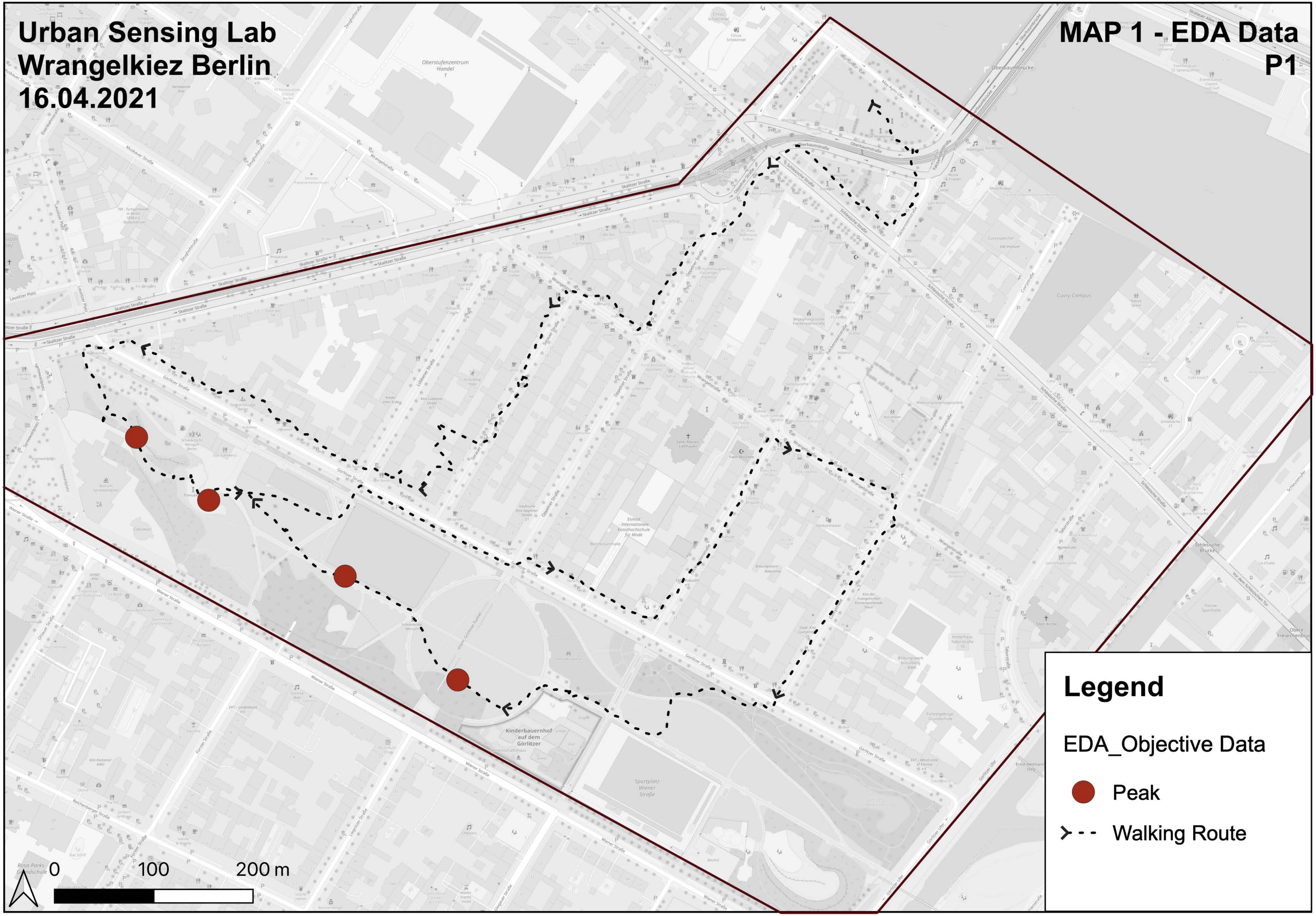
	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen		1			
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.			1		
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas			1		
Die Nachbarschaft ist frei von Beschädigung			1		
Parks und Spielplätze sind in einem guten Zustand		1			
Grünphasen von Ampeln waren ausreichend lang		1			
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander		1			
Es gab genügend Sitzmöglichkeiten entlang des Weges	1				
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden			1		
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg			1		
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	1				
Sie haben sich sicher gefühlt auf dem Weg		1			
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht				1	
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend		1			
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten					
Straßenübergänge sind frei einsichtig gewesen			1		
SUMME	8	24	12	1	**2.50**

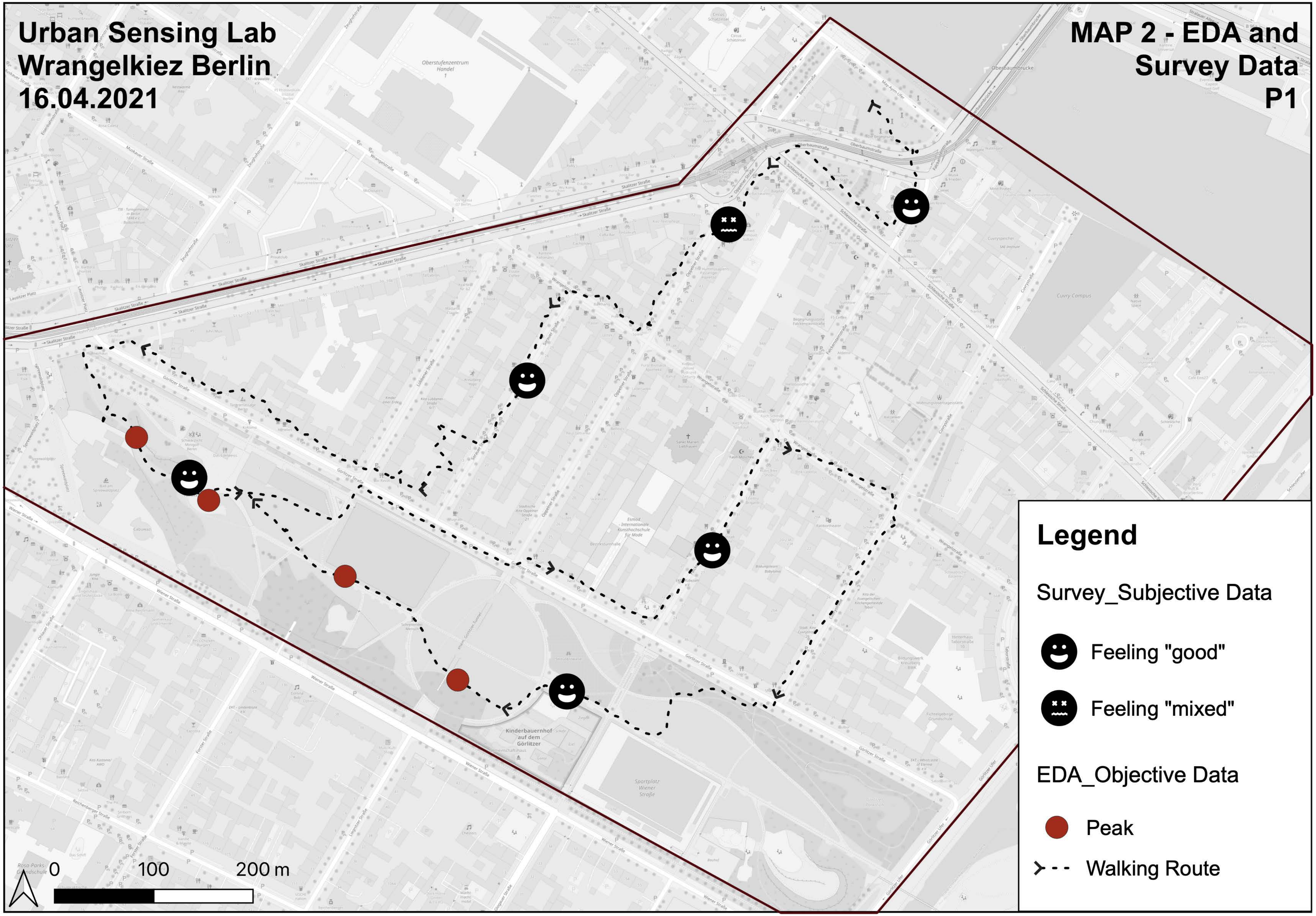
	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen			1		
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.	1				
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas		1			
Die Nachbarschaft ist frei von Beschädigung			1		
Parks und Spielplätze sind in einem guten Zustand		1			
Grünphasen von Ampeln waren ausreichend lang		1			
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander		1			
Es gab genügend Sitzmöglichkeiten entlang des Weges		1			
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden			1		
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg	1				
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	1				
Sie haben sich sicher gefühlt auf dem Weg	1				
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht	1				
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend		1			
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten		1			
Straßenübergänge sind frei einsichtig gewesen			1		
SUMME	20	27	8	0	**3.06**

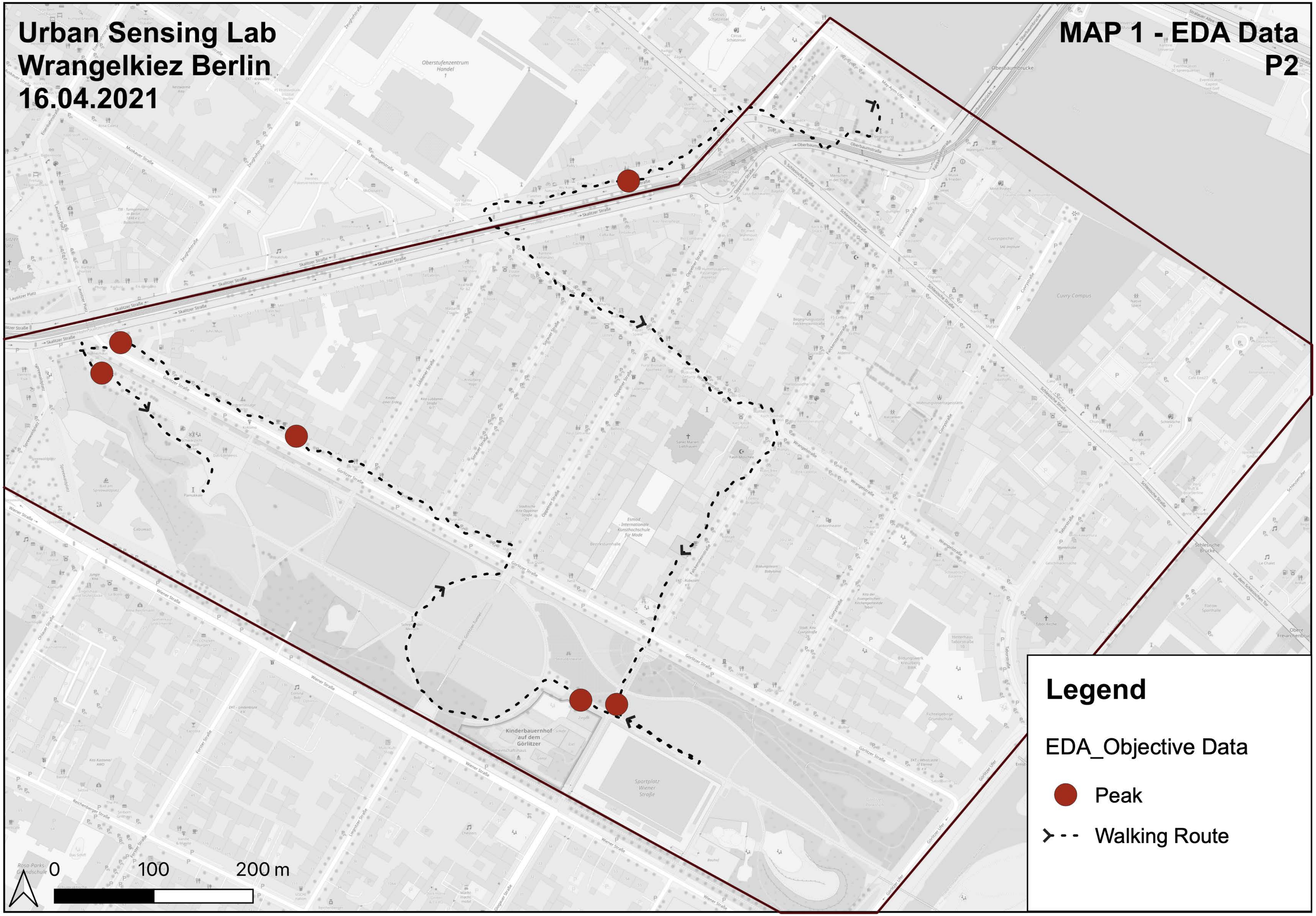
	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen		1			
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.	1				
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas			1		
Die Nachbarschaft ist frei von Beschädigung			1		
Parks und Spielplätze sind in einem guten Zustand		1			
Grünphasen von Ampeln waren ausreichend lang			1		
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander		1			
Es gab genügend Sitzmöglichkeiten entlang des Weges		1			
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden				1	
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg			1		
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg	1				
Sie haben sich sicher gefühlt auf dem Weg	1				
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht			1		
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend		1			
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten		1			
Straßenübergänge sind frei einsichtig gewesen	1				
SUMME	16	24	10	1	**2.83**

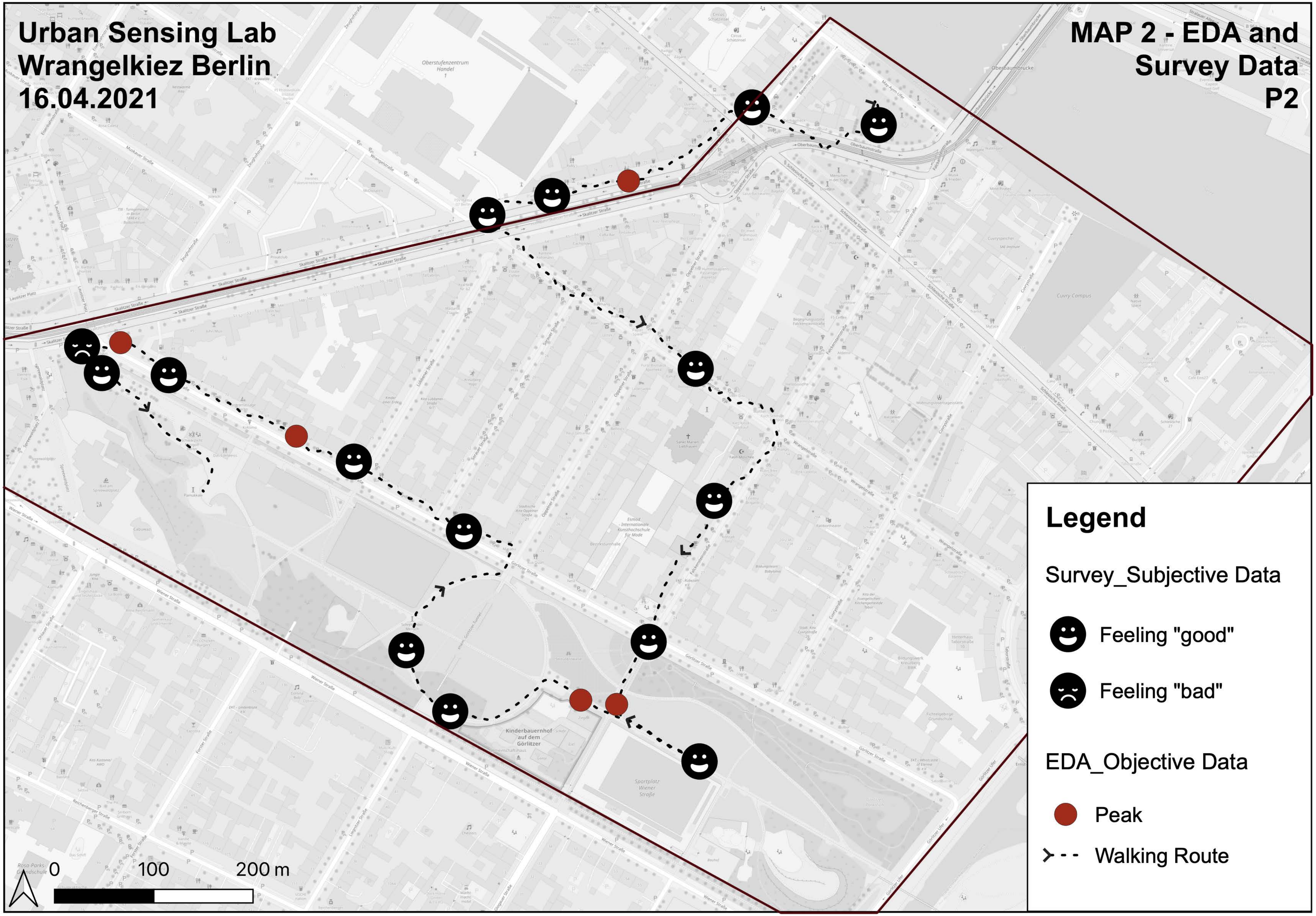
	4	3	2	1	SUM
Die Gehwege sind frei von Hindernissen (Parkende Fahrzeuge, Vegetation etc.)		1			
Begrünung entlang der Gehwege, die eine angenehme Atmosphäre schaffen			1		
Es gibt sehenswerte Gebäude, öffentliche Kunst, Sehenswürdigkeiten etc.		1			
Die Straßenfronten sind insgesamt attraktiv gestaltet		1			
Das Quartier ist frei von Abfall und zerbrochenem Glas				1	
Die Nachbarschaft ist frei von Beschädigung				1	
Parks und Spielplätze sind in einem guten Zustand		1			
Grünphasen von Ampeln waren ausreichend lang			1		
Die Wege boten ausreichend Platz zum Gehen, auch für Kinderwägen, Rollstühle, nebeneinander		1			
Es gab genügend Sitzmöglichkeiten entlang des Weges			1		
Unterstellmöglichkeiten zum Schutz vor Regen oder Hitze/Sonne waren vorhanden				1	
Es gab eine hohe Lärmbelästigung (z.B. durch Verkehr), es war laut auf dem Weg			1		
Es gab eine hohe Geruchsbelästigung, es hat unangenehm gerochen auf dem Weg		1			
Sie haben sich sicher gefühlt auf dem Weg		1			
Sie hätten sich mehr Fußgängerüberwege (Ampeln, Zebrastreifen etc.) gewünscht		1			
Der Abstand des Fußverkehrs zum Straßenverkehr war ausreichend	1				
Autofahrer:innen haben sich an die Geschwindigkeitsbegrenzung gehalten			1		
Straßenübergänge sind frei einsichtig gewesen				1	
SUMME	4	24	10	4	**2.33**

ANNEX XII – MAPS PER PARTICIPANT

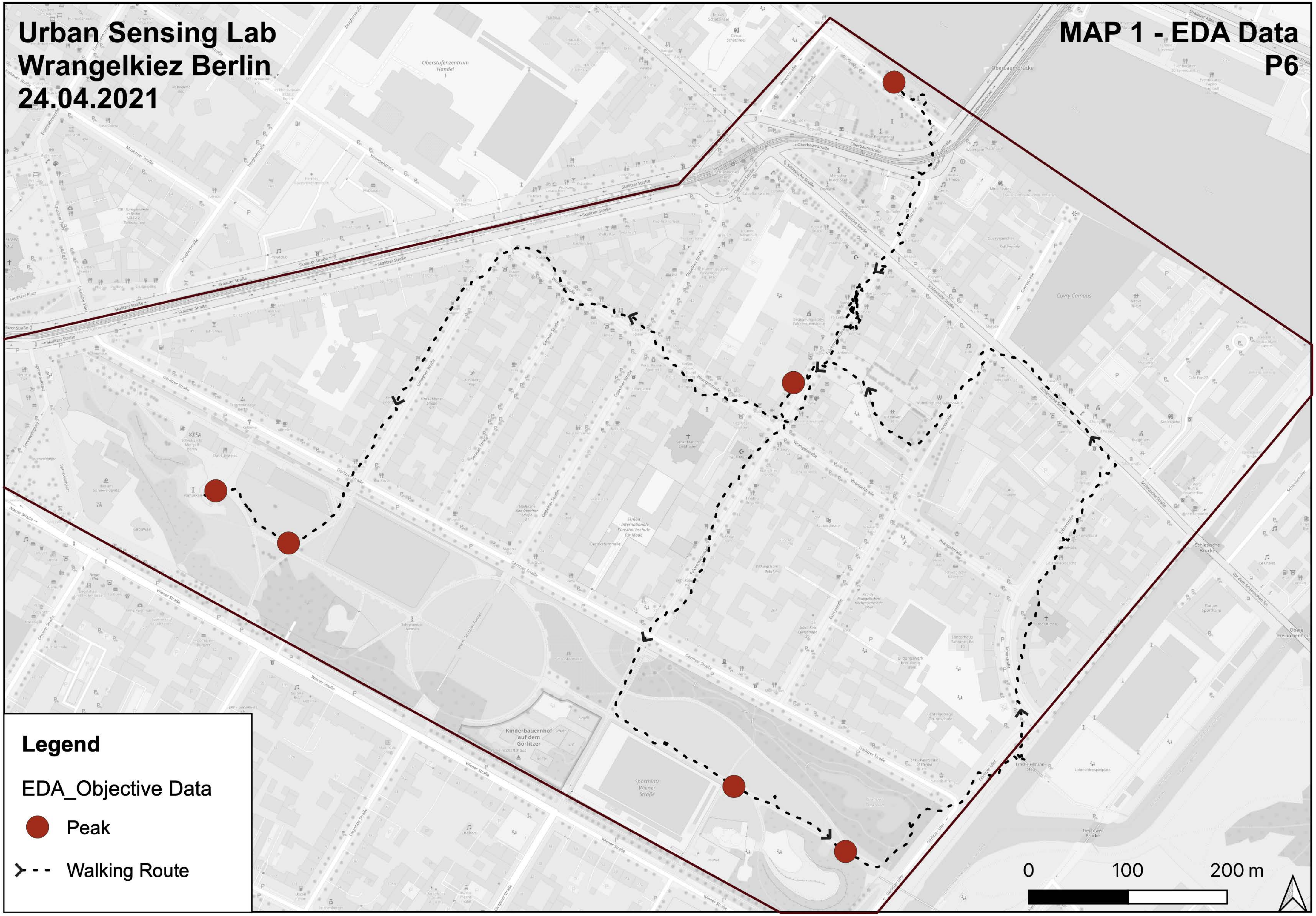

Urban Sensing Lab
Wrangelkiez Berlin
16.04.2021
MAP 1 - EDA Data
P1
Legend
EDA_Objective Data
Peak
Walking Route
0
100
200 m


Urban Sensing Lab
Wrangelkiez Berlin
16.04.2021
MAP 2 - EDA and
Survey Data
P1
Legend
Survey_Subjective Data
Feeling "good"
Feeling "mixed"
EDA_Objective Data
Peak
Walking Route
0
100
200 m

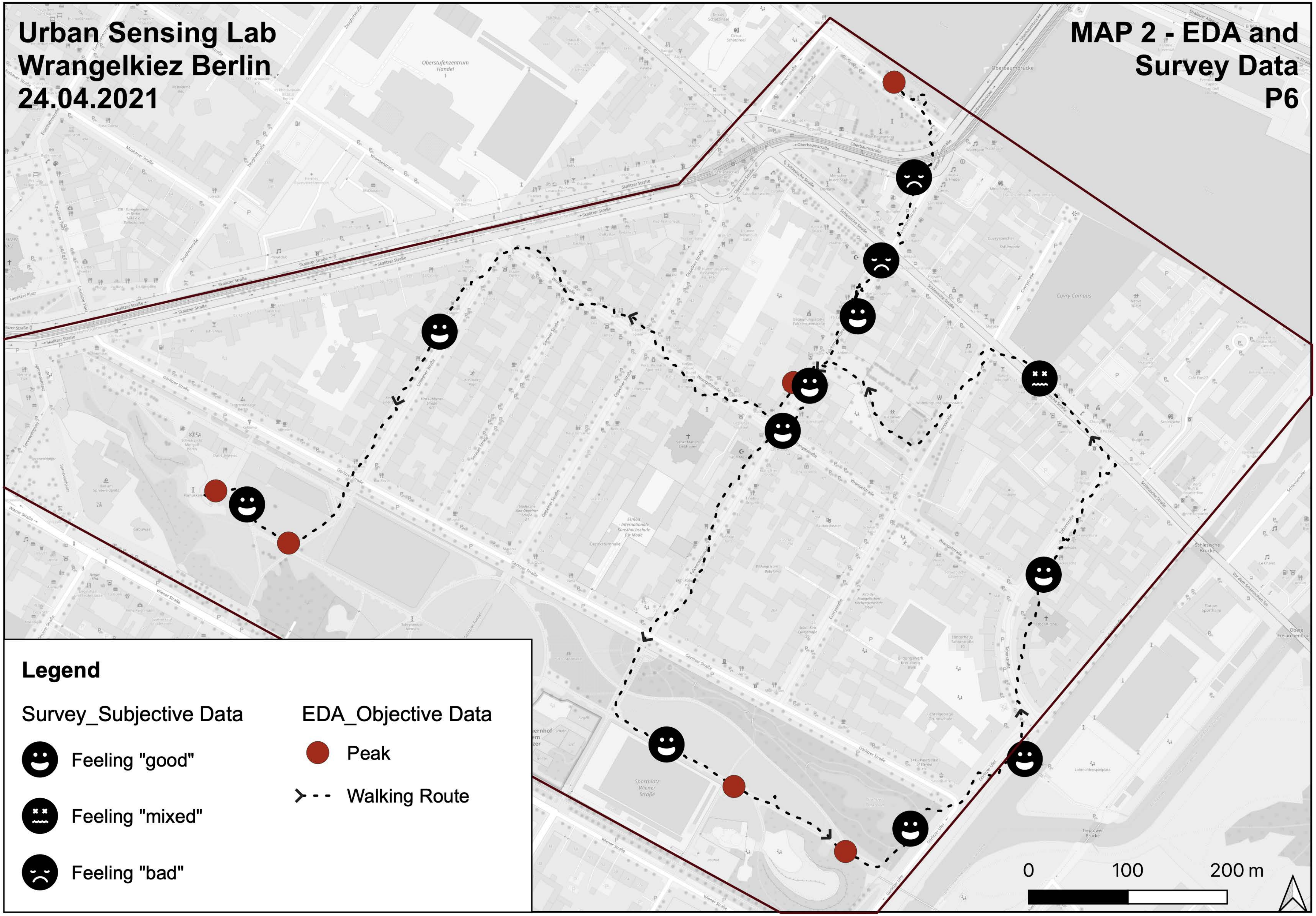

Urban Sensing Lab
Wrangelkiez Berlin
16.04.2021
MAP 1 - EDA Data
P2
Legend
EDA_Objective Data
Peak
Walking Route
0
100
200 m

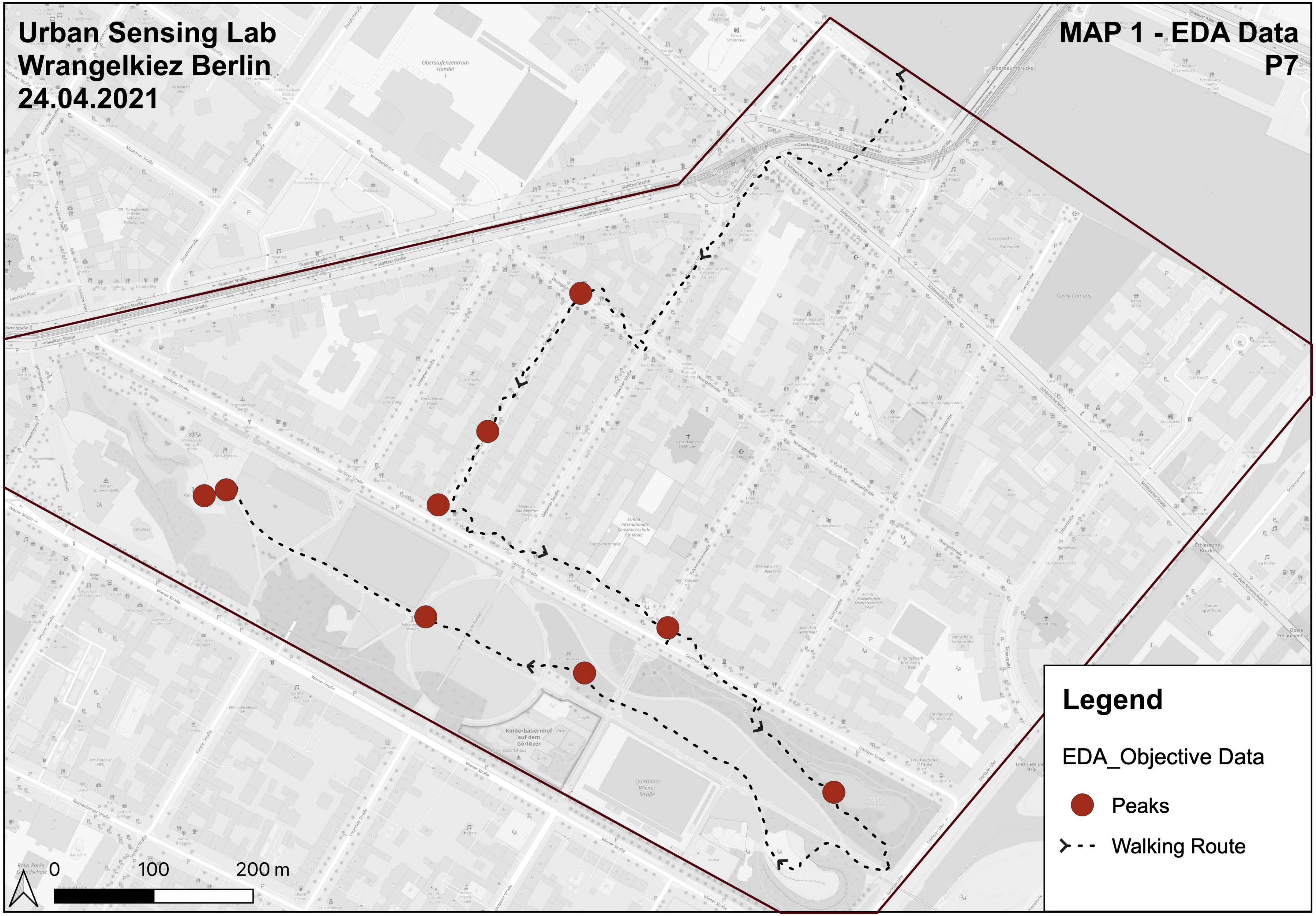


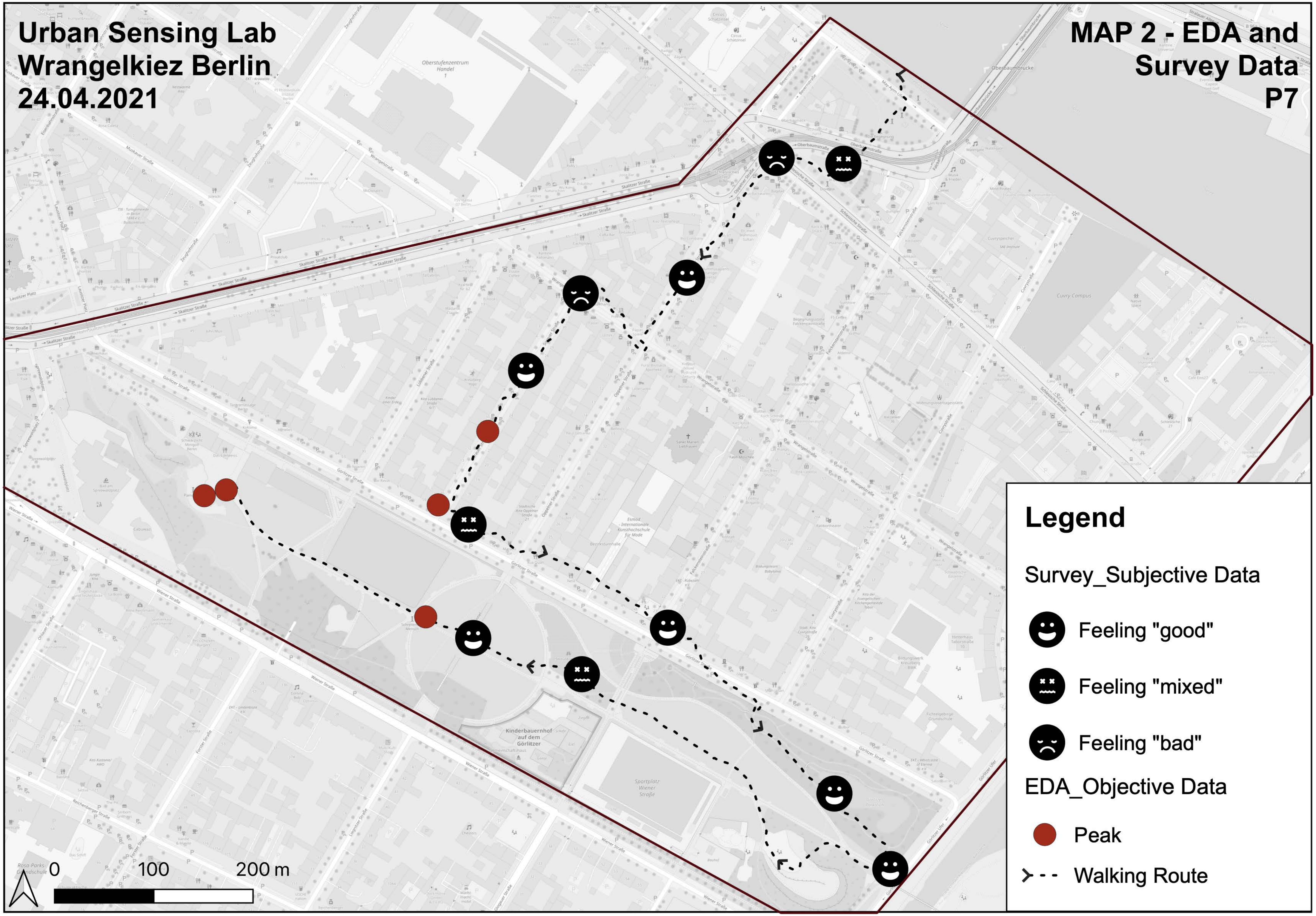
Urban Sensing Lab
Wrangelkiez Berlin
16.04.2021
MAP 2 - EDA and
Survey Data
P2
Legend
Survey_Subjective Data
Feeling "good"
Feeling "bad"
EDA_Objective Data
Peak
Walking Route
0
100
200 m

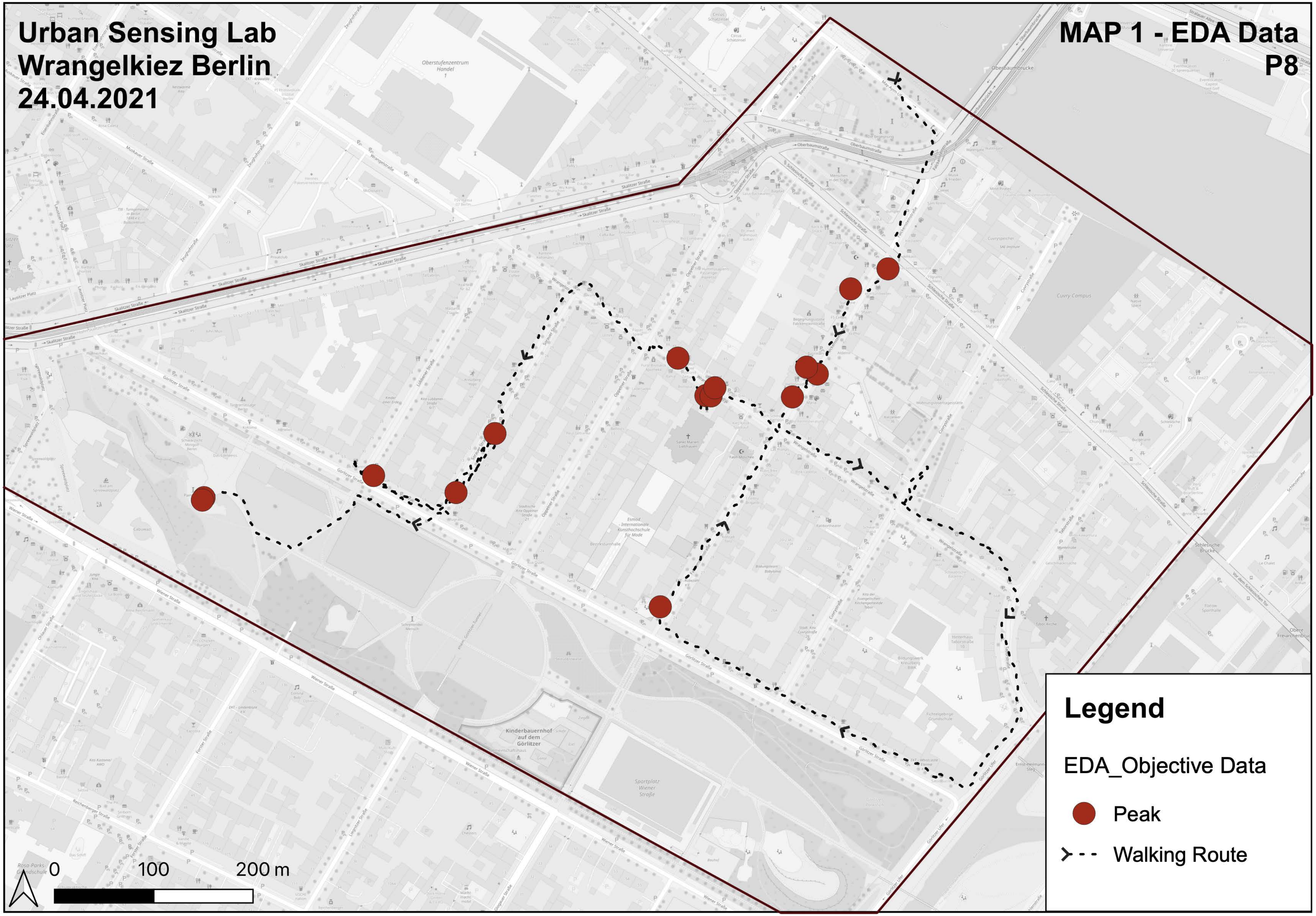


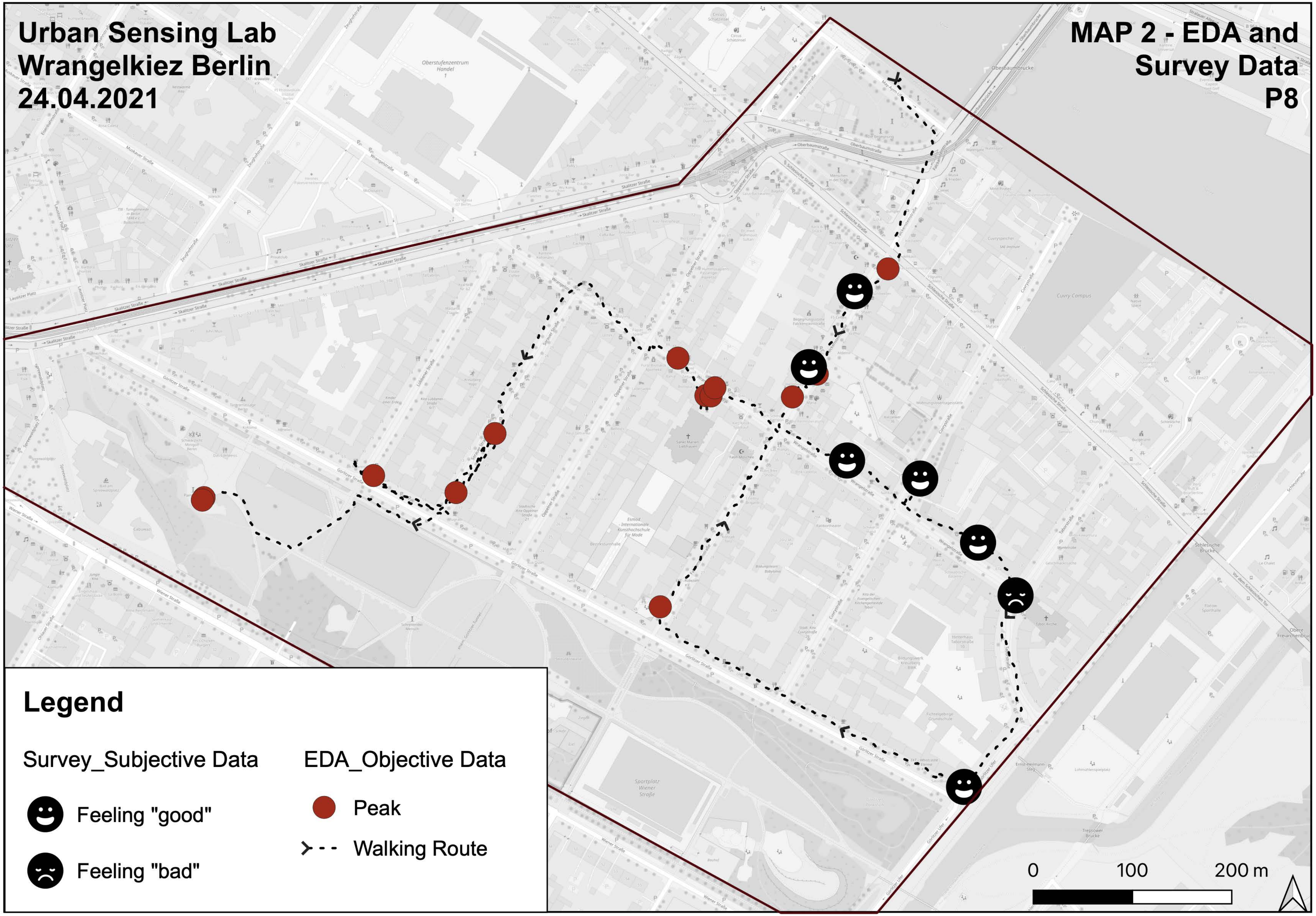
Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 1 - EDA Data
P6
Legend
EDA_Objective Data
Peak
Walking Route
0
100
200 m

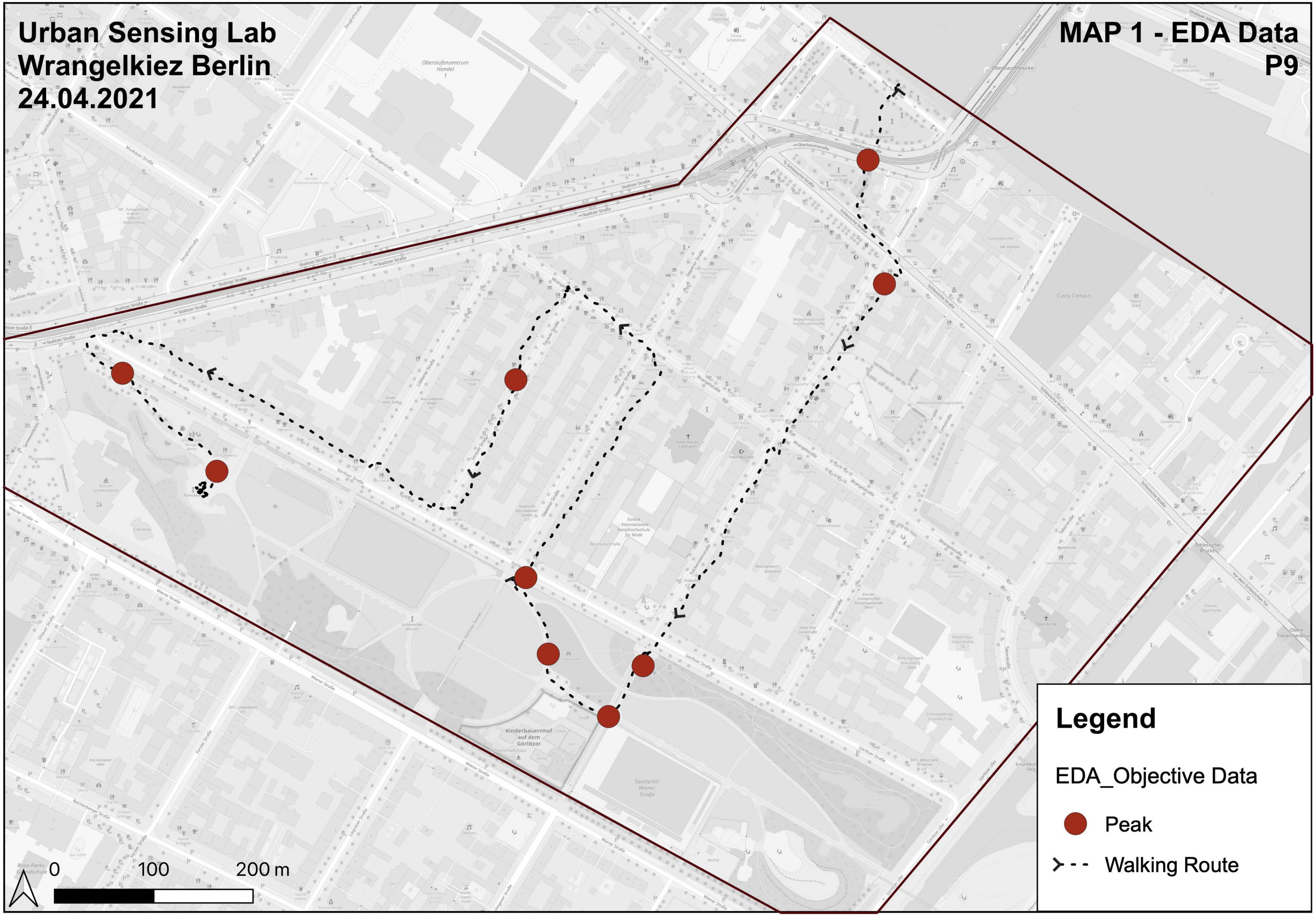

Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 2 - EDA and
Survey Data
P6
Legend
Survey_Subjective Data
Feeling "good"
Feeling "mixed"
Feeling "bad"
EDA_Objective Data
Peak
Walking Route
0
100
200 m

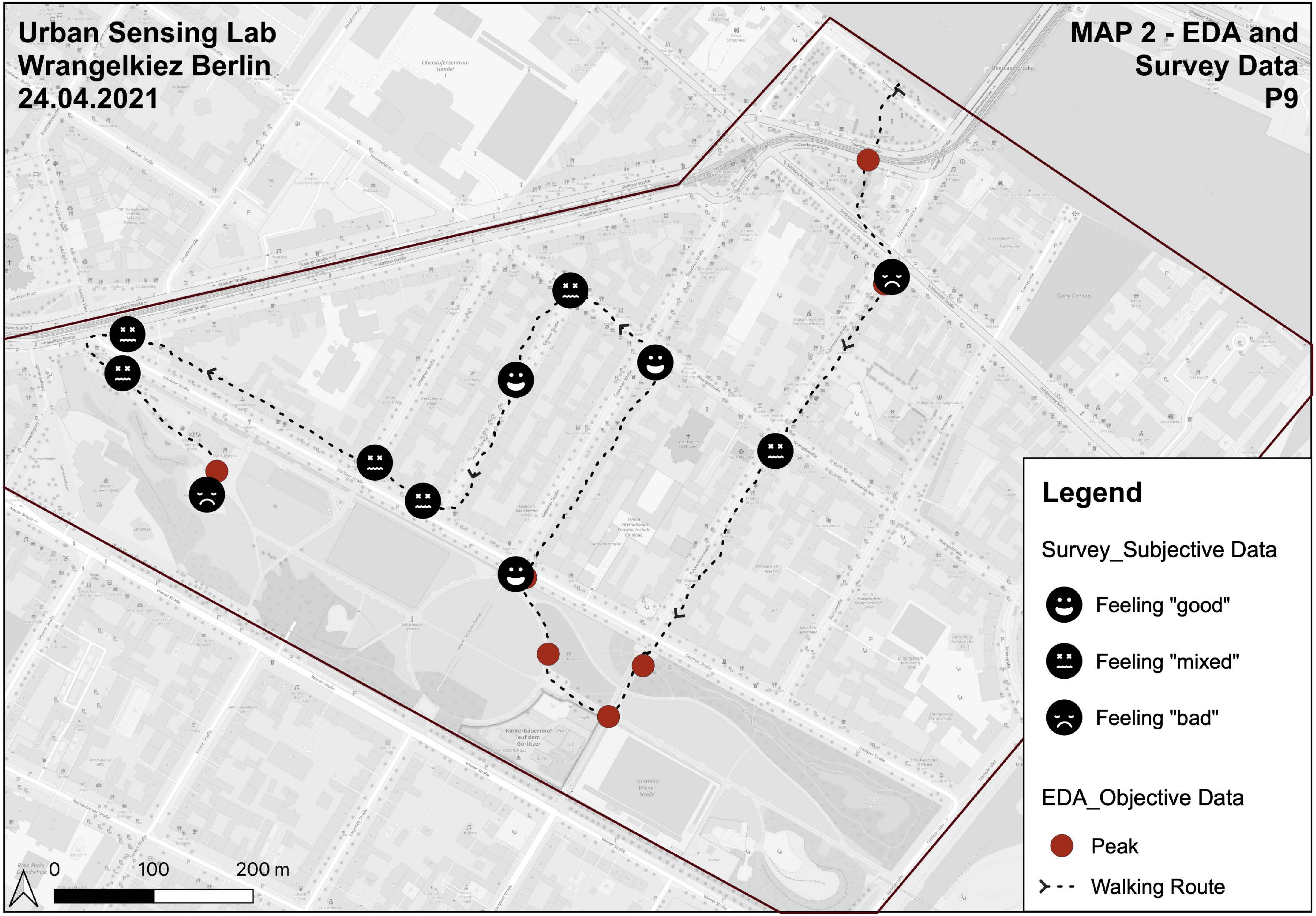

Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 1 - EDA Data
P7
Legend
EDA_Objective Data
Peaks
Walking Route
0
100
200 m
Kinderbauernhof auf dem Görlitzer
Sportplatz Wiener Straße
Curvy Campus


Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 2 - EDA and
Survey Data
P7
Legend
Survey_Subjective Data
Feeling "good"
Feeling "mixed"
Feeling "bad"
EDA_Objective Data
Peak
Walking Route
0
100
200 m


Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 1 - EDA Data
P8
Legend
EDA_Objective Data
Peak
Walking Route
0
100
200 m


Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 2 - EDA and
Survey Data
P8
Legend
Survey_Subjective Data
Feeling "good"
Feeling "bad"
EDA_Objective Data
Peak
Walking Route
0
100
200 m

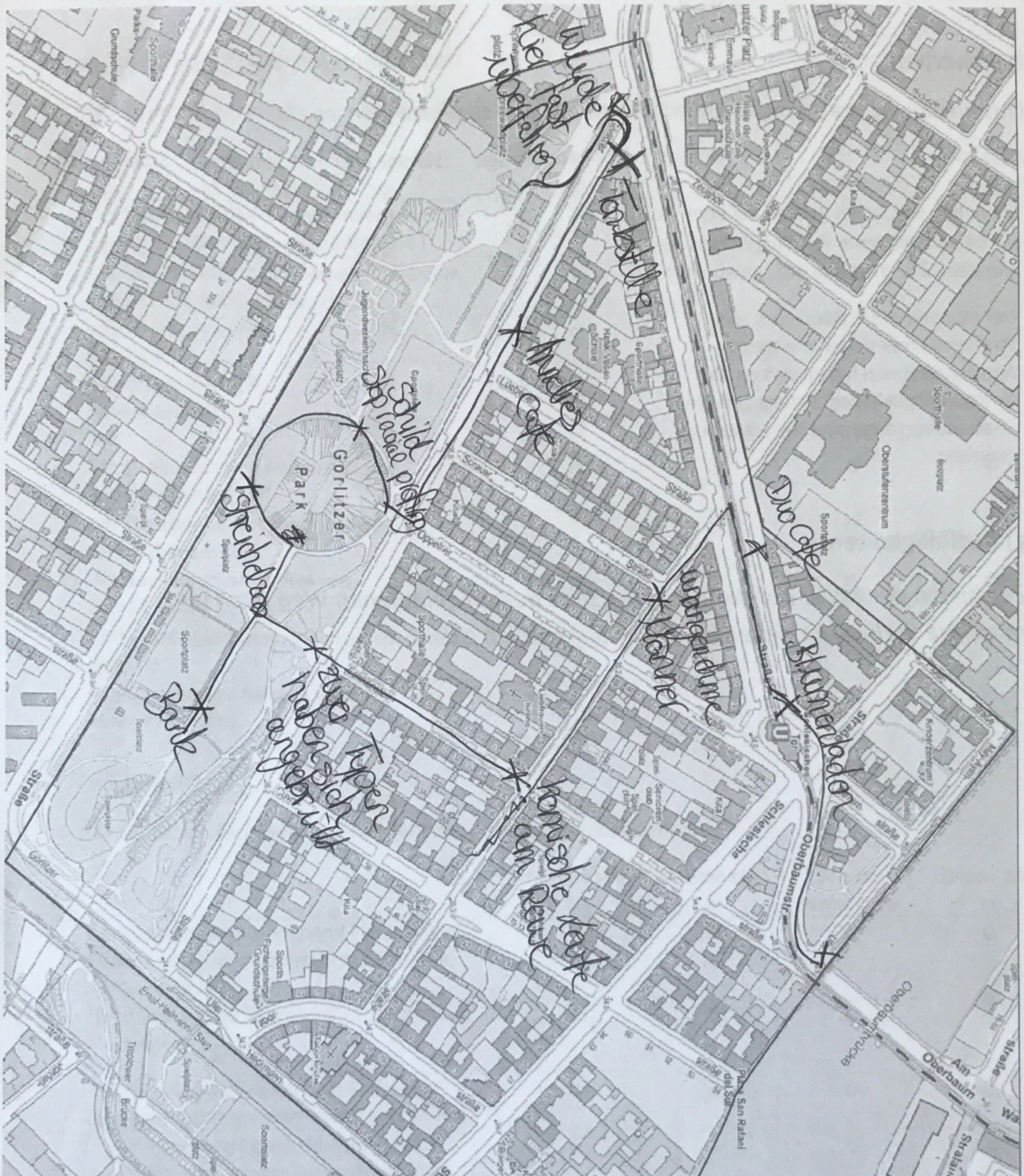

Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 1 - EDA Data
P9
Legend
EDA_Objective Data
Peak
Walking Route
0
100
200 m


Urban Sensing Lab
Wrangelkiez Berlin
24.04.2021
MAP 2 - EDA and
Survey Data
P9
Legend
Survey_Subjective Data
Feeling "good"
Feeling "mixed"
Feeling "bad"
EDA_Objective Data
Peak
Walking Route
0
100
200 m

ANNEX XIII – MENTAL MAPS

Testperson Nr.: 1 Sensor Nr: 2 Datum: Uhrzeit:

Testperson Nr.: 2 Sensor Nr: 1 Datum: 16.04.21 Uhrzeit: 14



Testperson Nr.: 3 Sensor Nr: 3 Datum: 16.04.21 Uhrzeit:

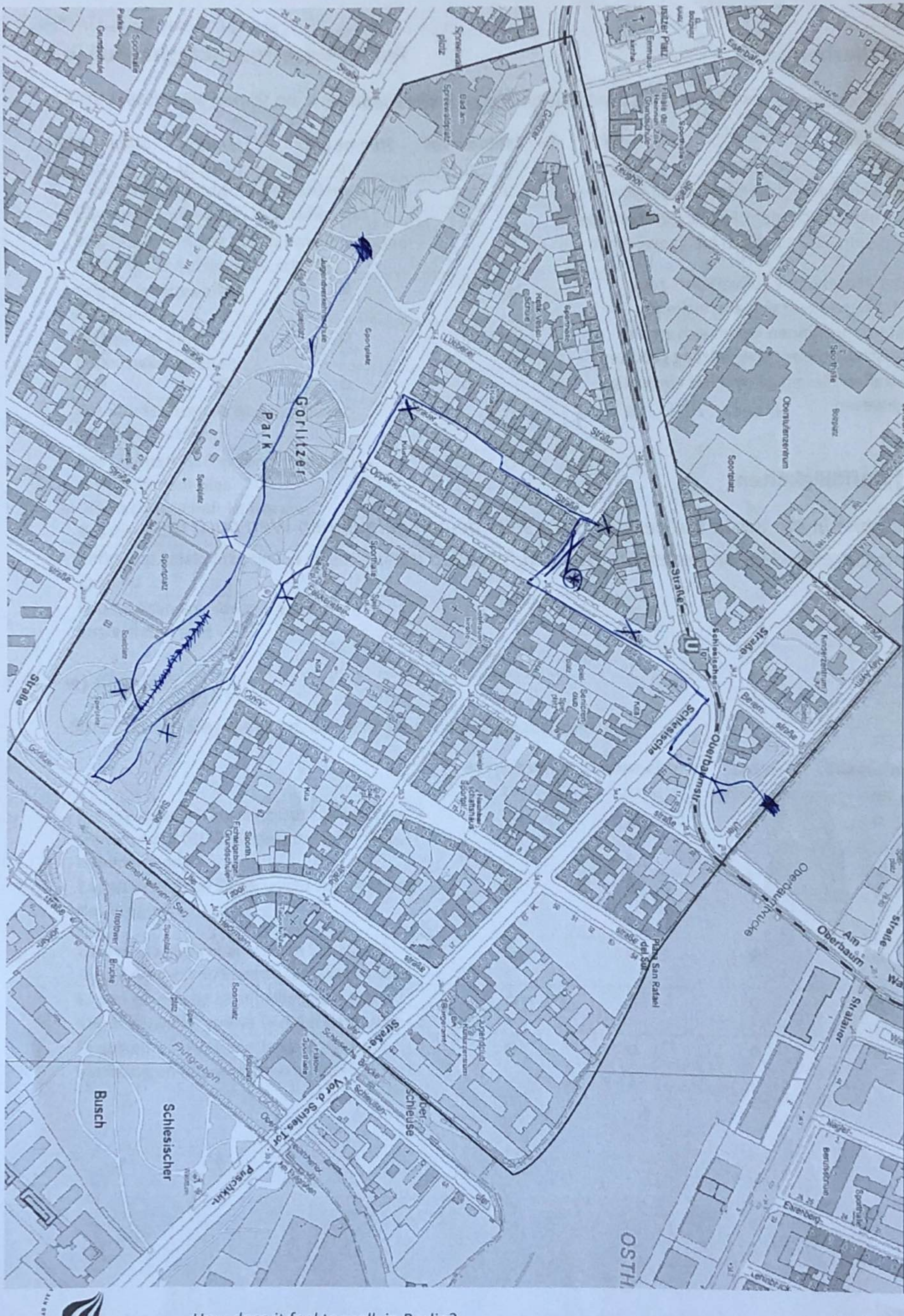
Testperson Nr.: 4 Sensor Nr: 5 Datum: 16.04.21 Uhrzeit:

Testperson Nr.: 5 Sensor Nr: 4 Datum: 16.04.21 Uhrzeit:

Testperson Nr.: 6 Sensor Nr: Datum: Uhrzeit:

⊛ hier in App eine Aussage gemacht: Sehr durchmischte Straße bzgl. Geschäften, Personenkreisen, Atmosphäre

Testperson Nr.: 7 Sensor Nr: Datum: Uhrzeit:



Testperson Nr.: 8 Sensor Nr: Datum: Uhrzeit:

Testperson Nr.: 9 Sensor Nr: Datum: Uhrzeit: