# Approaches of Practice-based Design for Sustainable Everyday Mobilities in Socio-Informatics

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# Abstract

This dissertation aims to contribute to a socio-informatics approach by addressing sustainable everyday mobilities through practice-based design. Supporting the sustainable transformation of everyday mobilities is a rising demand of our times that can profit highly from mobile sustainable interaction design (SID). However, conventional designs to support sustainable mobilities have often been criticized as too rationalistic and normative, ignoring the complex nature of mobility patterns. In particular, design interventions that only address a very specific mobility mode are often revealed to be insulated solutions that do not account how for their further embeddedness in everyday mobility practices. These shortcomings can either be ineffective or have problematic unintended consequences, such as rebound effects (Shove 2010; Banister and Button 2015). To address these issues, I studied SID for sustainable mobilities in real-life settings using a socio-informatic approach. In particular, this thesis examines how SID can be applied to focus on everyday mobilities as habituated practices. Thus, it aims to answer the following question: "How should a practice-based design approach be applied to support sustainable everyday mobilities in everyday life settings?" The research question is examined through the lens of three research fields: first transport information systems (TIS), second shared mobility services (SMS) and third eco-feedback tools (EFT). Therefore, six research studies were completed to study and support the environmental and social sustainability of everyday mobility practices. The studies showed that a practice-based approach addresses SID for everyday mobilities on three levels: first, by elaborating a new methodological understanding to study everyday mobilities as evolving practices; second, by evolving methods and tools that are able to reflect on the development of new mobility practices in real-life contexts; and third, by supporting SID that goes beyond the normative stance but is built upon the practices of everyday life mobilities in the research fields of TIS, SMS and EFT.



**Keywords:** Mobilities, everyday mobilities, transport information systems, shared mobility services, eco-feedback tools, travel behavior analysis, sustainable interaction design, socio-informatic, living labs.

# Content Overview

# List of Figures

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# Publications of the Author

Some parts of this thesis have already been pre-published as articles (journal articles and conference papers,) that emerged in the context of my work. The following publications are included as Chapters within this thesis:

**Meurer, Johanna**; Tolmie, Peter; Stevens, Gunnar; Müller, Claudia; Wulf, Volker (2020): 'Becoming a Smartphone User in Later Life – Supporting Elderly People's Appropriation Practices in R&D Projects'. Reviewed with a 'major revision' in *Journal Computer Supported Cooperative Work (JCSCW)*, 2019. **[Chapter 4]**

**Meurer, Johanna**; Stein, Martin; Wulf, Volker; Randall, David (2018): 'Designing for wayfinding as practices – A study of elderly people's mobility'. In: *International Journal of Human-Computer Studies (IJHCS)*, 2018, 115, 40-51. **[Chapter 5]**

**Meurer, Johanna**; Stein, Martin; Randall, Dave; Rohde, Markus; Wulf, Volker (2014): 'Social dependency and mobile autonomy – Supporting older adults' mobility with ridesharing ICT'. In: *Proceedings of the 2014 ACM annual conference on Human Factors in Computing Systems CHI, (CHI)* Toronto, 1923-1932. **[Chapter 6]**

**Meurer, Johanna**; Pakusch, C.; Stevens, G.; Randall, D.; & Wulf, V. (2020). 'A Wizard of Oz Study on Passengers' Experiences of a Robo-Taxi Service in Real-Life Settings'. In: *Proceedings of the 2020 ACM Designing Interactive Systems Conference, (DIS)* Eidhoven, 1365-1377). The paper achieved an honorable mention. **[Chapter 7]**

**Meurer, Johanna**; Dax, Julian; Stein, Martin; Ludwig, Thomas; Wulf, Volker (2015): 'Bridging Location-based Data with Mobile Practices. Introducing a Framework for Mobile User-Studies' MOBILITY 2015. In: *Proceedings of the 5th International Conference on Mobile Services, Resources, and Users (MOBILITY).* 2015, Brussels. Belgium. 22-41. **[Chapter 8]**

**Meurer, Johanna**; Lawo, Dennis; Pakusch, Christina; Tolmie, Peter, & Wulf, Volker (2019). 'Opportunities for Sustainable Mobility: Re-thinking Eco-feedback from a Citizen's Perspective'. In: *Proceedings of the 9th International Conference on Communities & Technologies-Transforming Communities*, ACM, Vienna, Austria, 102-113. **[Chapter 9]**

# Abbreviations

| | |
|---|---|
| API | Application programming interface |
| Apps | Mobile phone applications |
| $CO_2$ | Carbon dioxide |
| CHI | Computer Human Interaction |
| CSCW | Computer-Supported Cooperative Work |
| EFT | Eco Feedback Tools |
| EUD | End User Development |
| GaNEsHA | Ganzheitlicher Netzwerkansatz zur Erkennung systemimmanenter Hindernisse and Abstimmungspotentiale |
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| HCI | Human-Computer Interaction |
| ICT | Information and Communication Technology |
| INNOLAB | Living Labs in der Green Economy: Realweltliche Innovationsräume für Nutzerintegration and Nachhaltigkeit |
| IS | Information Systems |
| ITS | Intelligent Transport Systems |
| MA | Mobility Analytics |
| MPD | Mobile Phone Data |
| PD | Participatory Design |
| SAV | Shared autonomous vehicles |
| SID | Sustainable Interaction Design |
| SME | Small and Medium Entrepreneurs |
| S-Mobil100 | Sehr Mobil mit 100 - Mobilitätsketten für Senioren in der Modellregion Siegen-Wittgenstein' |

| | |
|---|---|
| SMS | Shared Mobility Service |
| TIS | Transportation Information Services |
| WoZ | Wizard of Oz |

# Part I: Foundations

The first part of this dissertation presents the conceptual foundations of this thesis. Chapter 1 (Introduction) covers the motivation, aims, objectives and structure of this work. Chapter 2 (Related Work) describes related work, relevant concepts and theoretical foundations for the practice-based approach. Based on these foundations, Chapter 3 (Research Design) outlines the research approach, research setting and methodology used for this work.

# 1 Introduction

This dissertation contributes to the research field on sustainable interaction design (SID) from the perspective of practice-based computing. Despite sustainability being a major challenge for humanity, it has a short history in HCI (DiSalvo, Sengers, and Brynjarsdóttir 2010). A seminal paper that is often quoted as the starting point was presented at the Computer Human Interaction (CHI) conference by Blevis in 2007 (2007). With increasing digitalization and the challenges of a sustainable future, SID has become increasingly important for decreasing negative social and environmental impacts on current consumption practices. With regard to mobility, the use of mobile and ubiquitous ICTs has increased in recent years and has major potential to support individual behavior changes (A. Aguiléra, Guillot, and Rallet 2012; Aguilera and Boutueil 2018). A plethora of mobility apps are available today to support users' everyday travel and provide features such as the planning of intermodal trips, usage of new sharing services or behavior analysis and more. This demonstrates that ICTs are a promising path for an accommodation of a more sustainable living, but they can at the same time be part of the problem. For instance, facilitating mobility through ICTs can cause rebound effects, as it can encourage people to travel more. To tackle this issue, this thesis explores how a practice-based approach can be developed and applied to study and support everyday life mobilities of citizen-consumers with SID at the micro level.

## 1.1 Motivation

Over the past 100 years, population and mobility have significantly grown, and the trend of increased travel is likely to continue for decades, at least on a global scale. Increasing means of personal mobility are also highlighted by the German study "Mobilität in Deutschland" (MiD 2018). This is one of the most comprehensive studies on everyday mobility worldwide commissioned by the Federal Ministry of Transport and Digital Infrastructure (BMVI). Over a period of one year, people from more than 150,000 German households reported on their mobility habits. As the world's largest empirical study on private mobility, the report provided a basis for transport planning in Germany. According to the study, Germans travel approximately 3.2 billion kilometers per day. As a result of an increase in population and employment, demand for transport has reached a new high. For instance, on average, each person in Germany travels 39 kilometers per day. Thereafter, mobility trips are conducted 3.4 times for the

majority of us in a day. A similar picture was found in other Western societies. European citizens travel more frequently, over longer distances and faster than ever before for work and leisure (European Commission 2019).

While transport growth is in general widely perceived as economically and socially beneficial and mobility is seen as a key sector of the European economy, negative social and environmental impacts of increased motorized mobility have also been broadly acknowledged:

- Mobility is a top concern in current debates about the transition towards more sustainable patterns of consumption and production. Transport is a major consumer of energy and material resources. Nearly 30% of the world's final energy consumption is used for transport, mostly from non-renewable energy sources (IEA 2012).
- The production of vehicles and transport infrastructure requires large quantities of materials and accounts for 20–40% of the consumption of materials such as aggregates, cement, steel and aluminum (OECD, 2000, p. 28). In addition, transport is a major contributor to local, regional and global pollution of air, soil and water. Transport activities cause approximately 20% of anthropogenic carbon dioxide ($CO_2$) emissions worldwide and nearly 30% in OECD countries (IEA 2012).
- Transport infrastructure contributes to landscape fragmentation and the destruction of habitats and ecosystems, and many public transport systems cannot keep pace with urban and spatial development. Roads consume 25–40% of land in OECD urban areas and nearly 10% of land in rural areas. Worldwide, 1.2 million people are killed on roads each year, and up to 50 million more are injured. Approximately 30% of the European Union (EU) population is exposed to urban traffic noise levels that cause significant nuisance and health problems (OECD, 2000).
- While mobility has increased on average, it has not been the case for all. Marginalized groups such as the elderly, the poor, people with disabilities, women and a growing number of low-income immigrants in developed countries have had little access to transport means, which entails the risk of social exclusion (OECD 2009; 2016).

Regarding these issues, sustainable everyday mobilities are related to both *environmental* and *social sustainability*. In this thesis, environmental sustainability is understood to mean the avoidance

of resources and pollutants, while social sustainability is defined as the possibility of participating in public life through mobility offers. In general, sustainable mobilities are promoted on different levels:

- At the *macro level,* there are major structural and political programs to promote mobility innovations, such as autonomous driving, e-mobility and the creation of new infrastructure standards.
- At the *meso level*, local districts realize specific mobility services such as smart mobility solutions and mobility sharing concepts.
- At the *micro level*, individuals are addressed as citizens and consumers to support socio-environmental change.

This thesis focuses on the micro level. The latter is highly influenced by neoliberal economic policies and the invocation of "choice" as a mechanism for increasing public engagement (Clarke et al. 2007; Giddens 2013). Close to this political reliance, individuals are often addressed in SID as agents for social change (Banister 2008; Barr, Gilg, and Shaw 2011). This places the emphasis on "citizen-consumers" to overtake responsibilities and find ways to reduce their environmental impact on, for example, pollution through shifts in mode choice.

Shove (2010) and Banister and Button (2015) have criticized such conventional design approaches to support pro-environmental behaviors that operate in a rationalistic manner and top-down perspective. They have claimed that models of behavior change that assume knowledge as the major driver in promoting change are insufficient for actually changing mobility practices. To support sustainable mobilities, in particular Banister (2008) emphasized the need for more flexible interpretations of how and why people travel and how they use time. For him, sustainable mobility has a central role to play in the future of sustainable cities, but it is only through the understanding and acceptance by the people that it will succeed.

This thesis agrees with the mentioned critiques about the shortcomings of an individualistic stance based on abstract rational choice models. These often miss to reflect the complex factors that shape everyday-life mobility patterns, such as personal living situation, social network or personal preferences and life-style. Dealing with these short-comings the complexity of mobility in everyday life must be studied more seriously and carefully to better support SID for micro-level mobilities.

## 1.2 Aims and Objectives

This thesis aims to contribute to SID by addressing the above mentioned complexities through a practice-based approach to better support sustainable everyday mobilities. To this end, this dissertation aims to provide answers to the following research question: "How should a practice-based design approach be applied to support sustainable everyday mobilities in everyday life settings?" This addresses a praxeological perspective on individual mobility habituations.

Thus, answering the research question goes beyond considerations about the right design and also requires reflecting on theoretical concepts regarding our understanding of sustainable everyday mobilities and methods for studying them. In particular, SID in everyday mobilities is explored in three contexts: transport information services (TIS), shared mobility services (SMS) and eco-feedback tools (EFT).

In particular, the research question on how a practice-based approach can support SID for sustainable mobility practices is answered according to the following levels:

- What theoretical concepts are needed to study everyday mobilities as evolving practices?
- What methods are helpful for reflecting on the development of new mobility practices in real-life contexts?
- How does a practice-based approach shape SID for everyday mobilities?

## 1.3 Structure of the Thesis

This thesis is divided into three main parts: (I) Foundation, (II) Selected Findings and (III) Analysis.

***The first part***, Foundation, encompasses the first three Chapters: Introduction, Related Work and Research Design.

*Chapter 1 (Introduction)* presents the conceptual foundations and covers the motivation, aims, objectives and structure of the work.

*Chapter 2 (Related Work)* describes the theoretical foundations of the research. It outlines the state of the art of TIS, SMS and EFT. All three research topics present major research fields in the current HCI discourses to address sustainable mobilities.

*Chapter 3 (Objectives and Research Design)* develops the conceptional outline of this thesis. Accordingly, I outline a practice-based perspective on everyday mobilities and the three research fields of TIS, SMS and EFT. Further, I introduce the framework of design case studies and grounded design to study and design for everyday mobilities and finally outline the methods and the research setting of the following studies that are presented in part two.

***The second part***, Selected Findings, forms the main part of the thesis and covers previously published papers that are part of this cumulative dissertation. It includes six Chapters (Chapters 4–9), with each Chapter focusing on one publication.

*Chapter 4 (Becoming a smartphone user in later life)* is about the long-term appropriation process of becoming a smartphone user at an older age. The paper shows how the device and supporting TIS are experienced over time by users and how new technologies support orientation in the environment and even how elderly users perceive their self-identify.

*Chapter 5 (Designing for way-finding practices)* explores the everyday use of TIS by the elderly, including how this technology can support them in their everyday mobility practices as well as its shortcomings and potential to overcome experienced mobility barriers.

*Chapter 6 (Social dependency and mobile autonomy)* concerns the informal ridesharing practices of elderly adults and compares these to other forms of everyday travel. The study identifies expectations, fears and practical issues related to ridesharing, with a special focus on feelings of dependency and autonomy.

*Chapter 7 (A Wizard of Oz Study on Passengers' Experiences of a Robo-Taxi Service in Real-Life Settings)* explores how passengers experience robo-taxis as a service in real-life settings to inform the interaction design of a robot-taxi service. We conducted a "Wizard of Oz" study in which the driver was hidden from the passenger to simulate the service experience of using a robo-taxi. The findings provide insights on four design themes that could inform the service design of robo-taxis along the different stages of hailing, pick-up, travel and drop-off.

*Chapter 8 (Bridging location-based Data with mobile phones)* outlines a prototype to select personal mobile phone data of individual mobility patterns. In particular, the paper concerns the connection of automatically and manually collected data that can provide more insight on personal mobility contexts.

*Chapter 9 (Opportunities for sustainability design)* uses an eco-feedback approach to study the potential of mobile phone data to study and support sustainable mobility practices. The results showed diverse approaches to using such datasets (e.g. in smart city approaches to support better mobility planning by local municipal city services).

***The third part*** of the thesis, outlines the results to answer the question, how a practice-based design approach should be applied to support sustainable everyday mobilities. The findings indicate that SID must be adjusted in three ways: the theoretical conception, methods and design. This part concludes with an overall summary, critical reflection and an outline of possible future works.

*Chapter 10 (Understanding and Designing from a Practice-based Lens*) argues that moving beyond behavioral and rational models on sustainable mobilities requires an alternative theoretical conception to study everyday mobilities as evolving practices. Therefore, I develop a practice-orientated understanding of moving in space. Furthermore, I outline the methods and tools used to apply a practice-based approach in the three research fields of TIS, SMS and EFT. To conclude, I outline the main outcomes for the related SIDs to support everyday mobilities.

Finally, *Chapter 11 (Summary, critical reflection and future works)* summarizes the findings and provides a conclusion. Furthermore, limitations and recommendations for future research that can be developed from the thesis' insights are discussed.

# 2 Related Work

In this Chapter, I introduce the relevant themes for this thesis. They are divided into three vertical themes and two horizontal themes (see Figure 1). The first horizontal theme is *sustainable interaction design* (SID). It is understood as interaction design in HCI that aims to support future ways of sustainable being. The second horizontal theme is *mobility analytics* (MA), which describes tools and mechanism to track and learn more about the user and they mobility behavior.

The vertical themes address the micro level of everyday mobilities and refer to three main themes in the current HCI literature. The first vertical theme is *transport information services* (TIS). The research investigates how technologies facilitate the management of mobility though access to real-time information: better routes, arrival time of the next bus, comparison of the performance of different modes on a route (in terms of cost, speed, CO2 emissions, calories burned, etc.). The second vertical theme is s*hared mobility services* (SMS). It investigates how the arrival of digital technologies in the field of passenger transport fostered the development of new mobility services. SMS have either changed the operating conditions of existing services such as taxis, bicycle rentals and car rentals or developed new shared mobility services (e.g. car sharing and ridesharing). Finally, the third vertical theme is *eco-feedback* (EF). Related research analyzes and models individual travel behavior with support from different mobile tools. These approaches offer new prospects for transformation in travel practices. Later in the thesis, the three vertical themes on the micro level are introduced and outlined in terms of their current restrictions and potential to support sustainable everyday mobilities.

The two horizontal themes both shape the three vertical themes. SID and MA provide a fertile ground from which the vertical themes develop. While SID can be understood a comprehensive paradigm for TIS, SMS and EFT, MA builds the central technical basis that the three topics have in common.

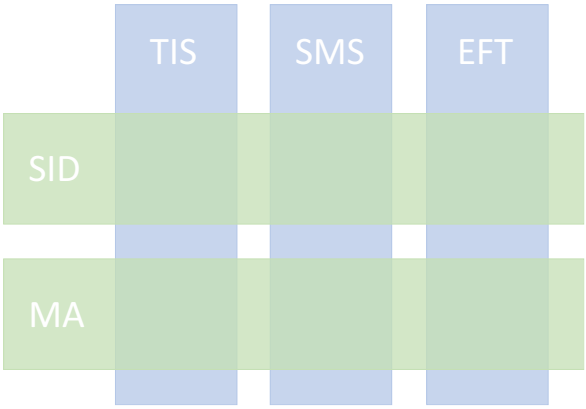


**Figure 1. Landscape of related work: horizontal themes (SID and MA) and vertical themes (TIS, SMS and EFT).**

## 2.1 Sustainable Interaction Design

Sustainability is one of the great challenges of our time. The digitalization of all areas of life plays a dual role in this. On the one hand, digitalization is accompanied by an increase in power consumption (e.g. for online streaming services or through the mining of Bitcoins). On the other hand, digitization enables the optimization of production processes, traffic flows, enterprise resource planning and more or to better coordinate the production and consumption of resources. In HCI, sustainability has become a special topic with regard to supporting, inspiring or persuading people to adopt pro-environmental behaviors (e.g. Blevis 2007; DiSalvo, Sengers, and Brynjarsdóttir 2010; Dourish 2010; Pierce et al. 2013).

Traditionally, HCI has had a strong focus on the micro level of individual behavior. This is especially the case for EFT. Such ego-centric design approaches have been criticized by authors such as Shove (2010) and Banister and Button (2015). They have asserted that (pro-environmental) behavior models operate only in a rationalistic and linear manner that assumes knowledge as the major driver in promoting change. In his manifest for a sustainable mobility paradigm, Banister (2008) wrote the following:

> *The sustainable mobility paradigm goes beyond the actual measures and attempts to understand the reasons behind effective implementation. The concepts of travel as a derived demand and time minimization have been questioned, and a case made for more flexible interpretations of why people travel and how they use time. Effective implementation of sustainable mobility requires the engagement of key stakeholders, so that they can understand the reasoning behind different policy initiatives and support their introduction. […]*

*Sustainable mobility has a central role to play in the future of sustainable cities, but it is only through the understanding and acceptance by the people that it will succeed.*

However, while the transport sector produces technological and organizational innovations at a fast pace, these do often not necessarily enhance the sustainability of everyday mobilities. In particular, the complex grown nature of mobility patterns have often been neglected. Isolated interventions, which employ single instruments to address single, isolated problems, are frequently turned out as either ineffective or produced problematic unintended rebound effects (Pakusch, Stevens, et al. 2018; Stevens et al. 2019). Examples include e.g. the introduction of free Park and Ride options to reduce congestion in inner urban centers, which can tend to attract more car travel (Clayton et al. 2014); the promotion of bike and ride (Martens 2007); and free bus rides, which induce low value travel, and a reduction in cycling rather than of car use (Van Goeverden et al. 2006).

Furthermore, mobility needs regarding TIS and SMS vary considerably among different parts of the population in diverse locations and mobility settings. In addition, mobility practices are deeply entrenched in people's everyday needs, practices and lifestyles. Travel decisions are taken locally. What is appropriate for one place, may be inappropriate for another. Furthermore, users often assess transport options against their individual needs and values; as a result, social and economic aspects such as the accessibility of the work place or the convenience of the travel experience often trump environmental or social considerations relate to sustainable mobility (Holden 2012; Berger et al. 2014).

In addition, even if travel mode choices appear to be voluntary and deliberate decisions from the individual perspective, everyday mobilities are deeply grounded in grown structures that have developed mostly over a long period of time. These are often unconsciously realized as seemingly simple everyday performances and have become a part of the personal lifestyle. Multiple complex factors shaped mobility patterns such as the personal living situation, the social network or personal preferences. These patterns are taken for granted in everyday life and become visible at the analytical level only. This thesis shares the critique about the shortcomings of an individualistic stance based on abstract rational choice models. Based on these challenges the complexity of mobility in everyday life must be considered more seriously that include not only environmentally sustainability, but the social, too.

## 2.2 Mobility Analytics

Digitalization enables new opportunities for MA to track and analyze personal mobility behavior. As smartphones have become increasingly personal companions that are always powered on and carried by the user, they can generate huge datasets of individual mobility behavior and became important tools for MA. These datasets contain a diversity of data types, among which detailed abundant locational and motivational information is conveyed using various collection methods (Järv, Ahas, and Witlox 2014; Chen et al. 2016). The data can be processed in real time, but it can also be stored over long periods of time to detect mobility patterns and create mobility profiles. As a result, the localization of smartphone devices has become a key data resource. There are different but not mutual exclusive strategies.

The first one is to make use of the mobile network's infrastructure, in which location data are "passively" collected by operators. This involves call detail records and floating phone data.

A second strategy also includes other access points such as Bluetooth and Wi-Fi networks that connect to access points (Bonnel, Fekih, and Smoreda 2018). These datasets originate from mobile applications that collect the geolocation of their users. Apps such as Google Maps and Apple Plans collect data for en-route guidance, self-monitoring of activities such as running, different kinds of location-based services, marketing analysis of user's activities and spatial practices in order to detect consumption styles, tastes and desires.

A third strategy is based on global positioning systems (GPS). Such sensors have become a commodity in modern smartphones. Operating systems such as Android provide a location application programming interface (API) that combines several information sources (multi-source data) to achieve greater temporal and spatial precision (Zhao et al. 2016). Location data is then normally collected passively various installed apps. The tracking of mobility data is closely linked with its analysis, such as to identify movement phases, travel modes, places and activities and gain information on the populations performing the activities.

Methods to infer *mode* can be based on very different data sources such as cellular network, accelerometer or other phone sensors. Average speed has been used to infer mode and is sufficient to make a distinction between walking and mechanized modes (Zheng et al. 2010). Feng and Timmermans (2016) reported success rates of over 90% in their comparison of several methods based not only on an algorithm but also identified patterns, sensors, types of factors,

urban setting and data used to validate the inference. Similarly, Bluetooth and Wi-Fi data improve the accuracy of activity-type inferences. Data from calling and app use patterns can also improve accuracy (Do and Gatica-Perez 2014). The two categories of "home" and "work" comprise the primary focus of most mobility analytic studies and have had the highest success rates amounting to 90% (Yin et al. 2017). Recognition of other activities has had a relatively variable success rate within different papers, but it does not tend to exceed 70%. To identify an activity, two main pieces of information are used: temporal information and exogenous geographical information system (GIS) data. Temporal information can include the day of the week, time of day, duration of the activity and the frequency a person has been visited a specific place (Alexander et al. 2015).

Furthermore, much effort has been dedicated to the identification of *places*. The latter are normally identified by clustering points that should belong to the same place despite points being separate due to the lack of precision with data (Chen et al. 2016). For instance, Xiang et al. (2016) compared different parameters to assess which of their algorithms identified the closest number of "true" stops as reported by individuals. They found 74 stops (with a maximum distance between two points inferior to 50m). However, the disadvantage of using low thresholds is that very short activities, such as drop-offs, pick-ups and quick purchases, are difficult to identify, whereas being held up by traffic, stopping at a traffic light or waiting for the bus may erroneously be identified as stops. In interviews based on users' automatically discovered locations, Zhou et al. (2012) found that users have an average of 20 significant places and encouraged further research to identify appropriate categories for location labels and activities. Barkhuus et al. (2008) differentiated four labels of geographic references, personally meaningful places, activity-related labels and what they called "hybrid labels." Furthermore, Lin et al. (2010) augmented this classification by adding more fine-grained categories and organizing them according to a hierarchy. Studies such as Lian and Xie's (2011) have proposed a location-naming approach based on mobile sensing information such as user check-in histories. Chon et al. (2013) developed a system that automatically extracts a wide range of semantic features about places from crowdsensing data and social networks.

This outline demonstrates that MA can be a promising approach to know "what people [are] doing in space and time" (V. Aguiléra et al. 2014). Tracking on a large scale, in combination with mode identification, allows a dynamic analysis of flows and travel times. With the help of such data demand peaks to supply disruptions can be monitored. The field of transport is highly

impacted by private companies such as Google (though Sidewalk Labs, the Google Maps app or Waze) and Uber (through its various mobility services and its data platform, Uber Movement). In addition, there is a rising market for companies to create new mobility or urban services, new datasets via individual choices and feedbacks and new relationships with public stakeholders regarding data provision. Derived travel data could enable transit operators, planners and researchers to conduct in-depth analysis of service quality more efficiently, whether on public transit or road networks (V. Aguiléra et al. 2014). The analysis can include information regarding the balance between travel demand and transport supply, which is evaluated using criteria such as network saturation, link betweenness, centrality and intensity of road use (Toole et al. 2015). Information like that can make significant practical implications for cities, as it enables them to characterize detailed traffic conditions like critical elements, such as where congestion is likely to occur. Furthermore, MA is becoming an increasingly important part of transit system management. By locally implementing sensors in passengers' mobile phones, transport timetable schedule information can be updated in real time in order to estimate transport traveling routes and predict vehicle arrival time (Zou et al. 2014). Some mobile apps have been developed to report and visualize real-time public transport information. For example, TrafficInfo is an app that provides real-time transport information for a given city on Google Maps (Farkas et al. 2015). In the following Sections (2.3 – 2.5), I outline how the three vertical themes relate to MA in particular.

## 2.3 Transport Information Systems

The first vertical theme, TIS, has a long history, from its beginnings with paper-based timetables to smartphone apps such as DB Navigator and Google Maps. In particular, TIS are used with MA to optimize travel time. In that regard, Balakrishna (2013) has highlighted that access to traffic information can avoid peak time traffic congestion in which people leave for work at different times. In a similar vein, Clayton (2012) has reported that people use TIS to time their departures precisely with bus arrivals in order to minimize waiting time. Mobile TIS are also an important element in intelligent traffic management, enabling car users to adjust their timetables and journeys using real time-route optimization to avoid congestion, quickly find a parking space or a charging terminal for an electric car and more. This is also covered in a study by Nyblom (2014a), in which he demonstrated that people use TIS to address questions such as which route to take when traffic congestion is reported or which alternatives are available when

a train experiences a lengthy technical problem. In addition, public transport users could be supported with real-time information on timetables and reasons for a disruption (Ben-Elia and Avineri 2015). Furthermore, on smartphones, a growing number of mobility support apps use collaborative data such as data produced by users for other users (e.g. Waze, Moovit and Twitter; Dickinson et al. 2015).

With regard to SID, there is often an expectation that these mobile apps will support environmental sustainability by encouraging practices that are more multi-modal (i.e. use several modes) and intermodal (i.e. use several modes within the same trip), thereby altering the mode to reduce the use of private cars. The argument is that these apps can increase the fluidity of a fragmented transport system on a regional scale, thus promoting intermodal practices. The idea is that individuals will be encouraged to change their behaviors based on the benefits of intermodal journeys (.e.g. cost, time, environmental impact, etc.; De Souza e Silva 2013). However, only a minority of studies, such as the one by Shaheen et al. (2017), have found that the use of multimodal apps contributes to reduced vehicle use. However, this assumption contrasts with several other empirical studies. Some have shown that simply providing more comprehensive real-time information is insufficient for prompting a significant proportion of car users to switch to public transport. In this regard, the evaluation of Optimod, a multimodal calculator implemented in the city of Lyon in France, did not reveal any significant impact on modal choice. Although participants were provided with an advanced multimodal route calculator, hardly any changes were observed by the users who tested the device (Pronello, Veiga-Simão, and Rappazzo 2016). Sunio and Schmöcker (2017) have indicated that this could lead to unintended time rebound effects that reinforce the marked share of car use. Furthermore, Christin et al. (2014) analyzed how mobile professionals living in the Jakarta urban area made real-time adjustments to their day-to-day activities using smartphones, with the result that they actually traveled more than before. Anderson (2014) reached a similar conclusion in a study on taxis in several Southeast Asian cities. Taxi drivers could more easily adjust their rides and thus increase customer numbers on average by using mobile apps that provide a better match between supply and demand. Overall, TIS appears to support marginal adjustments and optimize existing mobility practices rather than reflect modal choices motivated by environmental sustainability.

Hence, the findings regarding ecological sustainability are perhaps unsurprising, given the considerable literature about the determinants of modal choice. In contrast to utility theories that explain modal choices through factors such as cost, transport time and comfort, it has been

shown that mobility infrastructures, habits and social norms are also crucial factors (De Witte et al. 2013; Tyrinopoulos and Antoniou 2013; Mokhtarian, Salomon, and Singer 2015). This insight has significant implications for the design and use of TIS apps. Apart from the fact that it can be difficult to absorb and respond to multimodal information in real time, people do not choose mode on a trip-by-trip basis but as a part of their daily or even weekly schedule of activities that entails a sequence of different journeys, only some of which could be transferred to public transport without excessive time loss. In other words, realizing that it might be advantageous to make some of these trips on public transport will not necessarily lead people to change mode, especially when they own a car and it seems more cost-effective to use it, as taking public transport would require buying tickets upfront. While some of the factors that determine modal choice are practical (e.g. transport of children or packages) or cognitive (e.g. habits or dislike of social mixing in public transport) in nature, others are symbolic and defy purely economic or logistical rationales (De Witte et al. 2013). In addition, research has shown that adherence to ecological values is insufficient for most people to switch over to car alternatives (Brynjarsdottir et al. 2012). Hence, individuals are more likely to use TIS to improve, ease or adjust their existing travel practices rather than make any substantial changes to transport modes.

In addition to their smaller impact on ecological sustainability, TIS are expected to make a greater difference with regard to social sustainability. They are especially useful in situations where re-scheduling travel routines becomes relevant due to unforeseen circumstances such as scheduling delays, accidents or traffic congestion. Stein et al. (2017) have highlighted that elderly people in particular felt that using TIS was more secure when unexpected travel changes occurred. There are strong indications that TIS have great potential to support social sustainability, particularly for certain user groups such as the elderly, as Stein et al. (2017) mentioned. The elderly and people with special needs, for instance, could be supported through additional information on the accessibility of different places and how to reach their destinations more safely. Furthermore, other user groups, such foreigners who are new to a city, people who just moved or refugees, could be supported to find places of interest (Dieberger et al. 2000).

In such cases, TIS go beyond pure transport information and must consider the special use contexts of these user groups and their mobility practices. However, save for a few exceptions, little research has been conducted on this topic thus far, which is explored in the following findings.

## 2.4 Shared Mobility Services

The second vertical theme focuses on SMS, mainly ride-sourcing and carsharing services but ridesharing in particular. Recent trends towards diversification in urban mobility services have been observed in developed cities and identified as the outcome of mobility's entry into the "sharing economy" in the late 1990s (Le Vine and Polak 2015; Shaheen et al. 2017). The term "shared mobility" is used in the broader context of the sharing economy defined by Le Vine and Polak (2015) in the following way:

> *Shared-mobility sits within the broader phenomenon that has been termed the 'Sharing Economy', in which widespread usage of emerging information and communications technology (ICT), particularly smartphones, enables new form of marked interactions that can enable both new services and improved efficiency in asset utilization. Rather than individual physical items being purchased, owned, controlled, maintained and used solely by their owner, in shared-mobility systems the physical assets (bicycles, automobiles, small aircraft, etc.) are accessed sequentially by multiple users on a pay-per-use basis.*

Services associated with shared mobilities, which are often described as "new" or "innovative" in the literature, have in reality been around for decades in one form or another and were already used before the arrival of the smartphone. This is especially true for carsharing and ridesharing services (Jittrapirom et al. 2017). Access through mobile apps, however, has radically changed the availability and use of such services. In particular, in case of vehicles such as cars, bicycles and scooters, SMS makes it possible to locate them in real time and reserve the mobility service at any place and at any time. Mobile access is viewed as a driver for the growth of the shared economy.

Carsharing services are growing particularly rapidly in large cities, often with competition between multiple players. They are primarily based on fleets of (often electric) self-service cars such as Zipcar and Car2Go that can be accessed exclusively via mobile applications. Some require the vehicle to be returned to the pick-up point (round trips), while free-floating services do not (Jorge and Correia 2013). In Germany, carsharing is a predominantly urban phenomenon. In 5% of all households, at least one person is a customer of a carsharing organization. In metropolises, this figure is much higher at 14% (MiD 2018). Hence, in Germany, users of carsharing services have a fairly specific profile, which raises the question of how such services may spread to other population segments. In particular, current studies on carsharing have

shown that users either own a car but want to use it less frequently, do not want to buy another (second) car or do not own a car and opt for carsharing when they must take an automobile trip. Therefore, carsharing often coincides with practices that are already multimodal and tends to involve households with few or no cars whose members are interested in controlling or reducing their transport costs (Schaefers 2013). Existing studies have further demonstrated that shared vehicles are used firstly for occasional trips and as a complement to public transport. However, the overall effect of carsharing on environmental sustainability is still subject to debate. Costain et al. (2012), for instance, observed an increase in short-distance car trips, and Sioui et al. (2013) found that levels of car use among users of carsharing services remained lower than those of other households with similar characteristics. In addition to these controversies, little is known about concrete carsharing practices and its use contexts, but it is possibly an appropriate solution particularly for those who cannot or do not wish to own a car. In this respect, carsharing also raises the overall car usage of users who do not own cars and thus tackles rebound effects (Pakusch, Bossauer, Shakoor, et al. 2016). Hence, while the effects of carsharing on ecological sustainability are widely discussed, its social aspects are still underexplored (Schaefers 2013).

There is also a long tradition of ridesharing as an informal practice between neighbors, work colleagues or parents who give their children rides to extracurricular activities and other events. In peer-to-peer ridesharing, a distinction must be made between "traditional" ridesharing services and ride-sourcing. The former involves sharing a trip in which the destination is set by the driver (for their own mobility needs) and dividing the cost between driver and passenger(s) without any profit (i.e. cost-sharing). By contrast, the latter competes with traditional taxis in that the destination is set by the passenger(s) and the driver's aim is to make a profit (i.e. for-profit ridesharing). Once again, high-density urban areas have an advantage in reducing the risk of not finding a driver at the right time in peer-to-peer-ridesharing (not to mention the difficulties and possible danger of meeting outside dedicated meeting zones). Dynamic ridesharing is likely to primarily consist of occasional use by people who rarely drive their own car or do not own a car and of one-off trips, alongside public transport and ride-sourcing services (Aguilera and Boutueil 2018). Its effects on environmentally sustainable mobility practices will only be significant if ridesharing develops and becomes a regular practice for commuting, which accounts for a significant proportion of $CO_2$ emissions from urban mobility (Banister 2008). A prominent example in this context is Waze carpooling for commuters. However,

questions of planning (especially in terms of pick-up points), linkages with public transport and transport policies remain essential if ridesharing is to develop, especially in lower-density areas. Vehicle fleets and ride-sourcing vehicle services are, for now, mainly used in urban trips and large cities for both urban and inter-urban mobilities (Furuhata et al. 2013; Anderson 2014). Currently, the real success of short-distance ridesharing (both planned and dynamic) can be found in ride-sourcing services such as Uber, Lyft or Didi. For the time being, Uber is the largest and best-known mobility-on-demand ride-sourcing service provider, with a presence in 450 cities worldwide (Somerville 2016). In Germany, Uber is currently only available in four major cities: Berlin, Munich, Düsseldorf and Frankfurt. Despite their rapid growth, these services currently account for only a tiny proportion of urban trips. While their impact on urban mobility, especially from an environmental perspective, remains an open question, studies have shown that occupancy for these car services is greater than that of traditional taxis used for occasional purposes by business travelers, people venturing out for shopping, people who are meeting friends, etc. (Rayle et al. 2016). These services can also encourage travel by increasing mobility options for people without a car and who find taxis too expensive, therefore generating additional car journeys. Furthermore, some drivers buy a vehicle expressly for profit-based ride-sourcing work. Thus, there is a risk that they will increase car traffic, $CO_2$ emissions and vehicle congestion (Anderson 2014). Therefore, despite generally optimistic theoretical simulations (e.g. Baptista, Melo, and Rolim 2014), the capacity of these services to cut household motorization rates and significantly reduce the number of miles covered by car is in fact uncertain (Alemi et al. 2018).

Hence, while it is undeniable that services related to shared mobility have gained a second wind thanks to mobile apps, this does not mean that all of the obstacles associated with their use (for both providers and users) have been eradicated and that these services will lead to more sustainable mobility practices. Further, shared autonomous vehicles have great potential to develop more sustainable services and to blur the boundaries between car-and ridesharing (Pakusch et al. 2020). For now, this growth is uneven and appears to be concentrated in carsharing and ride-sourcing services. To function well, these services require a sufficient volume of supply and demand, which seems to have been achieved for inter-urban rides (Blablacar) and day-to-day trips in only very large cities. Moreover, they are predominantly or even quasi-exclusively expanding in major cities, but their numbers remain small relative to the overall urban population and all urban journeys (Alemi et al. 2018). This is due to density and the presence of public

transport systems, which these services can link to and can guarantee a backup solution. However, in terms of environmental sustainability, there are first indications that ridesharing can support the social sustainability of user groups with special needs, such as elderly people (Stein et al. 2017). However, the overall potential of SMS in this regard remains an open question and must be explored in greater detail.

## 2.5 Eco-Feedback Tools and Eco-Literacy

The provision of EF has become an increasingly active field of research in its own right (cf. B. J. Fogg 2007; DiSalvo, Sengers, and Brynjarsdóttir 2010). The aim of EF design is to persuade people to change their behavior in favor of more sustainable lifestyles (cf. (Brian J. Fogg 2009; DiSalvo, Sengers, and Brynjarsdóttir 2010; Brynjarsdottir et al. 2012). Eco-feedback has been applied in various consumption areas, including addressing recycling habits (Thieme et al. 2012), food consumption (Zapico et al. 2016), electricity consumption (Strengers 2011; Pierce and Paulos 2012) and mobilities with the aim of fostering sustainable behavior through diverse incentives (see e.g. (Ross et al. 2010; Gabrielli et al. 2014; Jariyasunant et al. 2015)).

As noted by Froehlich et al. (2010), the concept of (eco-) feedback is based on the assumption that appropriate information about the one's own behavior and its environmental effects would support more environmentally friendly and sustainable habits. As it is expected that people have a pro-environmental attitude; non-sustainable driving actions are perceived as deviant behavior, and current mobility practices are perceived as an example of an "attitude-behavior gap" (de Barcellos et al. 2011; Pierce et al. 2013). In particular, there are different kinds of persuasive strategies to change sustainable mobility behavior, such as addressing emotions by influencing the intended behavior through positive or negative feelings (J. Froehlich et al. 2009). Gamification uses games as incentives to make the desired behavior more enjoyable (Ross et al. 2010; Bliznyuk 2011). Social-normation feedback attempts to motivate users through comparisons or rankings often embedded in a social network such as Facebook (Bie et al. 2012; Broll et al. 2012; Jylhä et al. 2013; Gabrielli et al. 2014). Lastly, awareness-related feedback aims to attract the user's attention to personal $CO_2$ emissions by using different types of information visualization and route recommendations (Spagnolli et al. 2011; Jariyasunant et al. 2015; Meurer et al. 2016). Such eco-feedback tools based on persuasion enjoy increasing popularity, but long-term evaluations in real-life settings are lacking (Hamari, Koivisto, and

Pakkanen 2014). Hence, persuasion-based analysis has attracted criticism (see for example (Brynjarsdottir et al. 2012; Huber and Hilty 2015)). The main point of criticism concerns the normative departure point, in which the "desired" mobility behavior is already labeled as sustainable. This means that measures aimed at encouraging behavioral change can face complex constraints and even resistance (Pierce and Paulos 2012).

Beyond this criticism, Schwartz et al. (2013) have argued in the context of home energy consumption that EFT can support people to better understand their consumption behavior. They call this understanding "consumption literacy." Because routines and everyday activities such as consumption are usually unconscious, Schwartz et al. (2014) have indicated that it is important to make them visible through pattern and activity recognition approaches. To foster more environmentally conscious mobility behavior, MA could help to identify such daily mobility activities, detect patterns and classify them into types. Identifying trips, tours and destinations at the individual level could enable the analysis of more general types of behavior. These findings could support individuals to make conscious mobility choices or cities, municipal services and urban and transport planners to provide more environmentally friendly mobility infrastructures better aligned with the actual needs of citizens (Bassolas et al. 2019).

# 3 Objectives and Research Design

In this Chapter, I outline how the design process for social and environmental sustainability could benefit from the analytical lens of mobility practices for problem framing and envisioning solutions. The practice-based design approach has prominently emerged in HCI and in the field of Computer supported cooperative work (CSCW) in recent years (Wulf et al. 2011; Kuutti and Bannon 2014). Practice-based design includes theoretical frames such as activity theory, action theory, phenomenology, techno-methodology and user-centered design. The need to study practices is shown, for example, by Suchman (2007), who – in accordance with the practice-theoretical perspective – elaborated in her seminal work on plans and situated action that human actions in social contexts are driven by complex expectations and interpretations, which make their results contingent, unpredictable and non-deterministic.

With this in mind, the aim of this Chapter 3 is to outline how a practice-based approach can be applied in the three research fields of TIS, SMS and EFT to support everyday mobilities. First, I begin with a theoretical lens to frame everyday mobilities as social practices. Second, I outline how TIS, SMS and EFT can benefit from a practice-based research perspective to better support SID for everyday mobilities. Third, I introduce the methodological framing for studying everyday mobilities as practices. Lastly, I summarize basic insights on the research settings.

## 3.1 Everyday Mobilities as Practices

Often, the study of everyday mobilities in HCI from a theoretical standpoint is still confined to transportation theories that are based foremost on behavioral and rational models. These date back to Hägerstand's (1975) mobility studies, which investigated how individuals primarily used time and space to organize their activities. This temporal and spatial focus has become materialized in artifacts such as timetables; in particular, the organization of public transport or shared mobilities predominantly manifests through locally based timetables. The local placement of departure and destination timetables supports a good overview of the availability of mobility offers. However, beside the suitable practicability of time-space organization, this perspective does not explain habituated everyday mobility practices that are often deeply rooted in personal lifestyles and accommodated by situated personal needs.

In HCI research, multiple scholars have already argued for the need to better understand daily mobilities as social practices, including Brown and Perry (2002), Ciolfi and Bannon (2007), Kjeldskov and Paay (2012), Church and Oliver (2011) and Cranshaw et al. (2014), Foell et al. (2013) and Choy et al. (2014). However, in general, there is not a single practice theory but rather a family of practice theories (Wulf et al. 2018). In HCI and design research, researchers have typically adopted contributions made by Schatzki (1996), Shove (2012) and Reckwitz (2002). For Reckwitz (2002), social practices go beyond individual needs (homo economicus) or social norms (homo sociologicus). Social practices maintain that human actions take place in certain cultural contexts that allow humans to interpret the world and make their actions meaningful:

> *[P]ractice theories do not locate the origin of the social in the mind, discourse, or interaction, but in 'practices' – routines consisting of a number of interconnected and inseparable elements: physical and mental activities of human bodies, the material environment, artifacts and their use, contexts, human capabilities, affinities and motivation. Practices are wholes, whose existence is dependent on the temporal interconnection of all these elements, and cannot be reduced to, or explained by, any one single element. Practices are relatively stable performances, ways how things get done, continuously produced and reproduced. Practices are also the substrate for the shared understanding and perception of the world, for common language games and the formation of shared identities. (Kuutti and Bannon 2014)*

Applying this to mobility, it is important to mention that the term "mobility" is in common usage and has several meanings from a scientific viewpoint. The term "mobilities" may refer to the movement of people but can also include the movement of ideas and things, as well as the broader social implications of these movements. Several typologies have been formulated to clarify the wide variety of mobilities. Most notably, Urry (2007) divided mobility into five types: mobility of objects, corporeal mobility, imaginative mobility, virtual mobility and communicative mobility. However, this definition is quite broad, as it far exceeds corporeal travel. Furthermore, mobility has often been defined in contrast to transportation. A definition by Udo Becker reads as follows:

> *Mobility describes the need aspects of changes of location: (Realized) mobility is a movement after an individual decision for a social offer that covers a need. Mobility therefore always stands for needs. [...] For every mobility resources, instruments, aids are necessary. Transport is defined*

> *as the set of all instruments that we need for the above-mentioned mobility, i.e. for all means of transport [...], for transport routes, traffic rules, transport infrastructures, etc. One can even combine both terms: Transport is the instrument that makes mobility possible. (U. Becker 2013, 5 own translation)*

Thus, the concepts of "mobility" and "transport" are often referred to as counterparts of the actual "doing" and "use of the infrastructure and space," which each describing one side of the coin that we understand as "mobility practices."

In HCI, this need to merge both traditional transportation theories, which refer to the category of space, and cultural understanding, which mainly addresses the category of place, was in particular addressed by Harrison and Dourish (1996), among others. They outlined an alternative conceptual framing that considers the complexities of lived everyday mobilities, which achieved considerable popularity in HCI mobility research (cf. Dourish's (2006) for a later revision). They emphasized the distinction of "space" as the geographic location and "place" as the experienced or lived environment. They indicated that "place" rather than "space" is the concept needed to understand people's interactions within their physical environment, arguing that "we are located in 'space,' but we act in 'place'" (Harrison and Dourish, 1996). Thus, the concept differentiates the environmental "space" from the social "place":

> *Our experience of the world is not an experience of mathematically derived uniformity and connectedness; what we experience are places, heterogeneous locales with local meaning, different extents, and individual properties. Space is something we can encounter only afterwards. (Dourish 2006)*

For Dourish (2006), the ethnographic characterization of "place" serves as a starting point for informing location-based services of different kinds. The idea of grounding the design of mobility assistance ICTs along the "experienced place" was further applied by Brewer and Dourish (2008). They focused on particular kinds of mobility actions, such as those conducted in pilgrimages or sports, to conclude that mobility is more than moving from point A to point B. Their goal was to show that the concrete practices of moving around are directly interwoven with the intentions of movement. The need to explore mobility practices as part of the intentions of movement was also claimed by Banister (2008) and Hasselqist (2016). They argued that mobility preferences must be explored beyond issues of time optimization to better understand sustainable mobilities.

However, although Dourish's conception of "re-placing space" was fairly influential in HCI research, my own work shares some critical points expressed in the literature, in particular the criticism outlined by Brown and Laurier (2005) and Brown and Perry (2002). They highlighted methodological problems related to how exactly the concept can be empirically applied. In particular, they drew attention to the missing methodological piece of how to study mobility practices with the differentiation between "place" and "space."

## 3.2 Research Objectives

The previous Section 3.1 outlined the analytic conceptions of mobilities as social practices in current HCI research. In this current Section, I demonstrate how a practice-based lens can support SID for TIS, SMS and EFT. As previously shown, mobility must be understood as a valued activity that is an indispensable part of our lives and that reshapes the self: our everyday activities, interpersonal relationships with others and all other connections with the wider world. The way that we move is an inseparable part of our individual lifestyle choices. Sheller and Urry (2003) formulated this in the following manner:

> *The scale of the travelling is immense. One consequence of these social practices is the variety of people's social networks and how they make the complexities of social life work within the social context of others who are often 'at-a-distance'. These others, family, friends, work and leisure colleagues, are themselves 'networked'. Making social life 'work' thus involves much scheduling and rescheduling of events, meetings, dates and trips.*

The above quote shows that mobility decisions take place in often complex arrangements; they are involved in (social) networks and take place locally. Central life questions of where we want to live, work or raise a family often have a major influence on the ways in which daily mobility is conducted. Vice versa, mobility resources can greatly influence the ways in which we live our lives. This can even mean that users assess transport options against their individual needs and values; as a result, social and economic aspects such as the accessibility of the workplace or convenience of the travel experience often trump environmental considerations (Holden 2012; Berger et al. 2014).

Thus, if we aim to design for everyday mobility as a lived practice, mobilities cannot be understood as transportation from point A to B but rather raises the need to develop a holistic perspective that allows us to study them as lived and emerging practices. Mobility practices are

part of the complex ecosystem that is embedded in very personal networks, the different activities that are fulfilled each day, the placement of these activities, its social embedding and the local mobility resources such as infrastructure, health or money.

### Transportation information systems (TIS)

As outlined in Section 2.3, TIS are predominantly used to support mobility mode switches towards more environmentally friendly mobility choices. However, the literature has shown evidence that mobility support apps alone are not enough to prompt a significant proportion of car users to switch to public transportation. On the contrary, they can result in serious rebound effects (Pronello et al. 2016; Sunio and Schmöcker 2017). The reasons for this are multifaceted, but a major issue seems to be that mobility choices are not made on a trip-to-trip basis. Decisions are based not only on rational considerations such as cost or transport time but also daily or weekly routines and personal lifestyles (De witte et al. 2013; Mokhatarian et al. 2015).

I also outline in Section 2.3 that TIS have great potential to support certain user groups with special needs, such as elderly people. These user groups may feel limited or restricted in the use of public transport due to physical impairments. Unfamiliar travel regions and lack of local knowledge about the supply, use and availability of transport options may cause insecurities, unsteadiness or feelings of helplessness. Thus, the potential of TIS to provide orientation, safety, confidence and trust for social sustainability is further explored in this thesis, particularly in Chapters 4 and 5.

### Shared Mobility Services (SMS)

The literature shows that, while SMS has gained in popularity, this does not necessarily mean that it has led to more sustainable mobility practices, as argued in Section 2.4. Despite optimistic theoretical simulations, the capacity of SMS services to reduce household motorization rates and significantly reduce the number of miles covered by car is uncertain at best (Rayle et al. 2016). Furthermore, the growth of SMS is uneven and, for the moment, seems largely confined to (inter)urban trips in the case of carsharing and ride-sourcing services or often long-distance trips in the case of ridesharing services. The services are expanding especially to large cities that include a public transport system as a backup means of travel.

Negatively speaking, one could argue that such services mainly support those who already use public transport, but they often neglect to provide incentives to switch from private car use to shared car use. In addition, there is some evidence that SMS may even lead to rebound effects based on increased car usage, even if this use is only sporadic (Circella, Lee, and Alemi 2019). Although such issues may blunt its overall impact on environmental sustainability, SMS also holds considerable potential to support social sustainability. In Section 2.5, I provide some evidence that ridesharing in particular can support the mobility of user groups with special needs. For example, Stein et al. (2016) showed that ridesharing can support elderly people to sustain a more mobile lifestyle in older age. In this thesis, I elaborate on the potential of SMS for social sustainability in Chapters 6 and 7.

### Eco-Feedback Tools (EFT)

As outlined in Section 2.5, EFT has gained considerable attention in combination with persuasive approaches to support more environmentally friendly mobilities. I argued that research on EFT is currently missing a practice-theoretical lens to overcome its normative stance to design for the desired pro-environmental mobility behavior (see for example (Brynjarsdottir et al. 2012; Huber and Hilty 2015).

However, beyond this, the literature has shown that EFT may have significant potential to support sustainable mobility planning (Severo and Omele 2017). This is due to the close link between MA and EFT. EFT is based on the ability to identify mobility patterns and structure in both, individual and collective behavior. Such data can be used to outline activity- and tour-based models (Bassolas et al. 2019). These, in turn, can be used as tools in urban and transport planning to calibrate models that continuously evaluate the impact of transport and urban planning decisions to motivate and support behavior changes of citizens (Wesolowski et al. 2014). Further, research lacks on understandings how citizens would use EFT to make their city more sustainable (Banister 2008). In the following I will outline a EFT prototype that is intended to be used by a municipal city service in Chapter 8 and explore the potential of EFT from a citizen's perspective through a practice-based lens in Chapter 9.

To study TIS, SMS and EFT, explorative approaches are needed that consider people's everyday mobility practices. If TIS and SMS cannot only be tools for optimized routing (mostly with regard to time and cost of travelling) but also tools for orientation, safety, confidence and trust for particular user groups who feel limited or restricted in the use of public transport, mobility

must be understood as an internal part of social life. In addition, the potential of EFT can only be fully explored if the strategies of user persuasion are questioned from the user's perspective.

## 3.3 Methodological Framework

Everyday mobility is deeply entrenched in people's daily needs, practices and lifestyles. Thus, its methodical framing should address real-life contexts that can be complex and difficult to change. Hence, social contexts are not stable and fixed but rather constructed by social actors through their own ongoing and emerging actions, interactions and experiences; they are thus continually reconstructed and renegotiated through interactions in their social practices (Garfinkel 1967). With this in mind, design researchers such as Pierce et al. (2013), Schwarz et al. (2013), Müller et al. (2015b) and Ganglbaur et al. (2013) have outlined the necessity of a practice perspective to understand and design for sustainable consumption. As characterized by Mietttinen et al. (2009, 1314), viewing social life as comprising living practices that must be holistically studied is a radical ontological commitment, which leads to the complication and restructuring of the entire research process.

To address this challenge, this thesis is positioned within the tradition of practice-based design approaches. In particular, my work is aligns with the tradition of *design case studies* and *grounded design* developed as a research framework at the University of Siegen (Rohde et al. 2009; Wulf et al. 2011; 2015a; Stevens et al. 2018). A key point of the approach is to engage with social practices, which become subject to the application of innovative ICT artifacts while exploring design opportunities. The approach is inspired by Lewin's action research as "comparative research on the conditions and effects of various forms of social action and research leading to social action" that uses "a spiral of steps, each of which is composed of a circle of planning, action, and factfinding about the result of the action" (Lewin 1946). Design case studies ideally consist of three stages that build on each other but are not necessarily in sequential chronological order (Wulf et al. 2015b):

(1) *Empirical pre-study* should offer micro-level descriptions of social practices before any intervention takes place. The analysis should describe in particular existing tools and media and their usage. It should also capture developments observed by practitioners from a technological, organizational and social perspective. Such documentation can be typically formulated as a

problem or need statement when developing the research agenda. The analysis is based on an ethnographic endeavor that aims to explore users' sense-making processes.

(2) *Prototyping and (participatory) IT design* should describe the innovative IT artifact from a product and process perspective. This includes a description of the specific design process, involved stakeholders, applied design methods and emerging design concepts. A focus should be on the documentation of changes in social practices that stakeholders anticipate and aim for, as well as how these considerations influenced the design of the IT artifact.

(3) *Evaluation and appropriation study* should document the introduction, appropriation and potential redesign of the IT artifact in its relevant domain of practice. Investigations into the appropriation of the technical artifact cover a longer period of time. Documentation enables the analysis of the transformative impact of certain functions and design options realized within the ICT artifact.

The design case study methodology is further rooted in the *grounded design* approach (Rohde et al. 2009; 2017), which highlights the contingent and emerging character of social practices. This implies two paramount consequences for the process and methodology of designing IT artifacts. First, it is up to users – not designers – to interpret the meaning of the ICT artifacts in use, since this meaning cannot be specified in advance. However, the grounded design approach emphasizes the high interdependence of appropriation and design activities as a self-referential circle. Thus, the design not only incorporates functionality but is also a result of how the design is appropriated and effectively used in practice. Second, the grounded design approach highlights the evolutionary character of design. It addresses IT artifacts as a reflexive endeavor in that the artifacts' appropriation and use change the social practices that they were designed for; thus, frequent changes of functional requirements during the system design and implementation are inevitable. The design methodology must therefore cope with this reality and organize design and implementation processes in a reflexive and evolutionary manner, with iteratively revised and improved versions of the artifact that each time lead to a new social practice (Stevens and Pipek 2018).

Hence, the following studies that are part of the findings section (Chapter 4 to Chapter 9) are all related to grounded design. All studies are related to one or two of the three steps of empir-

ical pre-study, prototyping and appropriation study. The studies often report on the appropriation of IT artifacts or evolved in conjunction with unanticipated opportunities that organically emerged when researching practices.

## 3.4 Methods

To apply the methodological framing of grounded design, I oriented my research on Living Labs' approach in general and PRAXLABS' in particular (Ogonowski et al. 2018). The concept of Living Labs was developed with a particular view on sustainability. The idea was to provide a research context as well as resources that allow to design close on everyday-life practices and address the broader context in which these practices are located.

The Living Labs approach was created at the MIT Media Lab as an instrument for innovative product development. Within the seventh EU framework program, the EU Commission piloted the European Network of Living Labs (ENoLL) to build a sustainable strategy for user-centered innovation processes in Europe. To successfully develop products, the crux is the careful study of users and their interaction with new IT artifacts in dynamic and complex real-life environments. To address this, four principles were established (Eriksson, Niitamo, and Kulkki 2005):

- The exploration of user behavior in context and market conditions
- The co-creation process between users, designers and other stakeholders in the value chain
- Experiments involving scenarios in real-life or quasi real-life environments with users and stakeholders in the value chain
- The evaluation of concepts, products and services based on defined criteria

According to these priciples, Living Labs can be understood as a methodological framework with regional infrastructures and methodological competencies in which users can interact with different stakeholders from several sectors – the public, academia and the economy – in an open innovative process that takes into account (semi) real-use contexts (e.g. living environments, urban spaces, work environments, etc.; Følstad 2008). Both access to contexts of application and the early and iterative integration of users in innovative processes foster a greater likelihood of success in such processes and help to reduce associated risks (Hellfeld, Oberweis, and Wessel 2015; Ley et al. 2015).

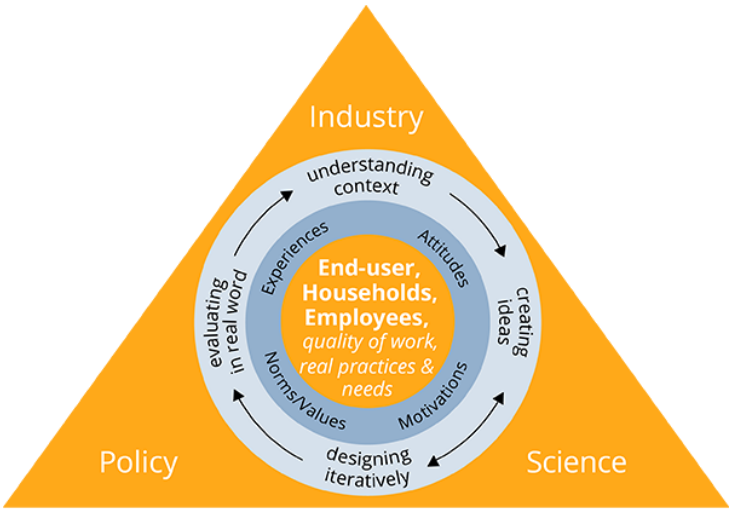


**Figure 2: Stakeholder and process stages in the PRAXLABS approach (Source: praxlabs.de)**

In our research group, we developed PRAXLABS as a variation on the Living Labs approach that goes hand-in-hand with grounded design methodology (cf. Section 3.3). In this regard, PRAXLABS served as an infrastructure for fostering local, intensive stakeholder involvement, end-user participation and their long-term engagement in research and development projects (cf. Figure 2; Ogonowski et al. 2018). A trust-based and continuous cooperation between the different stakeholders greatly increases the ecological validity of the research but also the complexity of research activities that accompany the development of a stable community and its related infrastructures (Meurer, Müller, et al. 2018).

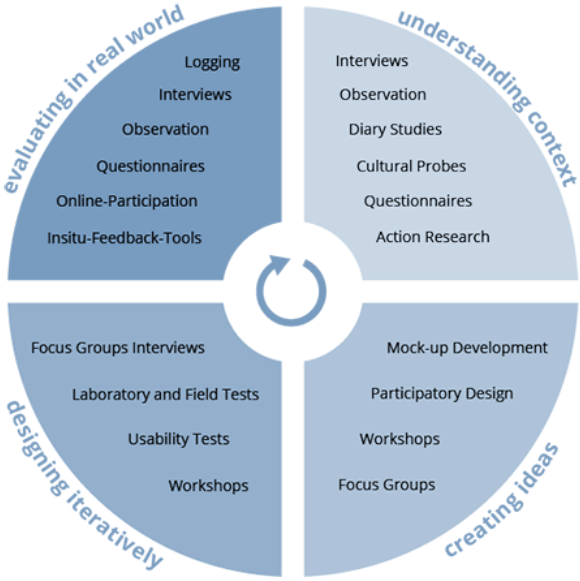


**Figure 3: Methods and tools of the PRAXLABS approach (Source: praxlabs.de)**

Regarding the specific methods applied, the PRAXLABS approach is quite open-ended, but it has an affinity with qualitative, ethnographic-oriented methods for understanding context and appropriation practices as well as supporting action research and co-design methods to design for very concrete contexts and situated needs (cf. Figure 3). Analytically, I applied in most studies the qualitative research paradigm with a form of open coding (Strauss and Corbin 1997) or the documentary method (Bohnsack 2014) to analyze the material and uncover noteworthy phenomena. This means that all empirical work was based on inductive and abductive analysis processes that did not entail any hypothesis testing but based instead on an "open" analysis paradigm, which aimed to reveal unintended and surprising phenomena associated with everyday mobility practices (Randall, Harper, and Rouncefield 2007). The focus that emerged was on change processes of practices or practice innovations induced by technology.

The following studies presented in the findings (Chapters 4 to 9) each have a unique methodological framing. A common point is that they are linked to the Living Labs approach in general and the PRAXLABS approach in particular. However, they differ widely in the ways that they emphasize this methodological framing. While some centered it, others did not mention it at all. Nevertheless, all of them share a set of core values: namely, to integrate users as participants and co-designers in the research process and to study appropriation practices in the users' real-life contexts. Methods were chosen accordingly to embody these values and thus had to be more experimental at times.

## 3.5 Research Settings

Before outlining the six studies in terms of related findings, I summarize the research contexts in which each study was embedded in order to provide more detailed insight into the overall research setting. They are presented in chronological order: the S-mobil100 project (February 2012 to January 2015), the INNOLAB project (March 2015 to February 2018) and the GaNE-sHA project (May 2017 to April 2020). See for an overview Table 1.

The S-mobil100 project "mobile with 100 - mobility chains for senior adults in the model region Siegen-Wittgenstein" was funded by the German Federal Ministry of Education and Research (BMBF).[1] Its aim was to support demographic changes in rural areas by sustaining the mobility of older adults through an inter-generational approach. A primary focus of the S-mobil100 project was to address limited a public transport system that shaped the real-life mobilities of elderly people, especially those who lived in more rural areas. Such users particularly need to develop new mobility practices against a background of declining driving skills. To address this challenge, it was crucial to co-design TIS and SMS that fit the needs of this user group. To this end, we built an intra-modal transport solution for smartphones that provided access to public transport (particularly buses and trains) and a ridesharing option. In addition to a smartphone app, we also completed a web and a smart television interface for accessing the intermodal mobility platform.

In the project, we worked with a heterogeneous group of 19 elderly users who were between 59 and 80 years of age and exhibited mixed mobility preferences. Since none of them were not proficient with smartphones, we aimed to support their learning process in weekly assistance workshops operated by the researchers, which were ran over a period of two years. An additional stakeholder, another small and medium entrepreneurs (SME) in the software branch, participated in the project and completed the inter-modal routing. Other partners included the city of Siegen, the district of Siegen-Wittgenstein and research partners who specialized in gerontology. Furthermore, the project took place in the district of Siegen-Wittgenstein. The region is densely wooded, hilly and located in the center of Germany. It has a surface area of 1,131.47 km$^2$, a population of 281,585 and a density of 250 inhabitants per km$_2$. The center of the region is the city of Siegen, which encompasses approximately 100,000 residents. Thus, a major characteristic of this region is that it includes both urban and very rural areas. The participants came from both the rural and urban parts of the city. The only public transport options available were the bus or train (mainly for inter-city travel). The bus service was very limited, especially in more rural areas. Additionally, the landscape is very hilly and distracted, so that travelling from one location to another can mean very indirect journeys.

[1] The official German name is: 'Sehr Mobil mit 100 - Mobilitätsketten für Senioren in der Modellregion Siegen-Wittgenstein' with the promotional code: BMBF 16 SV 5674.

The INNOLAB project 'Living Labs in the green economy – Real-world innovation for user-integration and Sustainability' was funded by the German Federal Ministry of Education and Research (BMBF) within the framework program, Research for Sustainable Development (FONA).[2] The project, which was coordinated by the Wuppertal Institute, focused on ecological sustainability research and aimed to demonstrate the potential of Living Labs in the green economy in three areas of consumption: living, retail and mobility. Within the project, the focus was on innovations for mobility assistance systems, in which we enhanced the mobility platform S-mobil100 with an EFT to support more environmentally friendly mobility. Therefore, we cooperated with the same group of users and SME from the S-mobil100 project to build an integrated eco-feedback system as a smartphone solution. Thus, the project was located in the same region as S-mobil100.

The third project, GaNEsHA, aimed to design digital instruments to make mobility in cities more environmentally friendly though a better match between supply and demand of mobility offers. The project was funded by BMVI under the mFUND funding line 2[3] to establish a holistic network approach to recognize systemic obstacles and coordination potential. Since very little is known thus far about the everyday mobility situation in cities, the goal of the project was to shed light on everyday mobilities in terms of how residents, commuters, families and students use the local infrastructure, how they justify their choices about means of transport and which factors become relevant. Developers and researchers cooperated with municipal city services in Stadtwerke Osnabrück (SWO) in the model region of Osnabrück. In particular, the aim was to make existing traffic data sources available to bundle them together and reprocess them to empower cities and municipal services for better customized mobility planning and to enable local citizens to pursue more environmentally friendly mobilities in their city. Our team at the University of Siegen developed a mobile application for smartphones to record, visualize and analyze the mobility behavior of citizens in particular. To identify meaningful incentives for creating behavior change and support local mobility planning, we adopted mobility analytics methods outlined in Chapter 2.2 to better support EFT.

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[2] The official German name is: INNOLAB – Living Labs in der Green Economy: Realweltliche Innovationsräume für Nutzerintegration and Nachhaltigkeit' with the promotial code: BMBF F01UT1418A-D.

[3] The official German name is: ‚GaNEsHA - Ganzheitlicher Netzwerkansatz zur Erkennung systemimmanenter Hindernisse and Abstimmungspotentiale' with the promotial code: BMVI FKZ: 19F2023D.

**Table 1: Project aims and settings for S-Mobil100, INNOLAB and GaNEsHA**

| | S-Mobil100 | INNOLAB | GaNEsHA |
|---|---|---|---|
| Funding agency | German Federal Ministry of Education and Research | German Federal Ministry of Education and Research | German Federal Ministry of Transport and Digital Infrastructure |
| Duration | 2012–2015 | 2015–2018 | 2017–2020 |
| Research setting in Living Labs | Model region with poorly integrated transport modes in Siegen-Wittgenstein and the city of Siegen | Model region with poorly integrated transport modes in Siegen-Wittgenstein and the city of Siegen | Model region of an average-sized larger city with integrated transport modes in the Osnabrück city center |
| Project partners and stakeholders | The city of Siegen; the district of Siegen Wittgenstein; the German Red Cross; the software SME, infoware GmbH; a group of senior citizens; gerontology experts at Heidelberg University; and the HCI group at the University of Siegen | Environmental experts from the Wuppertal Institute for Climate, Environment and Energy; the Fraunhofer Institute for Systems and Innovation Research; the software SME, infoware GmbH; a group of senior citizens; and the HCI group at the University of Siegen | Software SMEs such as YellowMap GmbH and the Urban Institute; DFKI Kaiserslautern; legal support from the University of Frankfurt; Pforzheim University of Applied Sciences; the HCI group at the University of Siegen; a group of citizens; and local city municipal services |
| Project aims | Support elderly people's daily mobility with assistance tools and access to new media practices | Support environmentally friendly mobility and a Living Labs approach | Support municipal city service to implement more sustainable city and mobility planning |
| ICT development | Multimodal mobility platform Sehrmobil to support the everyday mobility of elderly people | Eco-feedback component Ecomobil implemented into the Sehrmobil platform | Mobile application GaNEsHA to capture the mobility profiles of citizens and create incentives for environmentally friendly mobility practices |

Each of the three projects followed the abovementioned methods to differing degrees as well as the PRAXLABS approach. To familiarize ourselves with overall mobility contexts, conducted practices, their rationales and participants' experienced needs, different qualitative methods were used, including document analysis, observations, group discussions and focus groups, interviews, usability tests and user workshops. Table 2 provides more details on how the PRAXLABS approach was applied in the projects within the three phases of the design

case study methodology. Furthermore, the PRAXLABS approach enabled the transfer of findings based on experiences and technologies developed in one context to another. It also helped to establish maintenance with regard to the infrastructures used. This became particularly clear in the S-mobil100 and INNOLAB projects, in which a new component for the mobility platform could be designed with the same technical partner and user group (Meurer, Müller, et al. 2018).

**Table 2: Study design of the three research projects of S-mobil100, INNOLAB and GaNEsHA**

| | S-mobil100 | INNOLAB | GaNEsHA |
|---|---|---|---|
| Participants | 19 elderly adults between the ages of 58 and 80, the city of Siegen, the district pf Siegen-Wittgenstein and the software SME infoware GmbH | 19 elderly adults between the ages of 61 and 83, the software SME and environmental experts | 10 citizens and local municipal city services |
| Pre-study | 19 interviews with the participants, participant observation and diary study | Eight interviews with participants and three participatory design workshops with the SME and the environmental experts | 10 interviews with citizen participants and two focus groups with local municipal services |
| Prototyping | Design of the Sehrmobil platform in regular PD-workshops and weekly sessions for approximately two years. The technical realization of the mobile app was completed by the software SME. | Design of the additional eco-feedback component Ecomobil in the Sehrmobil platform, which was informed by regular PD workshops and some inter-generational workshops. Its technical realization in the mobile app was completed by the software SME. | Three design workshops with potential users on sustainable mobility practices and participatory engagement with local municipal city services. We completed both the design and the technical realization. |
| Long-term appropriation studies of the prototype | Rollout in 19 households with regular schooling sessions over a period of approximately 12 months | Roll-out in eight households over a period of approximately three months | Not applicable (The rollout is not part of this dissertation.) |

# Part II: Selected Findings

This part of the dissertation includes the chapters 4 to 9. It presents the studies and findings to answer the research question how sustainable everyday-mobilities can be better supported by a practice-based design approach. Each part of this chapter has already been published or resemble the accepted or current version of a journal paper under review.

Chapter 4 (Becoming a smartphone user) and chapter 5 (Designing for way-finding practices) explore the everyday use of *TIS* by elderly people. These chapters aim to answer the question how social sustainable mobilities can be better supported for elderly people with mobile applications. While chapter 4 explores a long-term appropriation process of becoming a smartphone user in older age, chapter 5 shows how TIS can support the mobility practices of elderly people as a user group with specific needs.

Chapter 6 (Social dependency and mobile autonomy) and chapter 7 (Designing cooperation for sustainable mobility) study *SMS* as informal ridesharing practices of elderly adults. In chapter 6 expectations, fears and practical issues of ridesharing were identified with a special focus on feelings of dependency and autonomy. Chapter 7 focusses on methodological challenges to study more sustainable travel options such as ridesharing in particular. It reflects the Living Lab approach as an innovative development environment and motivates to include experimental methods like the integration of MDA.

Chapter 8 (Bridging location-based Data with mobile phones) and chapter 9 (Opportunities for sustainability design) outline on *EFT*. Chapter 8 is about the connection of automatically and manually collected MPD data that can add more detailed insights about the personal mobility contexts. Chapter 9 uses an eco-feedback approach to study the potential of EFT to support environmentally sustainable mobility practices. The results showed divers approaches to make use of the data, e.g. in smart city approaches to support a better mobility planning on the side of local municipal city services.

# 4 Becoming a Smartphone User in Later Life – Understanding and Supporting Appropriation Practices of Marginalized User Groups

**Abstract**

In this paper we examine elderly people's appropriation practices in the process of becoming smartphone users in later life. This research is based on a long-term ethnography that took place in a participatory design-oriented research and development (R&D) project. As a part of the project we equipped 19 elderly people who had next to no experience of using smartphones with high-end devices. Use of the smartphones was supported and accompanied through weekly research-led workshops that took place over two years. In addition, we conducted interviews at the beginning and at the end of the research process with all participants and observations as part of the workshops. The paper trades analytically upon a certain affinity with Becker's classic study, 'Becoming a Marihuana User' in order to illuminate the problems associated with appropriating new technologies that confront elderly users. We found that becoming a smartphone user in later life addressed different dimensions structuring in terms of (1) what it takes to learn the actual practices of smartphone use, (2) the work of learning how to belong to the body of smartphone users, (3) shifting attitudes to smartphone use, and, to sum up, (4) what it takes to become a manifestly competent and 'ordinary' smartphone user. The findings could serve to inform other R&D projects or practitioners working and designing with and for elderly people.

## 4.1 Introduction

The title of this paper alludes to a well-known sociological paper written in the early 1950s by the symbolic interactionist Howard S. Becker, entitled 'Becoming a Marihuana User'. Although, at first sight, comparing smartphone use to smoking marihuana might seem to be something of a stretch, our borrowing here is not intended to be flippant and has a very specific purpose. Becker's original paper was motivated at the time by what he saw as a need to provide a corrective to a prevailing view that deviant behavior was a consequence of a person's pre-existing character traits and predispositions. His point was that there was a process whereby someone

might come to see a particular kind of behavior as attractive and worth pursuing and that this process is social through and through. He was also at pains to point out that the behavior had to be learnt and that the successful cultivation of it as a practice, even when initially considered desirable, is anything but a given. Instead, being a marihuana user is something that people have to learn how to be and learning how to be one is a social activity, predominantly embedded in people's interactions with one another. There are 'correct' ways to smoke marihuana and those correct ways are not self-evident and not automatically enjoyable. Instead, in the company of others, prospective users learn a series of proposed techniques, learn ways to ascribe positive rather than negative associations to the sensations that arise, and learn a body of language whereby 'being a user' can be convincingly demonstrated to the people around them. This paper takes as its topic the appropriation of smartphone technology by elderly people. It is built upon observations of smartphone appropriation by a particular group of elderly users in Germany as a part of a research and development (R&D) project. Whilst not exactly a deviant activity for elderly people, at the time of the study duration (from 2012 to 2016), smartphone use was not commonplace amongst them. In 2016 nearly 90 percent of 15 to 29-year-olds were using smartphones on a daily basis, but only 31 percent of 50 to 69-year-olds and just 11 percent of people over 70 (Beisch, Koch, and Schäfer 2018).

Despite the importance of smartphone usage in modern society, their use or otherwise their non-usage by elderly people is not very well studied, yet. Some researchers suggest that elderly people are being "left out" and "left behind". What this rather overlooks is the extent to which, at the time, elderly smartphone users were an object of curiosity amongst many younger users, with assumptions often being made as to how competent they might be as users and the level of engagement they might be capable of. This line of reasoning is very much founded upon an expectation that old age is debilitating and erosive of capacity. Thus, we find that many works examine the adaptation of older users to smartphone use in relation to possible bodily and cognitive issues (see e.g. Olwal et al. 2011; Zhou et al. 2014; Hwangbo et al. 2013). Smartphones are therefore seen primarily as tools to support mobile health services such as medication support, while their everyday use is largely set aside (see also Bert et al. (2014) for an overview). It is not going too far say that there was (and is) a prevailing view regarding how elderly users would be disposed towards smartphone technology and that this would inform their capacity to engage with it 'correctly'. Building upon older work regarding the relevant factors that can cause or prevent adoption behavior (Rogers 1976), many frameworks have sought to capture

and rank different factors according to their significance and to thereby explain the low adoption rates of smartphone usage by elderly people (see e.g. (Choudrie and Vyas 2014; McGaughey et al. 2013; Mohadisdudis and Ali 2014). While other studies single out sociological and psychological factors that cause low adoption rates (e.g. Pang et al. 2015; Nikou 2015), or socio-economic ones (Ma, Chan, and Chen 2016).

In this paper, we set aside treatments of how elderly people engage with technology that are founded upon the presumed frailties and limitations that come with age. Instead, we aim to draw a more detailed picture on smartphone appropriation by elderly people as it takes place in real-world settings, delineating a process of change that is socially embedded in the situated and local practices defined by appropriation studies (Dourish 2003; Stevens and Pipek 2018a). We examine how appropriation of technology is something that is emergent in and through their ongoing experience of using the technology in everyday life initiated and accompanied in an R&D project. As part of an R&D project that aimed to develop a mobile multimodal mobility platform for ridesharing and public transportation to sustain elderly people's mobility with mobile media, we applied a participatory-design approach (Muller 2003) to empower elderly people's mobility with a mobile transportation application. This meant that a capacity for independent smartphone use was considered to be of major importance for their participation. In a long-term study that took place in Germany from 2012 to 2016, we therefore explored smartphone appropriation amongst elderly people. We accompanied a group of 19 older adults for four years through their journey towards becoming smartphone users. Starting together as novice users in 2012, they were provided with high-end smartphone devices in 2013 and were supported in their learning process in weekly assistive workshops through until 2015. The workshops were organized by the researchers and were accompanied by on-site observations. Further, additional interviews were conducted at two key points: before the participants started learning how to use a smartphone in 2012 and at the end of the learning process in 2015.

Over the course of our work with them, it became clear that, whilst aware of how others might view their use of smartphones, many elderly people saw an attraction in the possibility of using such technology and were curious enough to want to try it out and see if it was for them. The prospect of using smartphones was something that elderly people talked about, both amongst themselves and with others and their interest was not just an individual whim but rather socially-grounded in their interactions with other people. Once the journey towards smartphone use had been undertaken, the elderly participants in our study quickly realized that smartphone

use was something that had to be learnt as a body of practice and that appropriate and effective use was not a given. In particular, they had to learn not just how to use a smartphone, but how to be a smartphone user, with 'correct' or 'appropriate' use not being necessarily self-evident. Learning this was, again, something that was social through and through and tightly embedded in an unfolding sequence of social interactions. Nor did all users take to it. Some found that, in various ways, it did not meet their expectations or was in some other sense less than they'd hoped for. In these cases, the technology was largely set aside. In ways that strongly echo Becker's overarching analysis of what it takes to become a marihuana user, becoming a smartphone user in later life was found to involve: learning a series of proposed techniques; learning to ascribe positive rather than negative associations to the practice; and learning an appropriate body of language and the ability to convincingly demonstrate one's status as a user to others around you.

Nowadays, even though it is only a few short years later, the uptake of smartphone use amongst the elderly population has increased. Since 2013, there has been a 144% increase in smartphone ownership amongst users of 55 and over in Europe to 2016 (Beisch, Koch, and Schäfer 2018). However, the point here is not one of simply documenting an historical instance of smartphone appropriation, it is about pulling out lessons regarding what appropriation of new technology looks like amongst elderly users and, by extension, what appropriation might look like for other presumptively 'improbable' communities. In a fashion that was almost prescient for the many studies of appropriation in HCI over the years, Becker concluded his analysis of what it takes to become a marihuana user with the following observation:

> *"…individuals who come in contact with a given object may respond to it at first in a great variety of ways. If a stable form of new behavior toward the object is to emerge, a transformation of meanings must occur, in which the person develops a new conception of the nature of the object. This happens in a series of communicative acts in which others point out new aspects of his experience to him, present him with new interpretations of events, and help him to achieve a new conceptual organization of his world, without which the new behavior is not possible." (Becker 1953: 242)*

So, by pulling upon the data we collected during our study, we will be posing the following question: What does the study tell us about appropriation practices of elderly people when they appropriate smartphones in later life? That is, what does it take to become a smartphone user?

Hence, there are three ways we can profit from studies that explore the appropriation processes of new technologies by elderly people: first, such a study could contribute by giving detailed insights into their particular needs, interests and the symbolic meanings of the use or non-use; second, appropriation studies are always settled in a certain context and could tell other practitioners or researchers how appropriation processes can be supported. A third key point, we shall focus upon later on, is that this study provides an insight into how appropriation occurs amongst cohorts outside the mainstream, where their very use of new technology can be treated as remarkable and called to account.

## 4.2 Background

Whilst the focus of this paper is upon the practices involved in the appropriation of smartphone use amongst elderly people, it is useful to briefly set the scene regarding how 'late' appropriation has been examined more broadly in the literature. We argue that the concept of appropriation offers an interesting and worthy perspective for technology design for elderly people to support their personal needs. Further, we outline a research gap on such appropriation studies and develop a perspective for exploration.

### 4.2.1 New Technologies and Elderly People

The existing literature tends to assume in various non-explicit ways that the 'correct' use and adoption of smartphones is best evidence by the practices of the young, the digital natives. Positioning use in this way enables elderly people – the so-called digital immigrants – to be reported as lacking the appropriate capacities, in other words in a deficit-orientated manner.

Researchers mainly studied the smartphone use by older users concerning bodily and cognitive issues (i.a. Olwal, Lachanas, and Zacharouli 2011; Hwangbo et al. 2013; J. Zhou, Rau, and Salvendy 2014). A major focus was on the smartphone as a tool to support mobile health services such as medication support, while their everyday use was largely set aside (for an overview see also Bert et al. 2014). Another body of work focused on solutions for managing the health consequences that are assumed to come with age (i.a. Dalgaard, Gronvall, and Verdezoto 2013; Parker et al. 2013). In addition to those more functional perspectives, many studies were conducted to study the adoption and diffusion (Davis 1985; Rogers 2010) to explain the low adoption rates of smartphone usage by elderly people (i.a. McGaughey, Zeltmann, and McMurtrey

2013; Choudrie and Vyas 2014; Mohadisdudis and Ali 2014). Some studies singled out sociological and psychological factors (i.a. Nikou 2015; Pang et al. 2015), while others highlighted socio-economic and physical ones (Hwangbo et al. 2013; J. Zhou, Rau, and Salvendy 2014; Ma, Chan, and Chen 2016).

Such studies suggest that if such barriers were to be removed, current non-users would be willing adopters. Also, this view supports stereotypes based on age-related impairments, and a lack of motivation and skill e.g. Richards et al. (2012) or Chan (2013). A result of this trend is that, in broader terms research about elderly people often risks neglecting the heterogeneity of the group and thereby promulgating a kind of ageism as it is warned by (van Deursen and Helsper 2015). Thus, some authors like Richards et al. (2012) or Durick et al. (2013) argued for a more detailed understanding of age. Even though it may be the case that around the age of 60, many individuals will encounter the social or health changes that can come with age, such as retirement, widowhood, physical and/or cognitive decline, and so on, it is also evident that most remain healthy and independent (Richards, Warren, and Gott 2012). This is why gerontologists refer to people aged between 60 and 80 as the "third age" or the "young-old", contrasting them to the "fourth age" or "old-old" who are aged 80 and onwards. In the last group, it is claimed, there is a much greater likelihood that people will be suffering from cognitive and/or physical problems that limit their autonomy (Richards et al. 2012; Higgs and Gilleard 2015). This differentiation fits with a more dynamic perspective on aging considering that personal values and interests can change over the course of a lifetime (Chan 2013). Alongside of this Ling, Bertel, & Sundsoy (2012) and Schreiber (2015) have shown that personal media consumption patterns can often evolve as we grow older and across different stages of aging. Light et al. (2016) and Vines et al. (2015) tackle the politics of age with respect to technology development and give the lie to the impression that HCI is complicit in treating older people as deficient.

Giving users an own voice and democratize technology development has a long tradition in PD/CSCW (Ehn 1988b). However, there is much less work that focuses upon elderly people's appropriation practices, how they become competent technology users and how those learning processes can be supported. In this regard, Rosales & Fernández-Ardèvol (2016) have described different interests of elderly people in smartphone learning and outlined different learning strategies when adapting to the use of mobile communication tools. Further, Müller et al. (2015) have described how elderly people started a long-term learning process to appropriate

new media that was initiated and accompanied by a R&D project. Based on such long-term interactions with elderly people Hornung et al. (2017) have researched arising privacy and security issues as older people become exposed to these kinds of technologies. And Nguyen et al. (2015) suggested that older people's family and friends play an important role in how they identify, select and learn to use mobile communication technologies. Furthermore, Bødker and Christiansen (2012) have outlined how elderly people who are non-smartphone users are affected by the processes of digitalization around then. Works like these allow detailed insights into the usage experiences from the point of view of elderly people, but are still quite rare. However, till now, there have been few studies that examine the process of appropriation in greater detail, especially with regard to smartphones. We still see a need to get a more detailed understanding of how the actual appropriation takes place within the situated actions of elderly people.

### 4.2.2 Becoming a user and making use

Making use of new technologies by its appropriation and domestication is a distinct process that changes both, artifacts, subjects, as well as social practices (Stevens and Pipek 2018). Silverstone et al. (1992) coin the term domestication to pinpoint to the generation of symbolic meanings and material expressions during the process of integrating technological objects within the daily life of their users. They describe the process of domestication by using notions of 'appropriation', 'objectification', 'incorporation' and 'conversion'. Before appropriation, commodities are desired (or undesired) for their potential functions, as well as for the possible changes and social meanings they emit. At the end of the appropriation process, the meanings of objects are transformed to fit the self-image of their users – or are not. An object is *appropriated* as soon as it "leaves the world of commodity at the generalized system of equivalence and exchange, and is taken possession of – or not – by an individual or household and owned" (Siverstone and Hirsch 1992, 22). While early studies on domestication consider the household as the unit of analysis (Siverstone and Hirsch 1992), later domestication studies take the individual consumer as the unit of analysis, either inside or outside the home (Haddon 2003).

Practice-oriented appropriation studies (Stevens and Pipek 2018) pinpoint that the introduction of new technologies, media, and material artifacts typically tends to frictions, conflicts, as well as opportunities that become a driver for evolution of existing practices and the evolution of new ones. In particular, in the tradition of de Certau, appropriation is linked to resistance and

a tactic power of the common men making profit out of the situation (de Certeau 2002): Everyday practices present performative acts of appropriating a language that is not one's own. Similar, to the behavior of indigenous cultures towards the imposed culture and religion of the conquerors, appropriation is a form of resistance not through rejection, but by the performative use of dominant structures (Füssel 2013). In a similar vein as Becker (1953), these studies draw attention that the notion of deviating behavior always depends on the perspective, where we have to ask critically who and how the norm is set.

In contrast to adoption theories (Davis 1985; Rogers 2010), appropriation studies do not count how many people use a technology, but ask for the local meanings and practices that have been accumulated around a technology. Stevens and Pipek (Stevens and Pipek 2018) further stress that appropriating an object to "utilize constructively, to build by incorporation" (Ollman and Bertell 1976) is inherently a dual process that changes both the object and the subject. The adoption includes acquiring new competencies through informal learning, resulting in a transformation of the practice itself (Draxler et al. 2012; Draxler and Stevens 2011). Appropriation is, thus, closely related to *expansive learning*, where neither the learning goals nor the learning activities are defined in advance but are open-ended (Engeström 2001; Engeström and others 1999). It starts with the diffuse feeling of a need and the reflection of inner contradictions in the situation at hand, followed by exploring and trying out new options and ideas.

Appropriating new artifacts and learning new practices do not happen in isolation but involve enculturation into a community of practice (Carroll 2004; Pipek and Kahler 2006; Pipek 2005). Such enculturation is characterized by forming and negotiating identities and by exchanging experiences and stories with community members. With the ongoing performance of a practice, the community implicitly communicates knowledge, values, and identities that can be learned by newcomers. Members share their commitment to the community as well as the competences, materials, and meanings, "in short a shared practice" (Wenger 2011). Enculturation happens by participating in a practice and negotiating the meaning of the practice with other members. Members provide social and symbolic support for newcomers, including resources for identification and understanding (Lave and Wenger 1991). In the reception of Wenger's work, identities were at times interpreted essentialistically by speaking about the identity of a community of practices. In contrast, we follow the ethnomethodological understanding looking on identities as their get their meaning in the interaction where they are made visible and thus negotiable in conduct of action. Hence, we neither understand identities as static nor

arbitrary, but as evolving objects that are parts and results of reflective practices. Therewith, this study stands not so much in contrast to earlier ones, but rather aims to build upon them and complement them. Therefore, we aim to address appropriation as a process of empowerment. We think that such a more holistic view on appropriation as a process might offer interesting insights for other R&D projects.

## 4.3 Method

In this paper, we want to share our experiences of observing and supporting elderly people in their *process* of *becoming* a smartphone user. Methodologically, we followed a bottom-up approach to do justice to the particularities of the contexts in which the smartphones were being used and the situational specificities of that use. We will take a nuanced look at how smartphone learning was framed in the course of the project and at the different forms taken by the elderly people's engagement with the smartphones over a four-year longer period of time. To do this, we used complementary data founded upon both observations and interviews.

### 4.3.1 Study Setting and Sampling

The study took place from 2012 to 2016 and was part of research project funded by the German Federal Ministry of Education and Research (BMBF). The aim of the project was to develop a multimodal mobility platform for ridesharing and public transportation (including buses and trains) that could maintain elderly people's mobility through the use of mobile ICT. The mobility platform was developed for high-end smartphones to ensure inter-generational use and to limit any age-based digital divide. Hence, we therefore avoided special senior-handys that could offer only a limited range of functionalities and would address the user group of elderly people more exclusively. As participatory design and smartphone usage were central elements in that project, supporting elderly people in the process of becoming smartphone users, was a research focus in its own right. Hence, due to concerns regarding emancipation and empowerment, the research and development process was founded upon the concept of Design Case-studies (Wulf et al. 2015b). This design-framework suggests working with the same user group over the whole design process based on a participatory-design approach (Muller 2003). In our project, we established a long-lasting relationship with the user group:

from the very outset, through until a final product has been developed and appropriated by the elderly people (please see for further details also Stein et al. 2017).

The study took place in a university city in the west of Germany with about 100,000 inhabitants. The initial contact with the participants was made through various local senior organizations who functioned as 'gatekeepers' to possible interested participants. In total, we identified 48 elderly people who were interested in participating in the project. Based on their demographic data we selected a heterogeneous group of 21 elderly participants in relation to age (ranging from 58 to 83 years, with a median age of 67) and local infrastructure (living in both urban and rural locations). However, because only 12 out of the 48 interested persons were male elderly people, we ended up with an imbalanced distribution of female and male participants in our final sample (5 male and 14 female). In addition, from the 21 participants two dropped out over the course of the project due to illness. We will therefore be reporting findings for just the 19 participants that were involved throughout the duration of four years. A more detailed list of the participants can be found in Table 3. The sample includes two married couples, the Wilson and Robinson families.

**Table 3: Anonymized overview of the participants**

| | Synonym | Sex | Age | Marital status | Area |
|---|---|---|---|---|---|
| **1** | Mr. James | m | 69 | Married | rural |
| **2** | Mrs. Johnson | f | 75 | Married | urban |
| **3** | Mrs. Williams | f | 73 | Widowed | urban |
| **4** | Mrs. Miller | f | 58 | Single | rural |
| **5** | Mrs. Brown | f | 63 | Single | urban |
| **6** | Mrs. Davis | f | 62 | Married | rural |
| **7** | Mrs. Wilson | f | 61 | Married | rural |
| **8** | Mr. Wilson | m | 64 | Married | rural |
| **9** | Mr. Moore | m | 80 | Married | rural |
| **10** | Mr. Taylor | m | 66 | Married | urban |
| **11** | Mrs. Anderson | f | 73 | Widowed, new partner | rural |
| **12** | Mrs. Thomas | f | 76 | Single | urban |
| **13** | Mrs. Jackson | f | 64 | Married | urban |
| **14** | Mrs. White | f | 58 | Single | urban |
| **15** | Mrs. Harris | f | 75 | Single | urban |
| **16** | Mrs. Thomson | f | 64 | Widowed, single | rural |

| | | | | | |
|---|---|---|---|---|---|
| **17** | Mrs. Deborah | f | 78 | Widowed, single | rural |
| **18** | Mrs. Robinson | f | 77 | Married | rural |
| **19** | Mr. Robinson | m | 77 | Married | rural |

### 4.3.2 Data Collection and Data Analysis

The study was segmented into three phases that followed each other over time: first, initial interviews; second, observations of the assistive workshops; and third, concluding interviews. The first step started with initial interviews right after the group of participants had been selected in 2012. All interviews were conducted at the participants' homes to get a better impression of their living circumstances and surrounding environment. We talked about their technical biographies and how they had learned to use technologies such as new media in the past and the role of third parties in that learning process. Outside of this we talked about their self-confidence, expectations, needs, fears or insecurities regarding the use of the device and the learning process.

The second step officially started one year later with a kick-off event in 2013. At this event the group of participants and the research-team met for the very first time as a group. We used that event to hand out the smartphones to the participants. After that, we began with the weekly assistive workshops. The workshops ended up running for over two years, from the beginning of 2013 to early 2015. In total, 72 regular sessions were conducted and documented using observation protocols. These protocols were often enriched with photos and screenshots from the participants' smartphones.

The third and last step, took place at the end of the project between 2015 and 2016. That phase was based on a second and concluding set of interviews with all 19 participants at their homes. We used these interviews to give the participants an opportunity to reflect upon the entire adoption and learning process that they had been through. Amongst other things, we asked them about their process of becoming a smartphone user: how far they had come to rely on them; in what kinds of situations they made use of smartphones; and how they felt they would be used beyond the project. All interviews (both initial and final) were transcribed and anonymized.

Analysis was based on a reconstructive, documentary approach (Bohnsack 2014). We started the process by subjecting some cases to intensive examination, while other cases were only

used to provide supplementary material. Relatively quickly, it became apparent that some interviews or protocols documented central appropriation practices of smartphones, while other cases gave less information. This was partly due to how well the interviewer managed to motivate the interviewees to give longer responses. The analysis process itself was carried out in three steps: First, sections were selected in which theoretically interesting aspects and the subjective relevance systems of the participants emerged with particular clarity. These sections were examined with regard to "what" was said and were 'immanently' or thematically annotated. In the second step, we sought to reconstruct the frame in which a topic was dealt with. At this point, the focus was no longer on "what" but rather on "how" interviewees talked about a particular topic. Finally, depending on how topics had been handled in concrete statements, they were compared and contrasted to other statements in the material. Through constant comparison of the cases, initial assumptions could be checked, validated, modified or rejected on the basis of further material. In the end, we identified a number of practices relating to ICT appropriation in later life that occurred during the process of technology adoption over the years. These will be discussed and elaborated upon below. The data was analyzed using the qualitative software program, MAXQDA 12 (http://www.maxqda.de/).

## 4.4 Becoming a Smartphone User in later life

Continuing our borrowing upon Becker's analysis of what it takes to become a marihuana user presented in the introduction, in the following, we will be examining a range of questions regarding the appropriation practices involved in becoming a smartphone user in later life. In Becker's discussion of the steps involved in becoming a marihuana user he comments that: "an individual will be able to use marihuana for pleasure only when he (1) learns to smoke it in a way that will produce real effects; (2) learns to recognize the effects and connect them with drug use; and (3) learns to enjoy the sensations he perceives." (Becker 1953, 235). Whilst we do not want to overstretch the analogy, the results of our study produced a number of interesting parallels so we will be structuring this section in terms of (1) what it takes to learn the actual practices of smartphone use, (2) the work of learning how to belong to the body of smartphone users, (3) shifting attitudes to smartphone use, and, to sum up, (4) what it takes to become a manifestly competent and 'ordinary' smartphone user. Many aspects of each of these

interests overlap. The structure is purely to make visible the journey towards smartphone appropriation amongst older users and to provide insights regarding how this process of appropriation is distinctive from the appropriation visible amongst mainstream users where the take-up of new technologies may not be treated as something so worthy of remark.

### 4.4.1 Learning the practices of smartphone use

The process, how elderlies become smartphone users are neither straightforward nor identical for everyone. However, we have noticed some patterns how we would like to illuminate here.

Hence, in the initial phase, it quickly became clear to us that we had to be particularly careful in setting up a socio-technical environment, as smartphone use involves the acquisition of a number of basic skills that cannot be taken for granted.

It was clear from the outset, that an accompanied learning environment was going to be a central requirement for the elderly people's participation in the project. Smartphone use involves the acquisition of a number of basic skills that cannot be taken for granted. Particular thought therefore had to be given to: the type of smartphone that would serve best as a training device for the participants; how to prepare the devices for individual use; and how to provide an effective learning environment for the ongoing development of the users' skills. Pre-testing of different devices was conducted with instructors at a local computer club that was organized and run by elderly people for elderly people so as to identify the most appropriate smartphone model. This led to the selection of a model that came with a big screen and a stylus so that the device would be easier to use for people with stiff fingers. Many participants already had a mobile phone, so we ensured that they were able to keep their number and advised them individually on how to upgrade their contracts to get an Internet connection. We also installed W-Lan in their homes so that they could use their phone at home for surfing, downloads, or updates, whilst taking care of any additional costs incurred by doing this. In addition, a Google account was pre-installed on their phones so that they could immediately use them without any hurdles to overcome. Further, a suitable learning environment was provided through local assistive-workshops. These were established as open and shared learning spaces. In the first ten workshops we sought to introduce some very basic functionality, such as operating the device itself and accessing apps, how to telephone and write messages, how to take photos, how to download new apps, and so on. We also designed a handbook to accompany the initial sessions.

However, after these sessions it became clear very quickly that the ten sessions were not enough and the elderly users did not feel confident afterwards to use their smartphone by their own. They formulated their need for further schoolings quite clearly so that we decided to continue with the assistive workshops at out university on a regular weekly basis for the next two years. The workshops were run with an alternating weekly rhythm on Tuesdays and Fridays to keep the groups smaller and to make sure that all participants could attend at least one time slot. It turned out that the same participants regularly joined either the Friday or the Tuesday group with a bi-weekly rhythm. Attendance at the workshops was not mandatory, but we tried to organize them in a welcoming way, offering coffee and cookies. On average 5-11 participants took part at each session. A minimum of 2 and maximum of 4 researchers accompanied each workshop to make sure that at least one person was available to provide the instruction, whilst another was able to provide support where needed, observe and take notes. In the following, we look at what it took to learn the practices of smartphone use in more detail. Following, we introduce different conditions or stages when becoming a smartphone user in later life.

### The initial fear of causing harm and being harmed

In first workshops, we recognize that even the most basic of functionality could not be taken for granted, but our participants must learn the fundamental interaction grammar of today's Smartphones from scratch. Thus, it took some time for the participants to get familiar with the menu structure of the phones, how to scroll and swipe, how to return to the main menu and how to orient themselves within the menu structure all caused varying degrees of trouble. For most of the participants, the first steps towards smartphone were accompanied by a great deal of uncertainty and reluctance. Even later, when they had learned how to download new apps and how to change the arrangement of their apps on the home screen, many hesitated. The cautious hesitation was also moved by the fear of causing harm. As result, there was a reticence to experiment or try anything out: *"I don't want to break it"* (Mrs. White, workshop protocol from April 2013), *"I do not want to cause irreparable changes"* (Mrs. Thomson, workshop protocol from March 2013). This reservation found voice in the first workshop sessions, where many participants reported that they were scared of causing irreparable 'damage' to their device. For instance, participants expressed the fear of downloading the 'wrong' app and then not being able to get rid of it. Mr. Brown, for instance, said: *"I do not want to have that application on my phone. I need more time to decide which apps I really need"* (workshop protocol from March 2013). It took a

while for the participants to understand that they could easily exchange installed apps. With time, the fear disappears, but re-surfaced at the slightest irritation, for instance, if the network disappeared, apps should be updated, or they should reconfigure in any way. These little changes generate a whole new set of concerns.

Our initial focus was to train basic features as quick as possible. However, the insecurity and hesitation of the participants quickly led to us having to reassess our own remit about what kinds of assistance should be provided. It became apparent that just teaching them about functionality was not enough. The work also entailed making the participants feel confident, reassuring them that they were doing nothing wrong and that things could be tried out quite safely. In addition, our aim was to demonstrate that mistakes were easily undone, and a part of the education became an education in repair.

The concern described above extended beyond just doing damage to the device. The participants also felt that they themselves might be exposed to some risk. For instance, some are worried that they might incur additional cost when downloading the wrong app. They also worried about downloading spam by accident. This made them feel vulnerable and uncomfortable. Many of the perceived risks were linked to privacy issues. Nearly all of the participants expressed serious security and privacy concerns, describing the whole nature of smartphone use as *"tricky"* (Mrs. Anderson, workshop protocol June 2013), *"not quite harmless"* (Mrs. Brown, workshop protocol July 2013) or *"unsafe"* (Mrs. Thomas, workshop protocol May 2013). Curiously, this was the case even though most of them were used to using the Internet on PCs. One of the participants, Mrs. Brown, was sufficiently troubled about her concerns that she prepared a local newspaper article and brought it into one of our workshop sessions. The article warned about unknowledgeable smartphone use and argued that Internet use could generate problems for elderly people who lacked knowledge about the Internet. As we will discuss later, articles like this trade upon stereotyped views regarding the use of technology and age. A key point to note about this here is that the participants did not just set these assumptions aside but were rather inclined to question their ability to act competently themselves.

### Getting used to the smartphone

Over time, the participants gained more and more trust and confidence in their smartphone handling, noticing that nothing bad or irrevocable occurred. After the first four to six months, we observed domestication activities where our participants began to make the smartphone to

their own and started to customize their devices on their own. Many had replaced the protective cover that we gave them and had bought their own cover. A few were even adding extra protection by wrapping the smartphone in an additional cloth bag. One participant had even sewn her own bag. Thus, the protection, careful handling and appearance of the smartphone had become manifestly important to them. This also included keeping the smartphone clean: surfaces were kept fingerprint free.

Further, we observed in the weekly meetings that many participants had started to take care over tidying up their storage folders by deleting, organizing or else exporting pictures and other files. These cleaning habits in relation to the smartphone content was not something the researchers had recommended or suggested. From our point of view, they had plenty of space to keep the data on their devices. However, they often asked for this kind of help in the workshops and nearly all of them put effort into keeping their data up-to-date and properly sorted. Many also had personalized wallpapers. using photos of family members, holidays or their pets. Taken together, these routine and mundane practices are the taken-for-granted stuff of displaying ownership of a device. To even assume one has the rights to engage in such activities is an assumption of ordinary ownership and a key indicator of appropriation on their part.

At around this time they were beginning, we noticed significant progress in the participants' smartphone skills. At the same time as their confidence and knowledge grew, they started to discover their own rationales for using their smartphones and sought to discuss these in the workshops as well. For instance, how to share photos, how to synchronize pictures on their phones with their PCs, and how to update their contact lists. This progress was important as learning a tool that produces an effect is essential to continuing use or as Becker notes: "*If nothing happens, it is manifestly impossible for the user to develop a conception of the drug as an object which can be used for pleasure, and use will therefore not continue.*" (Becker 1953, 237). The participants shared their new discoveries also in the meetings and suggested the others new apps like fueling apps, gaming apps (to play with the grandchildren or by their own), apps for hiking, apps to find the nearest pharmacy, and so on. Moreover, the *discovery of usefulness* by discovering useful features also happened during the workshops and through the interactions shared within the group such that. By the end of the smartphone project, most of the participants had developed quite sophisticated patterns of use. However, some insecurities persisted throughout the course of the study for some of the participants. Especially regarding new and unexpected changes, such

as updates or security changes, some participants kept asking till the end of the study and beyond whether it was okay to accept or not.

### Accomplishment and rebirth

When discussing the move towards long-term and sustained use of marihuana, Becker had this to say: *"In every case in which use continued, the user had acquired the necessary concepts with which to express to himself the fact that he was experiencing new sensations caused by the drug."* (Becker 1953, 239). Similarly, it is clear that, for many of the participants, they associated a number of important changes in their lives with their having become smartphone users.

Most of all, beyond the routines they had developed around the new device, the participants expressed pleasure and a sense of accomplishment in having learned how to use a smartphone. Statements like *"I'm so proud I could make it"* (Mrs. Thomas, interview, March 2016) or *"I did not believe I'd finally make it"* (Mrs. Davis, interview, March 2016) reinforced the point that integrating smartphones into daily life was about much more than learning the pure functionality but was a rather bigger achievement for the participants.

Many reported during the weekly sessions or in the final interviews that learning how to use a smartphone brought them a means of social inclusion and participation. One example is given by Mrs. Deborah: *"I feel more like a member of society again"* (Mrs. Deborah, interview, August 2015). In that quote she expressed that learning how to use a smartphone became an opportunity for her as a sense of rebirth and recovery as an ordinary member of society from that she felt excluded. Mrs. Thomson this experience even more detailed:

> *"I just want to be a part of this, and I do not want to belong to the people who reject everything and deny new technologies. I even think I would have had fewer interesting experiences without the smartphone in particular. […] I use it quite often to find something interesting and new, or become aware of something that is going on in my neighborhood." (Mrs. Thomson, interview, March 2016).*

This counter positions against those who "reject" new ICT developments is striking for its contrast to the initial skepticism expressed by the participants at the start of the study. Mrs. Thomson made clear in her statement that the smartphone has become a means for participation for her to keep updated and involved.

Generally, the participants had come to appreciate the value of having a smartphone by the end of the project. Thus, and in contrast to the beginning, they had begun to be characterized as a *"great invention"* (Mrs. Davis, interview, May 2016), as *"a door to the world"* (Mrs. Brown, interview, April 2016) or as *"little helpers"* (Mrs. Robinson, interview, June 2016). Several things were key to this. One is that the use of smartphones had become, for the participants, not something special and worthy of remark, but rather something wholly ordinary and mundane. There are also ways in which smartphone-based practices had become utterly routinized within their everyday lives so that the smartphone had become a taken-for-granted resource for accomplishing a range of ordinary everyday things. Alongside of this, the participants had become deeply appreciative of how smartphones had facilitated a kind of 'rebirth' into a world of social interaction that was otherwise seen as slipping away from them.

### Acquiring motivations for use

Over the course of the project, we observed a range of motivations, why participants wanted to become a smartphone user. In particular, our long-term study showed that motivation was not static, but evolved in and through the appropriation. In the initial interviews, all our participants expressed that they were curious and motivated in learning how to use a smartphone. At the same time, they were also quite skeptical about what value a smartphone would have in their lives and the degree to which they would be capable of mastering its use.

The initial skepticism was often expressed in the initial interviews, when the participants had no own user experiences with the smartphones. The fact that everyone else uses a smartphone did not imply that it must also provide an added value for themselves. Mr. James, for instance, said that he was unsure if he *"would ever use [a smartphone]"* (Mr. James, interview in May 2012). He argued he had managed to live without a smartphone thus far and felt no concrete pressure or striking reason to get one. He might even be said to have had a quite negative view of them because he expressed a dislike of the hype associated with smartphone-based ICT and its overuse:

> *"Sometimes it is a real plague these smartphones. Sometimes people hardly sit, like in the bus or the waiting room, and you see only smartphones, everyone is staring at them. Sometimes it is terrible" (Mr. James, interview in May 2012).*

When we suggested that the smartphone could be used for a range of activities such as communicating, taking pictures, listening to the radio, watching videos, and so on, he said he already had routines for doing all of those things. He was not alone by this position. Many of the other participants similarly considered the available functionality to be *"unnecessary"* (Mrs. Johnson, interview in June 2012), or *"gimmicks"* (Mrs. Williams, interview in May 2012), something where they "just don't know what to do with it" (Mr. James, interview in May 2012), or as "nothing new at all" (Mr. Lauder, interview in July 2012).

This initial skeptic changed, when our participants gained more experience how they could incorporate smartphone use into their everyday life. However, this was not an unalloyed transition. Hence, we were surprised, that the intention to use was less caused by satisfying an immediate need in the sense of the classical utility and adoption theory (Davis 1985). None of the participants came to the project with a specific desire why they wanted to learn how to use a smartphone. Instead, the usefulness of certain applications was only discovered in the process of appropriation. Hence, solving particular problems with a smartphone was not the main driver to get started. Moreover, we found that man participants experienced some curiosity of 'what it is all about with these smartphones' and wanted to give the smartphone a chance that using them might be of benefit in future.

In that regard, some participants saw the project as a welcomed opportunity to get a glimpse of why other people, especially younger people, were so interested in smartphones. Mr. Moore put it as follows:

> *"Of course, I know that these things [smartphones] exist and might be very useful... in multiple situations, otherwise I cannot explain why everyone is using it. I get advertisements for that nearly every day, see it on the TV and see young people using it, but... it is just, I cannot imagine something behind it. (Mr. Moore, interview in August 2012).*

He expressed the possibility that smartphones might be "*very useful in multiple situations*" (Mr. Moore, interview in August 2012), in part because they are so pervasive. However, at the same time he cannot 'imagine' what the attraction might be. Thus, he is curious about the possibilities that might go along with the use of smartphones, without a concrete understanding of what those possibilities might really amount to.

Further, some of the participants saw learning how to use a smartphone as necessary investment in their future. Mr. Brown and Mr. Wilson put it as follows:

*"I am just curious if it could bring some improvement" (Mrs. Brown, interview June 2012)*

*"At the moment I do not need it, but I don't know, maybe I can profit from the new service when I get older and things get more difficult. Maybe it brings some new opportunities to ease some things" (Mr. Wilson, interview May 2012).*

For Mrs. White, who was the youngest participant and living on her own, there was an assumption that the influence of smartphones would grow over the next couple of years and that learning how to use them would be a direct investment in her future:

*"I do not have a smartphone, but I'm not blind or deaf. I know that these things are getting more and more important to keep up with everything. I'm just 58, so in comparison I'm still quite young. If I do not get started now then maybe I'll regret it the rest of my life" (Mrs. White, interview June 2012).*

This curiosity and initial ambivalence about the possible outcomes of taking on a new experience is also quite nicely described by Becker, where he describes the attitude of a person on the point of trying marihuana out:

*"He knows that others use it to 'get high', but he does not know what this means in concrete terms. He is curious about the experience, ignorant of what it may turn out to be, and afraid that it may be more than he has bargained for." (Becker 1953, 236).*

Noticing that smartphones were becoming an increasingly common feature of their surrounding environment, some participants viewed smartphones as a resource that might ultimately help them to deal with impairments or age-related restrictions, as it was formulated by Mrs. Harris:

*"One has to go with the times. At least I think we [elderly people] have to try to cope with the modern... try the new media and use them as best we can. We have the internet and the smartphone so we have to learn and accept it, because we cannot ignore them anymore, it is everywhere, everywhere." (Mrs. Harris, interview July 2012).*

Mr. Moore formulated this benefit even as a kind of societal pressure towards life-long learning:

*"I know I have to keep up with such new things, even as we grow older, we still have to learn new things, although things are not getting easier (Laughing)" (Mr. Moore, interview August 2012).*

Hence, as we will see later on, the motivation to learn smartphone usage in anticipation of its benefits in the future was often entangled with the fear of social exclusion, which we will discuss below.

### 4.4.2 Social embeddedness of being a smartphone user

Our findings showed that becoming a smartphone user also entails evolving a set of meaningful practices that enable the device to be drawn upon to achieve coherent ends that give purpose to its use. During the study we noticed that much of this came to be premised upon the support network, the reconfiguration social relationships. Becker (1953) placed emphasis upon the fact that becoming a marihuana user is something that happens through participation in the groups where it is used. It is here that the user learns how to smoke the drug in the 'proper way'. It is also here that the user has it pointed out to them through specific conversational details things like the symptoms of being high that they might not otherwise have noticed. In other words, the group becomes a place where they are instructed in noticing relevant features that could otherwise be overlooked or dismissed. As Becker puts it:

> *"The novice… eager to have this feeling, picks up from other users some concrete referents of the term "high" and applies these notions to his own experience. The new concepts make it possible for him to locate these symptoms among his own sensations and to point out to himself a "something different" in his experience that he connects with drug use" (Becker 1953, 238).*

#### Formal support networks

This socially enculturation process and the existence of support networks was highly relevant in our study in various places. For elderly people to become smartphone users, we were also compelled to provide aid and to be able to intercept directly when necessary. This is, in a sense, a pre-requisite for bringing this kind of community into contact with this kind of technology. As result, we did not only serve as trainers, but as a help desk. too. For instance, we regularly needed to provide support in (re-)setting passwords. Even though we strongly recommended keeping personal track of passwords, adjustments often had to be made from our side. This meant that we frequently had access to their personal information, which required a good level of trust between the participants and the researchers.

As the participants' skills became more sophisticated, the organization of the workshops started to change. Originally, the researchers had dominated the agenda, but as the participants became

more certain about what they were doing, they began to point out their own preferences. This, we understood to be requests for specific kinds of assistance and sought to provide help accordingly. We as researchers, learned a lot through these kinds of workshops, too. In this way, the workshops became a mutual learning environment for all parties involved.

When the participants started to explore the possibilities of their smartphone more freely, they also developed a greater need for mutual exchange with each other, as well as with us. They increasingly engaged in more informal conversations with one another, both before and after the meetings. Often, they exchanged their experiences with new apps or problems. At the same time, we observed that the participants were starting to ask us questions based on their personal experiences and interests. More than this, we could see that the participants were starting to help each other in the workshops when questions came up or when someone got stuck. Thus, just as was noted by Becker (1953), a group of mutually interested practitioners was evolving, both directly and through conversation. People were able to instruct one another in what it was relevant to pay attention to in order to become an effective smartphone user.

In particular, during the first months, we noticed that the positive group dynamics between the participants was becoming an important motivational factor to join the workshops and attend them on a regular basis. The participants often stressed how important this friendly mutual exchange was to them. During the final interview, Mrs. White expressed it as follows:

> *"I'd never thought that a group like that would work like that. A group of such different people. For me that was really a great experience to see and that these people that probably would not have come together in another way could support each other in such a nice way. That really supported me. […] Some are a little faster in their learning process, and some a little slower, but you could always talk with each other, ask for help or get new ideas" (Mrs. White, interview in March 2016).*

These observations made by Mrs. White suggest that group exchange needs to be ranked alongside of other resources that are traditionally considered to make an appropriate learning environment, such as various technical infrastructure ecologies, the teaching of social media skills and trust-based relationships.

A key point also to note here, is that the workshops were by and large the only place that the participants, being of a certain age, could engage in mutual exchange about smartphone use. This strongly resonates with the problem confronting Becker's would-be marihuana users:

there is only the cohort of other similar users, be they 'deviant' or simply *extra*-ordinary in the eyes of others, with whom exchange upon the topic of use is possible. The practice in question is not one that just anyone like you is engaging in and able to discuss. The workshops had become a place for the participants were being an old smartphone user is not deviant, exceptional or, at the least, outside the norm, but something goes without saying. Have a room where you don't have to justify yourself has significant impact upon appropriation and how it accomplished and what the practice is seen to achieve, not just in practical terms, but symbolically.

### Boundaries of informal support networks

A further dimension attached to all this, is the question of just how elderly people are supposed to acquire the necessary competence to 'keep up'. Our special rather formal setting, where participants worked together to provide support for one another, could not be taken for granted at large. Mrs. Williams conveyed her concerns about this in the following way:

> *"And these new things [like smartphones] would interest me as well, of course the question is again: Where can I get the information, who- whom can I address and ask, who shows me how to deal with it and who helps if there are problems? And it makes sense only to deal with these things, if you do it regularly. Then you have to stay tuned and have to have someone to ask questions and problems. Yes, where can we elderly people get the training for these things, when I do not want to become a burden for someone who helps me?" (Mrs. Williams, interview May 2012).*

Mrs. Williams made it clear here that she does not have people in her close environment that could help and support her when learning how to use something like a smartphone. Hence, elderly people going into retirement may confront a particular issue here: Once they are no longer engaging with other people involved in the process of appropriating new technologies and practices. In contrast, younger people could engage in a range of possible mutual exchanges about use at school, at university, or at work. As Nguyen et al (2015) noted, many elderly people had no friends of the same age using a smartphone who they could ask for help. This makes elderly people feel dependent on their younger relatives, such as their children or grandchildren. However, being a complete novice, Mrs. Williams noted that she as many participants needed to learn many issues that were taken for granted by younger people. Hence, she had a fear to annoy their relatives by asking *"stupid questions", "asking the same things over and over again"* and, thus *"to become a burden"* (Mrs. Williams, interview May 2012).

### The smartphone as a social learning place

The special character of ICT artifacts is that the artefacts can be used as channels to exchange knowledge about these artifacts (Stevens and Pipek 2018). With this in mind, we decided to use a group messaging service to support group learning and active communication between the workshops. While this was not intended, this channel was not just used to exchange tool knowledge and support for problem solving, but was used to chat about personal issues and general group activities, too.

In particular, the participants immediately began to use this service for more informal interaction. Aside from posting technical questions they also began to help each other out whenever possible and started to post local events and share their holiday photos. They even developed a sort of game, where someone would share a picture and the group had to guess where it was. Not all the participants were equally keen on this kind of frequent and informal interaction, though they still wanted to receive the organizational information. To address these divergent interests, we implemented two group chats: one for the formal information about the workshops that sent messages to all of the participants; another that could be joined voluntarily for informal chatting. The first chat group included all 19 participants, while only 15 participate in the other chat group.

By the exchange in the learning group not only tool knowledge was exchanged, but implicitly the participants acquired social media skills, too. The learning group provided a 'safe' place for the practice of various skills. Here, the messaging service quickly became the preferred communication tool, displacing other options such as e-mail. Even after the project ended the participants remained quite active on the group chat, underscoring the way in which appropriation was serviced by the provision of a cohort within the confines of which smartphone use was a shared and unremarkable practice.

### Reconfiguring social relationships

Since smartphones are also a communication medium, it is not surprising that their appropriation is also an influence on the structuring of personal relationships. Many of our participants, for instance, said that their smartphone use had increased their feeling of being connected, as it was stated by example by Mrs. Thomson: *"It really allows a different and new form for communication"* (Mrs. Thomson, interview, March 2016).

In particular, many participants said that using a smartphone had changed their family life, especially with regard to their relationships with their children and grandchildren. However, we uncovered that it was not only the communication features, but the symbolic meaning of the smartphone that had an impact on the personal relationships among family members, but also the own peer-group. The families of many of the participants were using various kinds of family group chats to communicate and share pictures or videos. Once active with their smartphones, the participants were able to participate in this. Many said they liked how easy it was to keep in contact, sending and receiving messages or photos. In five cases the participants directly expressed the view that the smartphone had presented them with a new resource to actively take part in family life. For instance, Mrs. Anderson and Mr. James reported that instant messaging as being particularly helpful for supporting family communication when members lived at some remove. Also Mr. Lauder characterize the smartphone as a tool to *"re-connect"* with his family (Mr. Lauder, workshop, October 2015).

The smartphone did not only affect the maintenance of remote relationships. Mrs. Johnson, for instance, was living with her husband in the same house as her son and his family, including her two granddaughters aged 16 and 19:

> *"I mean, I am lucky enough to see my granddaughters almost every day. I prepare the dinner every day for all of us, but now, since I have WhatsApp I get here and there a message, sometimes a picture from them, just random times in between. What they do, what is going on with them. Today, for example, one wrote to me that she would come to dinner a little later. This is actually nothing special, but nevertheless it was just such a nice small message from her about which I had been pleased and I did not have to wait" (Mrs. Johnson, workshop, May 2015).*

Although, Mrs. Johnson saw her granddaughters pretty well on a daily basis and had a good relationship with them, she saw the new communication opportunities as an enrichment of what had existed before. In contrast to other communication tools such as email or telephone, she particularly liked the way it could be used *"on the fly"*, giving a sense of immediacy that was absent in other communication tools. It is especially worth noting how she appreciated the way she could be involved in the ordinary everyday patterns of routine communication, such as someone saying they'll be late for dinner, that make up the taken-for-granted resources in family life.

There were also cases where the participants reported that being a smartphone user had reconfigured how they were viewed by their grandchildren. For instance, Mr. Robinson said:

> *"My grandson says that he is the only one among his friends whose grandparents have a smartphone and that his classmates envy him that he plays around with a smartphone when visiting his grandparents [laughing]" (Mr. Robinson, workshop, February 2014).*

More than this, Mr. Robinson proudly stated in the course of one assistance workshop that his grandchildren liked to play games on his and his wife's smartphones. He also told us that they liked to use a painting program on them to create and edit pictures. Whilst this provided a new resource for interacting with grandchildren and clearly rendered them special in their grandchildren's eyes, there is a counterpoint to this that is worth noting: it makes clear that, by being smartphone users, they were not like *ordinary* old people.

An immediate question to pose is whether the enrichment being a smartphone user brought to family life extended to other kinds of relationships, for instance with friends in the participants' own peer groups. Here, however, the outcomes were somewhat different. Many of the participants complained that they missed having the opportunity to communicate in a similar way with friends of the same age. As Mrs. Williams put it:

> *"I know only two other people outside of our group who are a similar age and use a smartphone. Sometimes this can be even a little bit frustrating, because I know the advantages and how easy and nice it would be to share things, you know like some events, and information or just some nice pictures" (Mrs. Williams, interview, January 2016).*

Many participants like her regret that they cannot extend the advantages with their friends because most of their peers had no smartphone. For instance, Mr. James would like to share a hiking route, but since his friends did not have a smartphone, he could not share his experiences (digitally). As life, for them, went on as normal beyond the confines of the project and the specific group of users they were a part of, they would ideally have liked to bring some of the things they were uncovering to bear upon their wider set of interactions. No matter how positively our participants viewed the potential of smartphone use themselves, they were engaged in a set of practices that were not the kinds of things that older people in general *do*.

### 4.4.3 Attitudes to smartphone use

Proctor et al. (1999) have discussed how aging is 'co-produced' within the activities of old people and their networks of formal and informal caregivers. Along similar lines, de Beauvoir (1972) described old age in 'La Viellesse' as an 'unrealizable' category, in which old persons experience themselves as a subject but are perceived as an object by outsiders: ultimately the old person is obliged to accept the external image of themselves. Whilst this may have changed in some respects, the occasionally troublesome relationship between imposed images of aging and the self-image of elderly people themselves continues to exist. What we are left with here is the fact that elderly people have a sense of what it takes to act as an elderly person might act and to be seen as an ordinary elderly person by others. In our study we have seen various stereotypes, norms and societal expectation that shapes paths of appropriation in various ways. However, we did not saw a coherent picture, but the variety is characterized by tensions and partially contradictions that elderly people must cope with.

#### Challenging social stereotypes, expressing ordinariness

We uncovered various examples, in which the participants had to work against age-related stereotypes and where becoming a smartphone user challenged the notion of being recognizably ordinary. Mrs. Jackson, for instance, reported that she felt observed by other people when she used her smartphone in public. This made her a little nervous and anxious about making noticeable mistakes. She even expressed a fear of being perceived as strange or awkward for using the device in her age:

> *"Sometimes I'm really considering turning off my smartphone in public. Like in one situation in a train, when I sat in front of two young guys. Normally, I would play some games in such situations making the time go by. But in this one I considered twice. I felt it was a bit embarrassing […] what does it looks like, an old woman gaming with a smartphone?" (Mrs. Jackson, workshop, December 2015).*

This reflection is clearly geared towards a view of how elderly people might be perceived and how they might be expected to behave in public. It also makes clear that the way elderly people see themselves is not only shaped by their own experiences, expectations, and perspectives, but is also affected by the powerful images of aging they encounter in their surroundings. Thus, to be a 'smartphone user' and to be 'elderly' is a conjoining (or was then, at least) of two not

commonsensically conjoint categories, leading to a palpable discomfort when the two are put on display.

In some circumstances, participants even found the successful use of their smartphone in public to be self-enhancing. In the following anecdote from Mrs. Williams, she is talking about an event that happened on the street when she was asked for directions by a couple of adolescents:

> *"I remember on one situation in that I got asked for the right way by a group of younger people. I thought a while about their question, but I didn't know the street they were looking for. Then I got out my smartphone and looked it up. Everything went well, I found the street immediately and could give them a good answer. The youngsters looked at me smiling and I knew I'd astonished them (she smiled)" (Mrs. Williams, interview in January 2016).*

In this example it seems that she enjoyed playing with images of age. Mrs. Williams effectively used the smartphone as a symbolic resource to re-negotiate the view of others and also her own self-image as an elderly person.

In the later stages of the project many participants reported that they had surprised others in their social environment with the things they were capable of with their smartphones. Often these led to very positive outcomes, as reported in the following:

> *"In my gymnastic and choir course I'm always asked by the other [elderly people] how I managed that, and I know that they admire me because of it. Then I always recommend the courses and encourage my friends and neighbors to learn it – it was such a good experience" (Mrs. Johnson, workshop, September 2014).*

However, something to stress here is that their skillful smartphone use was commented upon as something *extra*-ordinary, not something that is taken for granted regarding elderly people.

### Something for younger people

In our study, we uncovered further that common stereotypes about who are the 'right' smartphone user and what is the 'right' use promotes subliminal inclusion and exclusion mechanisms. Even many of our participants, like Mr. Moore for instance, predominantly regarded the attraction of using smartphones as something for younger people:

*It feels like there is hardly any connection to me and I don't know any other older adult who is using it. […] Thus, it feels like it is not for the older people, it is something for the younger generation, but not for us the old ones" (Mr. Moore, interview in August 2012).*

Hence, in that regard the participants often reported in the initial interviews that the only contact they'd previously had with smartphones was passively observing their use by others around them, without being able to take part. There is more than a hint of a complaint in all of this about exclusion. In particular, this was founded upon a presumed difference in competencies between older and younger people. A number expressed the view that young people would have a playful and intuitive grasp of how to handle smartphones. While young people seemed to have *"learned [smartphone use] in the cradle"* (Mrs. Taylor, interview June 2012), smartphone use for elderly people was assumed to involve a lot of hard work. Thus, at the outset, many participants expressed a doubt that they would ever be able to use a smartphone properly: *"I wouldn't even know how to get started. There is no one I can ask",* claimed Mrs. Brown in her first interview in 2012 when we asked her why she had not become a smartphone user before the project. *"I guess I'm too old to learn this"* (Mr. Robinson, interview April 2012), *"I will not learn this anymore"* (Mrs. Garcia, interview April 2012), and *"I don't think I can handle this anymore"* (Mrs. Wilson, interview May 2012). Statements like these were frequent.

### The pressure to belong and the risk of exclusion

The predominant stereotype of the young smartphone user subliminally excludes older people as not belonging. At the same time, there is another, implicitly conflicting societal expectation that everyone should own a smartphone in these days and use it competently. The latter was perceived by many participants as subliminal pressure that, if they did not try to get to grips with using things like smartphones, it would result in their exclusion. Mrs. White, for instance, considered kind of social duty to achieve a competence in using new media *"to try to cope with the modern"* (Mrs. White, interview June 2012). In a similar vein, Mrs. Harris, commented:

*You can be part of that or not, but then it feels like being excluded from many areas of society […], because uh. It seems that is just the new way to do things and we have to cope with the technology today […] otherwise we have to accept to be no longer part of that new modern world" (Mrs. Harris, interview July 2012).*

As Mrs. Harris pinpoint by using the inclusive *"we",* the risk is not just perceived as an induvial problem, but as a general issue for elderly people in general. In this view, smartphone use is about much more than just functionality: use or non-use provides a route to either social inclusion or exclusion for elderly people in general. Implicit within this is a social criticism that elderly people are being somehow neglected in the processes of socio-technical change. In a similar way, Mrs. Brown noted:

> *"If you do not join, then you're out. Then you are only 'oh grandma, you know nothing'. Then we are not asked at all. So, WhatsApp was for me enrichment." (Mrs. Brown, interview, April 2016).*

The example turns out that the need to adopt new technologies is not only perceived as an external compulsion, but also as a personal enrichment at the same time. The instant messaging service had an added value as it is an enabler of social connectivity, but also a kind of gatekeeper. The external pressure, however, is a double-edged sword as it excludes elderly people, that in contrast to Mrs. Brown, are not capable of using them. Moreover, Mrs. Brown even suggested that there were ways in which smartphones did *not* necessarily support communication:

> *"If I want to know something, you enter a keyword [into a search engine] and you will get information as much as you want. But, mhm, this has the disadvantage that we, the older generation are no longer asked. Before, we were the ones who know things. We had the life experience. Today nobody asks you anymore. Because everyone can go to the Internet, even children can go on the Internet to get to know everything. The life experience of an older person and also the practical things of daily life are very much in the background. I think this makes the communication between the generations much less important and can cut contact points. Then, if you do not have a mobile as an elderly person then you are completely out. With one [smartphone] you can communicate based on that, but without it gets really difficult" (Mrs. Brown, interview, April 2016).*

Her argument is very much based on the notion of a generational contract where younger people can profit from elderly people's knowledge, thereby providing grounds for communication. Here she is suggesting that the connection between the generations is being eroded by the facility of on-demand access of information. In her view this makes communicating with elderly people unnecessary or at least less likely.

As a consequence, she sees the need for elderly people to adapt to new communication habits such as those afforded by smartphones just to avoid being sidelined. It is at least partly against this concern that the motivation exhibited by the participants to use their new-found social media competence as a resource for connecting with other members of their family must be seen. Thus, smartphone use was indexical of some much deeper-seated issues for elderly people that could be seen in both a positive and negative light. Smartphone use could operate as a symbol of exclusion, with elderly people not able to keep up with the times anymore, but, at the same time, it presented a powerful means of working against restrictive images of age.

### 4.4.4 Establish everyday use practices

Making use of a new technology is not just adopting it, but also come along with the evolution of existing practices and activity systems where the new technology became part of (Stevens and Pipek 2018). This was also shown in our study, where we observed the incorporation of smartphones into participants' daily lives and giving it a place in their everyday routines at two, entangled levels: first with regard to establish routinized practices for managing the device itself; and second regarding the variety of routine practices that were enabled and supported by having a smartphone.

During the project, the participants talked about their various ways in which smartphone use had also come to be embedded in their domestic routine. For instance, it became a habit for several participants using their smartphones for going on the Internet, rather than their PCs. Some reported that they found it more comfortable to surf from the kitchen table or the couch than they did sitting in front of a PC. Some also mentioned preferring to read on smartphone devices. The big display and zooming options made it easier if they were suffering from any kind of visual impairment. There was also widespread use of their smartphones as a feature of managing the everyday domestic routine, for instance via the calendar and note functions or by setting alarms, because they found it to be more at hand. When a device is oriented to as the most to-hand and reasonable resource for accomplishing ordinary everyday practices it is clearly something that has been appropriated because, instead of it being oriented to as a thing with a prescribed set of functionalities, it is being oriented to as a thing that is 'just there' for getting things done.

Speaking regularly with the participants, we found out that the regular smartphone use changed some daily habits of the participants. Here it showed up for, for instance, some participants spoke about replacing bulky paper maps by using Google maps, or using particular apps for hiking trips or city guidance:

> *"If I'm going for coffee and cake in [Name of a local city] or something, I always use my smartphone: I enter the destination and use it as a guide to reach a place, and I make use of waypoints, and if I'm going a longer distance I use it [the smartphone] for navigating, or to find a nice place I don't know, or that is close by, like finding a new café in the area" (Mr. Lauder, interview, March 2016).*

Many of the participants mentioned a similar regular use of their smartphones when undertaking journeys. Going to a new place could provoke a variety of smartphone-based activities, such as checking the weather, planning the route, acquiring more information about the local environs, or even looking up information about the local history. The smartphone was frequently described as a daily companion that *"is always at hand when needed"* (Mrs. Donna, interview February 2016). Mrs. Donna, who often took the bus, reported that her smartphone had made her trips on public transport much easier:

> *"Since I have the smartphone, I have the timetable always with me. This is quite useful, because when I see the bus comes in half an hour, I can just use the time for example for eating ice cream. This makes me much more flexible" (Mrs. Donna, workshop. August 2014).*

In other interviews, participants discussed in detail how getting access to a place could turn out to be a major issue, e.g. finding out what local walking constraints they might be confronted with, or how much walking would need to be done. With this in mind, one of the oldest participants reported that the various map applications on the smartphone provided her with a new confidence and freedom to undertake longer journeys to unknown places:

> *"This was exciting; I can tell you that. Here I traveled to [Name of city that is about 170miles away from the interviewee's hometown]. That was really a little adventure [laughing]. […]. So, I only knew the address of the hotel, but had never been in [Name of city] before. Yeah, but I just went there with my smartphone and took the train. And this really worked out so well. I'm still amazed, SO WELL! […] Without the experience with the smartphone I'd never have dared to travel there" (Mrs. Deborah, interview, February 2015).*

It is easy to see why this kind of functionality is appreciated by elderly users. What is interesting is how quickly it became embedded in their everyday routines, with smartphone use in this regard passing from being something worthy of remark into something that is turned to as a matter of habit.

Entertainment is another area in which the participants reported various evolutions of everyday routine and where the smartphones had become an ordinary to-hand resources. Mrs. Jackson, for instance, often spoke about how she was using it for games:

> *"I used to play on the pc computer, but now I'm using the smartphone. This is much more comfortable. I can sit on the couch and play cards or something else" (Mrs. Jackson, interview, April 2016).*

The participants also mentioned using their smartphones for listening to the radio and pod-casts, or for watching movies, etc. Some enjoyed taking photos with the smartphone camera, then sharing them through social media applications or uploading them to their PCs.

Another example is given by Mrs. Williams, who volunteered as a storyteller in a kindergarten and elementary school. She used her smartphone to practice her storytelling. During the final interview in March 2016, she told us how she loved to go for walks and that, whilst out walking, she would record her stories and listen back to them to support with their rehearsal. She said that this helped her to get a better feeling for the story and the pronunciation. The sheer mundanity yet evident reasonableness of this practice is especially powerful in how it demonstrates a point of appropriation. Here, a preexisting need (to rehearse stories) is supported by the creative recognition of how a smartphone might facilitate that by simply being there and to-hand.

## 4.5 Discussion

In our own analysis we have sought to draw a more nuanced picture regarding how smartphones are used by elderly people, without holding any pre-defined view as to what that use might be motivated by or look like. The user group we selected was quite heterogeneous in its composition and shared overall good health aside from smaller issues with their eyes, legs or backs such as one might find in any group of people in the 'third age group' (van Deursen and Helsper 2015). Hence, it was not their health that led us to focus on this group of users,

but the fact that they were all smartphone 'newbies' when the project started and we had a strong interest in their appropriation practices because we wanted to discover, without prejudice, what it would take for them to become a smartphone user. We have discovered a wide range of ways in which smartphone use became embedded in their lives and the advantages and challenges that accrued to that. In particular, we have seen that they initially separate, and partially contradictory identities of being an older elderly and being a smartphone user have been transformed in and through their technical appropriation into an own identity of being older smartphone user, in which both parts are equally connected as amalgam. However, we have also discovered, across a wide range of concerns, that smartphone use (at least during the time of the study) positioned the participants in relation to their social environment in ways that were not wholly unproblematic.

### 4.5.1 The 'deviant' practice of elderlies' smartphone use

Over the course of this paper we have somewhat mischievously played with the notion of becoming a smartphone user in later life being similar to how Becker (1953) once depicted the process of becoming a marihuana user. We must stress that this is not something we want the reader to take literally. Outside of their potential nuisance value in certain settings, smartphones are not typically met with the same level of disapprobation or legal stipulation one will encounter in many societies with regard to drug use, including marihuana. Nor would we want to argue that smartphone use might bring with it the same kinds of highs or risks of leading to other, less-savory practices. Nonetheless, there is a serious point here. In his examination of what was involved in becoming a marihuana user, Becker was deliberately setting himself up against a prevailing view at the time that deviant practices were somehow founded upon psychological predispositions. Instead, he was interested in understanding how deviant practices had a social organization and he wanted to make that social organization visible, using the smoking of marihuana as an example.

Now, smartphone use might not be typically labeled a deviant practice or spoken of in those terms. However, what counts as deviant is very much bound up with what is taken for granted about a particular body of people, with deviancy being used to index behaviors deemed to be outside the expected or acceptable ways of behaving amongst that group of people. Whilst it may not be extreme, the findings above have revealed that using a smartphone was, at the time,

something that sat outside of the expected behavior of elderly people. Thus, the users discovered that, on occasion, their use of a smartphone could elicit clear surprise and incredulity. What we have sought to make visible through our setting of smartphone use against Becker's discussion of marihuana users is that people bring to bear a range of assumptions regarding what other people's expectable orientations to technology will be. On the basis of this, assumptions were also made regarding what people's expectable technological practices will be, according to different identifiable bodies of uses. Appropriation of a technology is necessarily formulated against these expectations. As, at the time this study took place, smartphone use was not an expectable technological practice for elderly users, for others around them it constituted a breach of expectation. If not exactly deviant, it still informed how those practices were therefore seen, including how they were seen by the users themselves.

### 4.5.2 Identities as evolving natural objects in and through technology appropriation

Related to smartphone use as deviant practice, the question of identities raised. As Butler and Fitzgerald (2010) noted, one challenge for research on identity is to demonstrate that and how identities are made relevant for the participants of an interaction. Regarding this, we have seen that the smartphone served as a kind of *identity tool* in that sense it is used to express, negotiate, play and make identities accountable. Moreover, we have seen that the appropriation of technology is embedded with dealing and working on at least two identities: Being an older elderly and being a smartphone user.

Making identities accountable reveals parallels to Sacks' (1992) excellent, in-depth examination analysis of interactions between family members, visiting other members of the same family, where one of the parties was systematically worked up through the talk as an 'old man and burden upon the family' (Sacks 1992). He analyzed the visit from a husband and wife to their daughter's and they have brought along with them the husband's father called Max, who has only recently been widowed. They were all sat down at the table to eat some herring. However, Max persistently refused to accept any herring every time it is offered to him.

What Sacks very neatly demonstrated is how an assumed right to speak to elderly people in a certain fashion gets presented in talk. He pointed to how, were it any other party repeated refusals to accept Max's unwillingness to eat herring and efforts to persuade him to have some

anyway against his better judgment, would be not just insulting but interactionally problematic. Not only do they assume they can speak to him in this way, however, but he also does not call them to account for it. In this way, he suggests, someone's status as an 'old man' is not something overt and discovered for the occasion, rather it is an *evolved natural object* where even something like 'being obstinate' is taken to be a feature of the object and oriented to in that way (Sacks 1992).

We have seen a number of times in the above findings how the participants doubted their own capacity to master using a smartphone and were concerned about becoming a burden on the younger members of their families by asking for help. What we are pointing to here is something quite powerful. Once you are seeable as a member of the category 'elderly' and are prepared to also place yourself within that category, then a bunch of natural assumptions and presumptively associated characteristics come into play that larger screens or bigger buttons or any other purely technical 'fixes' are powerless to resolve, regardless of whether you want to use a smartphone or smoke marihuana. This is productive of a number of challenges that we have already begun to outline above, for instance, the problem of support.

### 4.5.3 Appropriation outside of the mainstream to belong to the mainstream

In this paper, we have stressed on a number of occasions that smartphone use amongst the elderly was viewed as remarkable at the time of the study. This is because the specific case of smartphone use is changing. As an increasingly large number of existing smartphone users enter retirement, the proportion of elderly uses is also increasing, as would be the case with any established technology.

However, the case we have examined is perspicuous, not because of the technology itself, but because of its examination of what appropriation looks like, and how it is confronted with challenges, when it is pursued by a community outside of the mainstream. We have delineated how, in this kind of situation, the fact that use is viewed as exceptional (if not deviant) leads to a number of interactional and organizational outcomes that can stifle the processes of appropriation without proper consideration of how it might be supported. In contrast to smoking marijuana, however our case characterized by the contradictory concurrency that one key motivation for elderlies to learn the smartphone use was not turning away from society but belong

to the societal mainstream, however by learning it, they become a member of the exotic specimen of an old smartphone user. In particular, the problems confronting elderly users of technology relate to the fact that they occupy a certain moral position within society that does not readily allow for them to become agents of their own fate because, as with young children, a variety of parties can presume the right to adopt positions on their behalf. When they seek to challenge such positions, this itself can be taken to be a manifestation of their age.

What we have shown here is that this is by no means a fixed outcome. Successful appropriation of new technology can take place amongst older users, this appropriation can be effectively supported, and they can arrive at a position where they have become ordinary users, with their use being embedded in, and taken for granted as an aspect of, everyday life. The key challenge, we would argue, is to identify appropriate mechanisms for support whereby their use can be rendered ordinary in this way.

### 4.5.4 Legalize it, don't criticize it – providing places for ordinary use

Becker noted that novices smoking marihuana for the first time often do not get high because it "*may be that the drug is not smoked 'properly'*" (Becker 1953, 236-7). He went on to elaborate that it has to be smoked in the right way to produce symptoms of intoxication, e.g. taking in a lot of air and holding it down. In other words, there is a technique involved in getting high that is not necessarily immediately apparent. Becker pinpoint that becoming marihuana user is not straight forward, but

> *"an individual will be able to use marihuana for pleasure only when he (1) learns to smoke it in a way that will produce real effects; (2) learns to recognize the effects and connect them with drug use; and (3) learns to enjoy the sensations he perceives." (Becker, 1953, 235).*

In a similar way, our participants did not enjoy the smartphone in the beginning but must learn this step by step. Further, we outlined that for our participants, the journey to apparently *ordinary* use entailed a body of work and accomplishments that unfolded over time. Thus, we learned that frequent repetitions of how to use the different functionalities were very important to the participants. At the start, some even made notes regarding the specific steps needed for individual tasks.

In addition, an essential part of learning to become a marihuana user was its pursuit in social groups where smoking marihuana was part of the normal business and the pursuit itself was

never called into question. Although, the use of smartphones by older people is not prohibited, it is by no means something that can be taken for granted, but extraordinary, where others partly smile at it, observe it with astonishment, or critically comment it. Concerning this, one of the key elements in this study that facilitated the move towards smartphone appropriation for the participants and their incorporation in their everyday lives was the existence of a group of other parties in much the same position. This alone would not have been enough, it was the regular constitution of this group in the workshops and the provision of appropriate supporting technologies, that were themselves premised upon use of the technology, that provided the all-important glue.

We have noted here how being a smartphone user in social settings outside of the group could result in unwanted tensions and visibility, undermining the sense of being a smartphone user in later life being something ordinary and acceptable. Even when this was resisted or celebrated, it only served to accentuate that the practice was considered to be anything but ordinary. This is one resource for research to reflect further upon how the appropriation of new technologies might be effectively brought about amongst the elderly. Put simply, this indicates a need to think less about reconfiguring the *technology* for appropriation by this group of users and more about reconfiguring the *ecology* within which appropriation might occur.

Something else worthy of note is that the smartphones were actively used by our participants for '(re)-establishing social relationships and for getting connected'. Elderly people, it turns out, can profit in multiple ways from a wider involvement in ICT-based communication. Particularly, we identified its potential to (re-)connect them with their own families. The point to emphasize about this is that this provided the participants with adequate grounds for wanting to incorporate the technology into their lives. The social aspects of using new media for elderly people have so far only been randomly addressed, with most works that relate to messaging, such as that of Ling and Bertel (2012), focusing on analyzing the data traffic, its frequency and its addressees, whilst leaving aside its actual impact on social relationships. This kind of support for preserving social ties and facilitating the uptake of new technology therefore needs to be taken much more seriously by the community.

Finally, it is worth noting how the smartphones became taken for granted resources in the participants' everyday lives. Specifically, there were four interrelated concerns that enabled the fluid accomplishment of this: 1) the support of communication; 2) the support of mobility; 3)

the support of entertainment; and 4) the support of managing ordinary everyday routines in general. This is a strong indicator that the current emphasis upon 'assistive' technologies that are largely focused upon health management and overcoming impediments is missing the extent to which elderly people are keen to use ICT for exactly the same kinds of things as everybody else.

### 4.5.5 Beyond learning: Providing places, where own use cultures can be cultivated

In Becker's observations of marihuana users, he noted that "many new users are ashamed to admit ignorance and, pretending to know already, must learn through the more indirect means of observation and imitation" (Becker 1953, 236). This kind of strategy is somehow feasible (if not ideal) when use is regularly undertaken in the company of others who are also engaging in the practice and who might be mimicked. Clearly, for elderly people entering retirement, this is not an option. Regarding this, one of the most important challenges, we uncovered, is that it is difficult for elderly users to exchange information about new technology with their peers or to find support. In relation to this, and with clear relevance to the preceding part of this discussion, we have also noted that smartphones are not only functional devices, but also cultural artifacts that are possessed of a notable symbolic value. This shifts the question away from how to design for the compensation of age-related impediments towards how one can more adequately support elderly participants in the appropriation of new kinds of technology when they: 2) lack a naturally occurring surrounding cohort of 'interested users'; and 1) are confronted with a series of natural tensions that mean that they are not necessarily well-positioned to ask for help from other seemingly obvious candidates, such as younger family members. Let us examine some aspects of how to provide support under these circumstances in greater detail:

At the outset, when attempting to arrive at appropriate rationales for use, elderly people found it hard to come up with ways in which smartphone use might actually complement their lives. One part of this, of course, was to do with perceived risks and anticipated physical limitations, many of which were associated with the cultural category 'elderly' discussed above. However, it was also clear that, given the opportunity to do otherwise, 'elderly' users are not necessarily happy to take this lying down. They are aware of how both exclusion and the cost of inclusion play out in this. They are curious about new technologies and willing to experiment with it, given the chance, they are prepared to risk being seen as being awkward, obstinate or even

deviant in the course of doing so. The problem we noted earlier is that, despite this potential interest, they are morally positioned in such a way that finding support in learning new technological practices is not evident and, setting aside well-intentioned academics and a handful of charitable concerns (which has its own moral connotations), there are not so many ways in which a natural obligation to provide such support might arise. This presents a question regarding how a natural and appropriate form of support without any difficult moral connotations might be developed for such a cohort of users. To put it another way, to lower the hurdles to uptake, there need to be good mechanisms for appropriate appropriation to naturally take place.

In relation to this, one of the significant features of this study was that, when an opportunity for a naturally evolving community of practice with shared interests was presented, a place where problems and interests could be safely expressed and mutually elaborated upon, the motivations for use, competence in practice, development of more sophisticated techniques and discovery of creative possibilities took to the air and flew. So, the findings emphasized the importance of an appropriate learning environment and a set of best practices framed around developing appropriate ecologies within which prospective new ICT-users might find their way towards use in later life.

## 4.6 Conclusion

As we pointed out at the start, the findings of this paper are relevant to understanding not just how elderly people may come to appropriate smartphones, but rather how they may develop a relationship with new ICT in general. We have already indicated that the relationship between elderly people and smartphone technology is changing apace as more and more current smartphone users become members of the 'third age'. However, the problem of engaging with new ICTs as they appear on the scene is not going to go away for elderly people. Completely aside from the bodily or cognitive impairments that mostly occur in very old age, there is a risk of people becoming "digital immigrants" at a much younger age, when retirement starts and people are no longer involved in the strong communities of practice where new ICTs are typically first adopted. Nor should the reflection end at this, for there are numerous groups of people who, for one reason or another, may find themselves in the position of being 'new' to some technology but in a position where that technology offers to bring them some kind of

value that would not otherwise be available. Thus, our reflections upon appropriation outside of the mainstream have potential relevance to other communities as well, though the moral positioning in each case may differ.

It should be acknowledged that there were limitations attached to the research process we have reported here. So, it should be noted, for instance, that we were not only observers of the appropriation practices of elderly users; we ourselves were heavily involved in and affected by that process. We selected only those participants who showed initial interest and who were somehow attracted by smartphone ICT. This makes the issues regarding exclusion and support all the more challenging because we were only tapping into the group who were 'curious about the experience'. We constantly motivated the participants and tried our best to support the appropriation process during the assistive workshops. Being this immersed in what was going on certainly removed any prospect of being somehow detached or 'neutral'. However, whilst some might consider this to be an issue, we feel there are important advantages that accrue to proceeding in this way.

First of all, ethnography hinges upon 'membership' (Malinowski 1922) and there is no question that our active involvement brought us insights about membership that we could not otherwise have acquired. More than this, the participatory design philosophy that we had adopted from the outset helped us to ensure that the process of smartphone appropriation by the elderly users was run under conditions that were geared towards success because we were continually getting direct feedback from the users when they disliked or liked our work. They were positioned to be able to make suggestions themselves regarding how to improve the process and, in most cases, we were able to implement their suggestions. Furthermore, the long-lasting and intense contact we had with the participants helped to create a relationship that was solidly founded upon trust. Hence, we were not only researchers posing questions, we were the people they could turn to and ask for help and support when it was required, so they came to view us in a positive light. Thus, a solid foundation for our interviews and observations was that the users knew that we trying to not only 'find stuff out', but also to support them, taking their needs and interests seriously. This in turn helped us to understand their learning processes much better and has fed actively into our understanding of how appropriation processes might be supported 'on the ground'. Vitally, by working this way, by providing the workshops as a resource, and by integrating a communication infrastructure that extended beyond the physical

workshops, we effectively presented the participants with the necessary milieu for natural support practices to evolve. We helped the participants to construct an ecology where they could become smartphone users without being made to feel incompetent, exceptional, or even deviant, when doing so.

# 5 Designing for way-finding as practices – A study of elderly people's mobility

**Abstract**

Mobility assistance ICTs have become important companions in daily life as digital affordances have become sophisticated. However, understanding and researching everyday way-finding is still challenging, mainly because of the sheer difficulty of collecting empirical data about concrete occasions of use. Hence, we argue that those methodological challenges make it harder to understand the mobility needs of certain user groups. We aim to address this gap while focusing on elderly people, a user group that has increasingly become a focus of HCI studies, and ask the following questions: (1) What are the everyday way-finding practices of that user group? And (2) how can these be supported by mobility assistance ICTs? For answering them, we developed a methodological framework to study daily mobility as way-finding practices and conducted an interview study with 15 'young elderly 'people supplemented with a probing technique. The paper concludes with reflections on the potential for and limits to, the study of, and designing for, way-finding as practices.

## 5.1 Introduction

Nowadays the digitalizing of mobility affordances is proceeding apace. Mobility assistance ICTs such as 'Google Maps', 'Google Now', 'Foursquare ', 'Qype', 'Quixxit' or 'Yelp' increasingly influence how we find our way about. Some services like 'Lyft', 'Zoomride', 'Car2go', or 'Uber' are ubiquitously accessible. Up until now, work on mobility assistance - related ICTs has mainly aimed to support the use contexts around particular mobility modes. Thus, current works often focuses e.g. on car use (Meschtscherjakov et al. 2011), public transportation (Repenning and Ioannidou 2006), car- and ridesharing (Pakusch, Thomas, Neifer, et al. 2018), or on other navigational features (B. Brown, McGregor, and Laurier 2013), just to mention a few of them. In this paper we want to shift that perspective from a research focus on particular transportation modes (like the car, public transport, newer sharing concepts or navigation), towards mobility studies that take a closer look at particular population segments (like those of families, children, commuters, refugees or elderly people). Hence, we aim to enrich this research corpus with a

new focus on the way-finding practices of particular user groups. In this paper we refer specifically to one group of people –the elderly. From our point of view, taking a closer look at elderly people has two advantages: first, they are a user group that is al- ready well established in HCI research (Durick et al. 2013; Vines et al. 2015), which means that we can refer to an existing regarding their mobility; and second, we can examine, in accordance with that literature, the degree to with elderly people are characterized by particular mobility needs (Ziegler and Schwanen 2011; Schwanen, Banister, and Bowling 2012), and which might make them a specific user group with distinctive mobility characteristics. Based on a detailed literature review we show that most works on elderly people's mobility is focused on particular modes of transportation. In particular, their mobility is often addressed based on diverse bodily or cognitive declines that may reduce or even hinder their ability to walk (K. J. Lee, Joo, and Nass 2014; Montuwy, Cœugnet, and Dommes 2016), to drive (Evans 2001), to use public transportation (Stein et al. 2017), or to navigate (Alsaqer and Hilton 2015; Wan et al. 2014). However, such a perspective on bodily and cognitive abilities cannot take the heterogeneity of the user group into account (Richards, Warren, and Gott 2012; Durick et al. 2013). Although there is no doubt that the user group of elderly people cannot be determined by limited health conditions, we have nevertheless little knowledge about other factors such as social and biographical constitutions, and its impact on the way that elderly people conduct and experience their daily mobility (Altman, Lawton, and Wohlwill 2013). To understand the daily mobility of particular user groups like that of elderly people better, we develop a means to study them in relation to their way-finding practices. Therefore, we owe something to the work of Tuan (2004), who delivered an "experimental perspective" on every- day way-finding by focusing on people's orientation towards places (see for instance Moores (2012)). The underlying research questions of this paper are therefore as follows: (1) What are the everyday way-finding practices of elderly people? And (2) how can these be supported by mobility assistance ICTs? To answer them we conducted an interview study with 15 elderly people between 59 and 80 years old. At the time of the study the participants were in overall good health and were relatively mobile, taking an active role in their social lives. A part of our sample group, however, have some relatively minor physical issues and therefore avoided walking over long distances with heavy bags, or had and have other sensorial impairments, such as eyesight problems. All of the participants were smartphone users and were used to mobility assistance ICTs. That al- lowed detailed insights

how they make use of different kinds of services in concrete mobility situations and the potential for future design work around such ICTs. Further, our study was designed to provide prompts as a 'probe' (see e.g. Boehner et al., 2007; Gaver et al., 1999; Wherton et al., 2012) to stimulate reflections and trigger rich descriptions on past mobility occasions. To this end, we tracked, with participants 'consent, their mobile GPS trajectories over a period of about a month and visualized the location data for each participant as paths on maps. The analysis of the map data in conjunction with our participants led to the identification of five outstanding way-finding practices: (1) way-finding towards habitual places, (2) way-finding in first-time visits, (3) way-finding in ridesharing cooperation, (4) way-finding to- wards places of particular kinds, and (5) way-finding towards to beloved places. Hence, although we do not want to and cannot claim that these practices address the user group of elderly people exclusively, we show how they are significant for the user group in some quite specific ways. The findings further reveal how current mobility assistance ICTs for elderly people can be applied and adapted to better support those practices. We conclude with considerations about the benefits and limitations of our study.

## 5.2 Understanding way-finding practices of elderly people

This chapter has a tripartite structure: we start with the state of the art on mobility assistance ICTs using the example of elderly people. We show that contemporary mobility research has a strong focus on bodily and cognitive impairments that may come with age, but fails to provide a more nuanced picture of their every-day mobility. In the following section we motivate more user-centered studies. Using the example of elderly people, we show the relevance of social and biographical factors besides issues of health. We end this chapter with a methodological argument about procedures for studying daily mobility as it occurs – as a part of ongoing way-finding practices.

### 5.2.1 Mobility assistance ICTs for elderly people

In the following, we take a closer look at mobility assistance ICT for elderly people. The group of elderly people is probably the single most researched user group in HCI when it comes to mobility assistance ICTs (Krainz et al. 2016). Having said that, elderly people's mobility is often

addressed by studying discrete transportation modes like walking, driving, or using public transportation. In that respect a significant amount of research focuses on mobility assistance ICTs to improve walking abilities with intelligent walkers. Two examples are the iWalker (Kulyukin et al. 2008) and the JAIST Active Robotic Walker (G. Lee et al. 2014). These devices are built to support elderly individuals with motor impairments to maintain their independence in familiar and unfamiliar environments. They include a multi- sensor way-finding system to operate in a smart space equipped with embedded sensors. Other research concentrates on fall prevention systems to promote improvements in mobility. Through the development of indoor exergames, muscular strength in the lower limbs, balance control, and even the cognitive capacity of elderly people may be developed and supported (Ogonowski et al. 2016; Skjæret et al. 2016). Another strand of research concentrates on navigation aids in support of elderly people experiencing relatively minor cognitive and perceptual declines.

Addressing them e.g. Montuwy et al. (2016; 2017) analyzed the navigation performance of older pedestrians and designed visual, auditory and haptic guidance for personal feedback. Regarding car usage the International Journal of Human-Computer Interaction published in 2015 a special issue on 'HCI for Elderly and Smart Vehicle Interaction'. In that Rhiu et al. (2015) presented a literature review based on 257 articles. Their results show that most articles were mainly related to safety and adaptive features such as "assistance systems", "physiological & mental state recognition", and "position sensor technology". However, they claim, along with Lee et al. (2015) that "in the wild" studies on actual driving behaviors and driver characteristics of elderly people are still rare. With respect to ridesharing ICT, Meurer et al. (2014) conducted a long term study to explore the potential of ridesharing for elderly people's mobility. They identified a paradoxical situation, given that ridesharing rationally seems to be an ideal matching solution for elderly people who experience mobility restrictions, but where ridesharing ICT is in danger to restrict their 'mobile independence 'and 'decisional autonomy'. Another group of studies addresses public transportation, mostly in regards to the design of information systems. Subasi et al. (2011) examined, for example, usage barriers of an online ticketing service for a nationwide public railway company. Their large-scale study indicated design recommendations how to improve and optimize the accessibility of such online systems for elderly people. As public transportation becomes increasingly diverse because of innovations in transport modalities and a concomitant increased in the number of service providers, work also focuses on inter- and multimodal passenger information systems that combine data from different providers and

transport modes. Here e.g. Stein et al. (2017) conducted a long-term study on elderly people's daily transportation habits. They identified a high affinity for a cooperatively organized mobility around shared events and activities. Last but not least, research has oriented to support for navigational tasks that facilitate or obstruct elderly people in their movements. For example, Sorri et al. (2011) developed and tested a prototype to guide elderly people with memory issues along predefined routes. In their work, orientation advice was given through three modalities, visual, audio and tactile signals, two of which were used at a time. Further, Wan et al. (2014), and Alsqer and Hilton (2015) developed GPS-based geofencing and monitoring systems to deal with the 'wandering' syndrome by persons suffering from late-phase dementia. They report on the design of a GPS-based tracking system and reflect on organizational, ideological and practical issues that the technology has to reflect. Furthermore, many works address the accessibility of information systems as outlined by Wobbrock et al. (2011) or Krainz et al. (2016). Both aim to support the accessibility of a navigation system in combination with a routing service that includes different levels of demands. This review of the literature demonstrates the wide-ranging and varied themes that are dealt with when elderly people and their mobility come into focus. Nevertheless, our view is that a 'transportation-based 'perspective emphasizing the possible affordances of different modes of transportation as well as the navigational challenges that attend upon them, fails to engage fully with the practices of elderly people. These research themes are unquestionably valuable in their provision of in- sights into how one might improve access for elderly people to mobility resources, in particular for a target group that is experiencing impairments of one kind or another. However, the 'deficit model 'based on increased health issues of elderly people has, we suggest, led to the relative neglect of the social and biographical aspects of moving around which, as we shall see, are critical factors to conduct mobility of our target group. In that regard e.g., the work of Stein et al. (2017) pro- vided an initial reference point for our study. It showed that elderly people (probably like other user groups) constantly adapt their mobility choices accordingly to their situational needs and embedded mobility contexts. In that regard the authors already indicate particularities for the group of elderly people. Praxis-orientated studies, which take these themes seriously, are currently, we believe, very rare. In the following section we take a more detailed look on the user group of elderly people and explore in more detail why studying their mobility practices might be worthwhile.

### 5.2.2 Elderly people as a particular user group

In their influential gerontological paper, Rowe and Kahn (2015) explored different models of successful aging. Much of what is argued in this literature remains controversial, but we can agree with them that,

> *"variations call for a greater emphasis on social factors that may in- fluence the capacity for successful aging …a more subjective definition of the concept itself and greater attention to individuals 'perceptions of their own aging and the effects of earlier life experiences" (Ibid., p. 593).*

This emphasis is, we argue, as yet, not adequately paralleled in the literature on mobility assistance ICTs. Hence, most people experience significant social change at the beginning of retirement. In that regard, Rosenbloom (2001) discovered, in a large-scale empirical study that elderly people, particularly at retirement, have much more spare time and take as many as 23% more non-work trips than people under 65. They drive more often to sports clubs, make visits, go to sightseeing tours, go for a walk or undertake a shopping spree. Accordingly, Nordbakke and Schwanen (2014) indicated that elderly people show a heightened interest in visiting non-work places and often create their own routines in getting there. In that respect Meurer et al. (2014) argued that the visit of such places is often cooperatively conducted as part of stable routines which make ridesharing arrangements an attractive transportation mode for elderly people. Further, Stjernborg et al. (2014) showed that elderly people live more often in rural areas with limited access to public transportation. That makes them more dependent on private car use to sustain their individual mobility. However, Altman et al. (2013) claim insights into elderly people's experiences of moving around are lacking. In their literature-based study on elderly people between the age of 60 and 85 they make us aware of the importance of perceived limitations, issues of control, environmental complexity, environmental (un-) certainty, or the experience of place identity. In this regard, they concluded for example, that differences between urban and rural settings with their mix of positive and negative affordances might have a great impact on how the mobility situation of elderly people is perceived and valued. Other authors like Durick et al. (2013) pointed to the heterogeneity of the user group in question. They argued that "the majority of older adults are well enough to live independently", have diverse interests and want to enjoy their life (Richards, Warren, and Gott 2012; Durick et al. 2013, p.472). Even given that, around age 60, individuals may start to experience health changes (e.g. physical and cognitive decline), most of them are still quite healthy, independent, and have an active life

style. Some researchers refer to the elderly from age 60 to 80 as the "third age" or the "young-old", in contrast to the "fourth age" or the "old-old" from age 80 onwards, who often start to suffer from having increased cognitive and/or physical problems that limit their autonomy (Richards, Warren, and Gott 2012; Higgs and Gilleard 2015). Accordingly, Rosenbloom (2001) argued that most elderly people will be in overall good health until they reach the age of 80 or even older, aside from what are, for most people, relatively minor problems. Those can include visual impairments, meaning that such things as road signs are more difficult to read or the sight at night is getting worse; physical decline in strength, meaning that, for instance, carrying heavy bags or coping with crowded streets might be- come more difficult. Therefore, she (ibid.) characterizes life from 60 to 80 as the "late freedom" in that older people typically can enjoy very active post-retirement lifestyles until very late on. Long before they might lose the ability to drive, they may be unable to board or ride public transit, or to walk to a bus stop (ibid.). Authors such as Mollenkopf et al. (2005), Ziegler and Schwanen (2011) or Nordbakke and Schwanen (2014) emphasize the ability to pursue an active mobile life for a self-perceived well-being in old age. Thus, health related issues cannot exclusively define the user group of elderly people. Beside health also social and biographical issues have a great effect on the ways that elderly people conduct their daily mobility. To understand their relationship better, we develop in the following section a conceptual framing to study everyday mobility as practices. We argue that this allows getting a more nuanced picture of elderly people's mobility.

### 5.2.3 Studying way-finding practices of particular user groups

Studying daily mobility as practices has often been claimed for HCI research: on the conceptual level by e.g. Brown and Perry (2002), Ciolfiand Bannon (2007), Kjeldskov and Paay (2010), Church and Oliver (2011) and Cranshaw et al. (2014). From more design driven perspectives e.g. Hoar (2010), Chon et al. (2013), Foell et al. (2013) or Choy et al. (2014) argued for the benefits of a practice-based approach. Hence, while the term, 'mobility' is in common usage; it has several different meanings from a scientific point of view. The term, mobilities may refer to the movement of people, but can also include the movement of ideas and things, as well as the broader social implications of those movements. Several typologies have been formulated to clarify the wide variety of mobilities. Most notably, Urry (2007) divides mobility into five types: mobility of objects, corporeal mobility, imaginative mobility, virtual mobility and communicative mobility. For this reason, we use the term, 'way-finding' in the following to focus

very specifically on the practices of moving around in space (Casey 2013). More precisely Arthur and Passini (1992) described way-finding practices as 'more' than

> *"navigational questions such as whether to continue along the present route or to backtrack, what turn to take at an intersection of paths, or whether to stop and acquire information from the environment to confirm the present route",*

but also identify the need to address the question of how people orient in and towards the environment (ibid., p. 32). That focus on orientation as the very personal attachment to, and feelings towards, places has been argued in similar ways by early pioneers in philosophical and sociological fields, too, such as Simmel (1903), Lynch (1960), or Massey (1995). Lynch (1960), emphasizes in his text, 'The Image of the City' that emotions like loneliness, or being lost, are part of the way we orient in and towards our environments. Using a so-called, 'cognitive mapping' approach he asked subjects in Jersey City, Boston and Los Angeles to draw their city to get a sense of what he called 'the image of the city', thus deriving insights into their inner worlds of feelings and emotions. Hence, his approach has enjoyed some popularity, particularly in urban planning and geographical information systems design, because it demonstrates how environmental access is a matter of personal perception and can be experienced differently (Vertesi 2008). In HCI, the most prominent conceptual framing in this regard is pro- vided by Harrison and Dourish (1996) and Dourish's (2006) revisions ten years later. They emphasized the distinction of 'space', as the geo- graphic location and 'place 'as the experienced or lived environment. They point out that 'place', rather than 'space 'is the concept that is needed for understanding people's interaction within their physical environment, by arguing: "We are located in 'space', but we act in 'place"' (Harrison and Dourish 1996). Thus, the concept differentiates the environmental 'space' from the social 'place':

> *"Our experience of the world is not an experience of mathematically derived uniformity and connectedness; what we experience are places, heterogeneous locales with local meaning, different extents, and individual properties. Space is something we can encounter only afterwards" (Dourish 2006).*

For Dourish (2006) the ethnographic characterization of 'place 'serves as a starting point to inform location-based services of different kinds. That idea of grounding the design of mobility assistant ICTs along the 'experienced place 'was further applied by Brewer and Dourish (2008) twelve years later. They focused on particular kinds of mobility like pilgrimage or doing sports

to argue that mobility is more than moving from a place A towards a place B, but is also a way to structure space. However, although Dourish's conception of 're-placing space' was influential in HCI research, it was also subject to some critique. Brown and Laurier (2005), and Brown and Perry (2002), for instance point to methodological problems of how exactly the concept can be applied empirically. Hence, to fill that methodological gap we suggest borrowing from media studies (see for a more detailed view Moores (2012)). In particular, we refer to the works of Tuan (1977) and Cresswell (2008). Accordingly to Cresswell (2008), Tuan delivers, in his book 'Space and Place: The Perspective of Experience', an experimental perspective on the formation of place in everyday living that he calls a 'sense of place'. As with Harrison and Dourish (1996) and Dourish (2006), for Tuan *"place …is more than 'location', while that more is related to the personal experiences of places"* (Tuan 1977). More particularly, for Tuan (2004) the attachment towards a place is based on experiences of former, broadly biographical, actions that influence the very personal orientation towards a location and way-finding practices in more general. Cuba and Hummon (1993) define Tuan's concept of a sense of place in the following way:

> *"[A] sense of place is inevitably dual in nature, involving both an interpretive perspective on the environment and an emotional reaction to the environment.... A sense of place involves a personal orientation towards place, in which one's understanding of place and one's feelings about place become fused in the context of environmental meaning."*

Therewith, it can be argued that the concept highlights the interplay between a place and one's orientation towards it, constituted in and through the act of moving in space. In his later work Tuan (2004) reflected on the experienced place as the movement to, from and around a spatial location. It is noteworthy, then, that way-finding practices are not only shaped by the given infrastructures, but also shaped by people's interactions and movements in space (also a basic thesis of Henri Lefebvre's (1991) Book 'The Production of Space'). Hence, until now, the impact of ICT on how people experience space is currently particularly driven by more experimental and game-related approaches (e.g. De Souza e Silva 2013). However, related research how ICT shapes way-finding practices in ordinary everyday mobility is still missing. Therefore, the interplay between movement and experience provides a methodological focus, an orienting device if you will, for studies of mobility that go beyond issues of navigation and the usage of selective transportation modes. It raises, of course, issues around how best one might recover

these interlocking experiences and below we suggest a methodological framing for the empirical investigation of way-finding as a practice.

## 5.3 Study design and methods

In this section we describe the study setting, the sample as well as the study design and analysis process in detail. The interview study was conducted with 15 sophisticated elderly users of smartphones. To study their daily way-finding in detail we developed a probing technique based on their daily way-protocols that were collected by GPS tracking. The probes were used to support the participants in recalling specific situations, enabling them to provide, with the prompting of the maps, detailed descriptions of their journeys.

### 5.3.1 Study setting and sampling

The interview study we describe took place in 2016 (February–August), and was part of a wider research project (Sehr-Mobil100 funded by the German Federal Ministry of Education and Research). The project context facilitated this study insofar as existing relation- ships with participants could be leveraged. The overall project aim was the development of a mobile multimodal mobility platform for use by elderly people. The elderly participants were drawn from a city in Germany with about 100.000 inhabitants. Contact was made through various local senior organizations that functioned as 'door openers'. With their help we organized about 5 regional events in that we introduced the project, its goals and the participatory design process. Our foundational assumption was that the participants were experts in their own practices and needs, but might also be learners of smartphone usage during the whole project duration. We selected a heterogeneous group of 19 elderly participants in relation to sex (female and male), age (diversity between 59 and 80 years with a median age of 67), local infrastructure (urban and rural living places), mixed technical skills (from none to handy at computer usage), and mobility preferences (car use, ridesharing and public transportation). The participants belonged to what we have called the third age group, or the young old. All of them were overall healthy, including only some typical, but minor, issues to be found in such a group. At the inception of the overall project, none of them were smartphone-savvy. In the project we had the financial resources to pay the costs in providing Internet access and to equip each participant with a high-end smart-

phone. Further, we supported their learning processes with the mobile devices in weekly workshops. These workshops ran over two years from 2013 to 2015 to provide an appropriate learning environment for practicing smartphone usage in their daily life. By 2016, when the specific study we report on here was conducted, all of the participants were fairly sophisticated in smartphone use and were familiar with a number of mobility assistance ICT applications. As a side note, we want to note that age is still the major factor for non-smartphone usage, as the largest national online-survey on Internet usage in Germany concludes (Koch and Frees 2016). They found that whereas nearly 90% of the 15–29 year-old used a smartphone on a daily basis in 2016, only 11% of people older than 70 did. The same study also showed that older age groups have the highest adoption numbers. Based on the rapid process of demographic change future adoption rates will even become much higher than nowadays which makes smartphones more and more relevant for that user group (ibid.). In the interview study on that this paper is based, only 15 of the original 19 elderly participants could attend. A married couple dropped out because her husband has died on cancer and two others were on holiday. A detailed list of the 15 participants is introduced in Table 4. The sample involves one married couple, the Wilsons (anonymized). All of them knew each other, based on the regular joint workshop-meetings. Further, all participants came from the same city region and some lived very close to each other.

### 5.3.2 Study design and analysis

Obtaining data about, and getting detailed insights into, daily way- finding practices turned out to be quite challenging. The difficulties were largely associated with the following factors: Firstly, mobility, in and of itself, is not always the focus of attention while people are out and about. People can travel from one place to another while other things are occupying their attention, such as listening to the radio or music, telephoning, reading or chatting, unless moving around becomes in some way problematic. For the most part, sitting in a bus, walking, waiting or just being on a journey is not the focus of our attention, though we may wonder at points where we are, whether we are where we want to be, whether we are on time, and so on.

**Table 4 Anonymisized overview of participants.**

| No. | Synonym | Sex | Age | Material status | Area | Technic skills |
|---|---|---|---|---|---|---|
| 1 | Mr. James | m | 69 | Married | Low density | More good |
| 2 | Mrs. Johnson | f | 75 | Single, widowed | High density | More good |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Mrs. Harris | f | 72 | Single, widowed | High density | More bad |
| 4 | Mrs. Miller | f | 58 | Single | Low density | More good |
| 5 | Mrs. Brown | f | 63 | Single, separated | High density | More bad |
| 6 | Mr. Davis | m | 62 | Married | Low density | More good |
| 7 | Mrs. Wilson | f | 61 | Married | Low density | More bad |
| 8 | Mr. Wilson | m | 64 | Married | Low density | More good |
| 9 | Mr. Moore | m | 80 | Married | Low density | More good |
| 10 | Mr. Taylor | m | 66 | Married | High density | More bad |
| 11 | Mrs. Anderson | f | 73 | Widowed with partner | Low density | More bad |
| 12 | Mrs. Clifford | f | 76 | Single | High density | More good |
| 13 | Mr. Smith | m | 72 | Married | Low density | More good |
| 14 | Mrs. Thomson | f | 64 | Married | Low density | More bad |
| 15 | Mrs. Deborah | f | 78 | Widowed, single | Low density | More bad |

Hence, there are only few 'natural triggers', for making way-finding actions accountable and observable to others. Secondly, leaving aside some explicit navigational tasks, it is hard to define where the practice of way-finding starts and ends. For example, finding the way to a concert hall may not necessarily 'start' when leaving the house. Rather, finding the way about to a concert one might have looked forward to for a long time, may already have started on different occasions: when one first became aware of the announcement, or the moment when one considers the best way to go there, given variations in familiarity, issues with timing, and so on. Further, way-finding towards that venue might be framed differently whether it is shared with friends, whether it is one's first visit to that location, or a recurrent journey with established routines for getting there, and so forth. Thirdly, direct observations of way-finding practices are difficult. Trust and privacy issues, difficulties in establishing when and where observations might take place, and so on, means that some kind of proxy is necessary to start the exploration. For these reasons we used mobility 'probes' like those introduced by Boehner et al. (2007) or Wherton et al. (2012).

Therefore, we tracked participants' GPS data from their smartphones to encourage and prompt detailed descriptions of their daily movements. More specifically, we used images of tracked paths, to support participants 'reporting on occasioned events. Those maps worked then as accounts that allowed the users to report on their personal experiences of concrete mobility situations. To prepare these probes, we provided all participants with a Google account to

assign the GPS data produced by their personal movement tracking. Their behavior was then, with permission of each participant, tracked and recorded automatically on date, time and location by the Google service Location History (https://maps.google.com/locationhistory). During the four-week trial, the participants continued their daily lives while the GPS mobile sensors constantly tracked their outdoor movements. After that period, we re- visited each participant at their homes with prepared print outs of the collected data. Each map illustrated one day of their movements. We used them in addition to a computer-based version that allowed zooming in and zooming out of the maps, during the interviews. Zooming in and out helped the participants to orientate to the map. The probes were specifically designed to facilitate the recollection of the sequential order of paths followed, with detailed time information of every measured GPS location available (see for a similar methodological outline, Jones et al. (2011)). The web-service additionally allows choosing be- tween two visualization forms, consisting of a street view or a satellite view (cf. Figure 4). The analyzing process was aligned with the coding principles of Grounded Theory (Strauss and Corbin 1990): essential to Grounded Theory is the principle of constant comparison, according to which a theory in development should be repeatedly adapted.

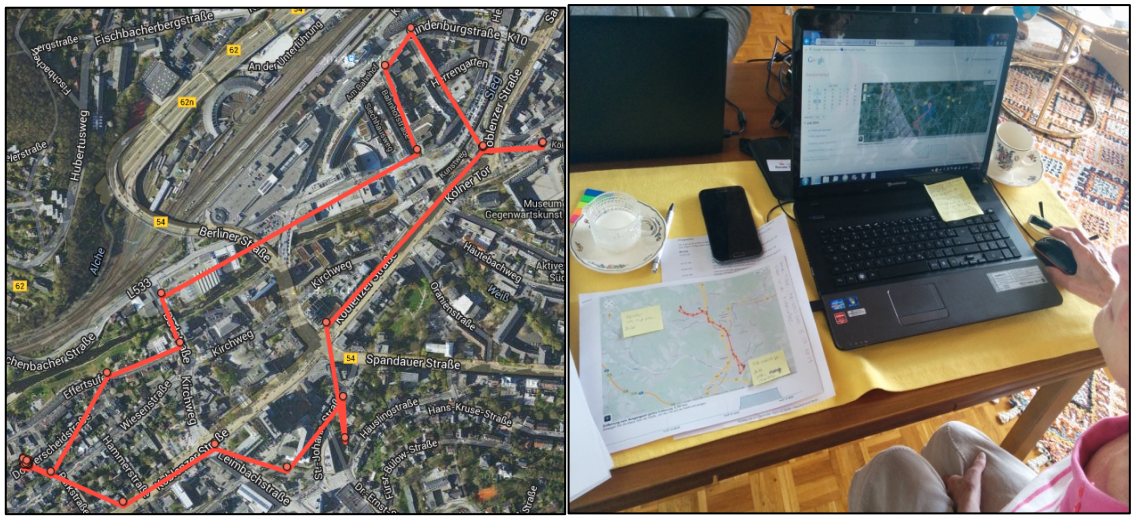


**Figure 4: Mobility probes in the interviews. The left picture presents an example of the probes and illustrates the movements of one participant on one day. The picture on the right shows the interpretation sessions with the user.**

Thus, the aim of this analysis was to explore how the participants oriented towards different places to reconstruct different kinds of way-finding practices. First, 'open coding' (ibid.) was developed which reflected a variety of narratives about how the participants oriented towards places. Thus, we collected descriptions about similar and different experiences to find their way

about. In a second step these examples were collected and themed into more general topics, by 'axially coding' (ibid.). That means that the themed text fragments were compared, sorted and enriched with sub concepts, which had to do with the rationales that people described for their practices. Finally, and as a third step towards 'selective coding' (ibid.), we sought to link the rationales we had identified to specific way-finding patterns. The data material was analyzed using the qualitative software program, MAXQDA 12 (http://www.maxqda.de/).

## 5.4 Contexts of elderly people's daily way-finding

Below, we reflect initially on the usage of the mobility probes and how the users reacted to them. We then present the main patterns of elderly people's daily way-finding that we identified. These are: (1) way- finding in more or less habitual ways, (2) way-finding in first-time visits, (3) way-finding in ridesharing cooperation, (4) way-finding towards a place of a particular kind, and (5) way-finding towards beloved places. We do so by presenting specific vignettes, which exemplify the patterns we describe. Each vignette describes a discrete case of one of the contexts and is enriched by complementary examples.

### 5.4.1 Reflections on the mobility probes

We began all interviews by asking the participants for descriptions of what they see on the mobility probes. In many cases their reaction was quite emotional. In one example of such an initial reaction to the material, Mrs. Harris expressed her surprise at recognizing past traces of her travels. She is a 72-year old woman who lives on her own on the edge of the city. She has a small car and is a dedicated hobby video maker. She likes making films on construction sites in her city, at private and public events, or about her own travelling. In the following example (#1), Mrs. Harris indicates the Internet café as an important place to get support for her film cutting program. The location is a meeting point for elderly people in the city and provides space to discuss media related topics of various kinds and to foster mutual learning processes among particularly elderly people. The interview situation is illustrated in the first part of vignette (#1) and starts with the following question by the interviewer:

> *Vignette (#1)*
>
> *Interviewer: […] So let's take a look at the details on the map. It (the Internet page) is just setting up…Mrs.*

*Harris: Yes, okay…Goodness, that's amazing! What's this? Whereabouts was I then? Right here I went to the Internet café yesterday. As clear as day! I can recognize that point right away [laughing].*

*Interviewer: What can you say about that place, what does it mean for you? Mrs. Harris: I visit that place [the internet café] regularly and it is the place to me where I can learn new things, but also where I can solve my current troubles with my laptop, my video editing computer or the smartphone, too. Therefore, it is important to me. […].*

When Mrs. Harris sees the map the first time, she exclaims, "Good- ness, that's amazing!", demonstrating the power of the visualization for her. She proceeds to explore her personal relationship towards the mentioned place: "I like to go there and I can recognize that point right away [laughing]." Although, these traces are only substituting for her way- finding, Mrs. Harris is able to recognize the well-known place "right away" by its location, as well as the experiences that she associates with it. The exclamation "Right here I went to the Internet café yesterday" gives also, some impression how she reads the map. She refers to the Inter-net café as if she could literally see the place on the map ("Right here!") and underlines that impression by finger pointing. Her reaction demonstrates that she (as with the other users in the interview study) is able to reconstruct the probes as footprints of past events. In a similar way, participants reported: „here I went to the cinema" (Mrs. Brown), „there I visited my friends" (Mrs. Johnson), or „here I drove along the street" (Mr. Smith). The participants commonly used deictic references such as "here" and "there" when they read the maps. Such references, and what follows them, indicate not only a location but also allow insights in related experiences and how the people orientate towards such places. Thus, one can say that notion of "here" and "there" deictically link a locality with related way-finding practices, which in turn link the GPS locations to biographical or historical significance.

### 5.4.2 Way-finding towards habitual places

We initially identified way-finding geared to 'habitual 'places, as was the case with the Internet café. Mrs. Harris further described her visit in the following way:

*Vignette (#1')*

*Interviewer: And how would you describe your movements towards that place - I mean to the Internet Café? Can you explain this in more detail?*

*Mrs. Harris: Mhm, yeah, but it is not that spectacular. (Short pause.) As you know I'm visiting that place regularly. Normally it is al- ways the same route. I'm there each Monday and sometimes even on Thursdays. It is just; I just sit in the car and drive there. (Short pause.)*
*Interviewer: I see. So, it is always the same?*

*Mrs. Harris: Yes. It is always the same. Mhm, there are also some days, when I ask my neighbor to join. You know Mrs. Volz. I do not want to push her, but sometimes I give her a ring and then she says OK.*

*Interviewer: Mhm.*

Based on a request from the interviewer, Mrs. Harris proceeded to describe her visiting habits as a "regular" part of a weekly routine. She also added that the weekly visits are based on solid travel routines that are usually conducted with her car. She further explained that she sometimes gave her neighbor (who has no driving license) a lift, too. Thus, Mrs. Harris described an example par excellence of what Tuan (1977) calls a place. For Tuan, places are formed by such routinely lived practices as 'habit fields'. With reference to the physical setting, he argues that "a place is accomplished though repetitive, habitual practices, giving rise to 'affective 'attachments in which people are emotion- ally bound to their material environment" (cited by Moores, 2012, p. 27). In an analogous way Mrs. Harris characterized the Internet café as such a habitual place ("I mean, I sit in the car and drive there") that guided her in an unnoticed and unreflective process based on stable and familiar time-space routines. In the interview data we found many other similar examples, bound to highly routinized travel experiences. Most of the 15 participants reported several repeated events that typically occurred in a weekly rhythm. Quite often, we found three to five such regular activities each week per person. Thus, beside the regular visits to the Internet café on Mondays and Thursdays, Mrs. Harris worked on a voluntary basis in a charity organization one to two times a week on Tuesdays and Wednesdays. Friday was her fixed and "holy" sauna day. Another participant, Mrs. James, reported to visit a senior sports clubs two times a week: one for swimming and one for gymnastics. She is, further, part of a theater group. Others, like Mr. Jackson, went hiking or, like Mr. Moore, played cards or (is very frequently the case) took care of their grand- children. All of these activities were well overall well organized and arranged by the participants on a voluntary basis. As Mrs. Brown de- scribed it, these recurring events provided some "stability" in her life while she planned other activities around these routines. Along with Schwanen et al. (2012), we suggest

that those familiar travel routines are of particular importance for elderly people. They are not merely to be seen as leisure time activities, but as providing structure and stability in the post-retirement period. Hence, as we soon learned, they are often of great personal value. However, there are always some exceptions to the rule such that adaptations to the routine can become necessary. When asked explicitly about deviations, Mrs. Harris described the following:

> *Vignette (#1")*
>
> *Interviewer: […] OK. Are there also some situations where you make use of your smartphone for navigation [when going to the Internet café]? Do you remember situations like that?*
>
> *Mrs. Harris: Well, there are some exceptions, like when I visit my brother. He lives in that street close by. Here, [she names the street and finger pointed on the map]. Then I give him a call from my phone to see if he is around.*
>
> *Interviewer: Like for a spontaneous visit?*
>
> *Mrs. Harris: Exactly. And there are other situations when I go to the Internet café and don't have my laptop with me. Then I try to arrange to go in the city afterwards and prefer to take the bus sometimes.*
>
> *Interviewer: Mhm. Do you make use of the smartphone then?*
>
> *Mrs. Harris: So, then I'm glad to have my smartphone with me. I use it for the bus. It makes me flexible …to react to different circum- stances.*
>
> *Interviewer: Mhm.*
>
> *Mrs. Harris: I can check when the next bus comes. And when I have to wait half an hour, then I can do something else. Eat some ice cream, or whatever. Then I'm really happy to have my smartphone with me. Before I had it I couldn't feel that independent.*

"Well, there are some exceptions" points to the occasional deviations from habitual patterns. The smartphone in those cases was stated to be an important assistive tool that allowed Mrs. Harris "to react [flexibly] to different circumstances." She added: "Before I had it I couldn't feel that independent." Thus, we can say that the Internet café is a fixed point from which she could examine her travel options and which gave her a greater flexibility in making plans. Hence, although the regular visit to familiar places has the "habitual nature of movements that occurs without or before any conscious intervention" (Seamon 2015), mobility assistance ICT

can becomes important when such patterns are (slightly) interrupted. Adjusting plans is, after all, a feature of many of our daily way-finding activities. Appropriate support for adjustments to habitual travel routines evidently makes a significant difference to the overhead involved in decision-making in this context. We should also bear in mind that, even where elderly people have relatively few mobility restrictions, they are nevertheless attentive to problems associated with walking longer distances, uphill, or over uneven surfaces. Such support, in those cases, can have significant additional value and can even determine whether any deviation from routine is worthwhile or not. What is clear her is that the flexibility and visibility of available options is of importance.

### 5.4.3 Way-finding in first-time journeys

A second relevant context we identified in the sample is that of first-time journeys, as illustrated in vignette (#2). In this case, Mrs. Deborah, one of the oldest participants in the sample, explored her trip to a (170 km) distant city to hear a talk about globalization. In contrast to the first practice (#1) of habituated and routine journeys she did not know that travel route. Although Mrs. Deborah was used to conduct long distances by train with some regularity, travelling means considerable exertion for her, particularly with luggage. She has no critical illness, but her constitution is already a little more fragile. Thus, to avoid com- plications during a journey, she planned her trips in detail, often long before her journey took place. That helped her to get a better orientation towards unknown places. In vignette (#2) she described the travel situation in detail while she looking at the probe:

*Vignette (#2)*

*Mrs. Deborah: This was exciting; I can tell you that. Here I travelled to [Name of the city]. That was really a little adventure [laughing]. I can tell you! […] I went there to hear the talk of [name of the presenter followed by further explanations about the topic and the event]. So, I only know the address of the hotel, but I have never been in [name of city] before. Yes, but I just went there with my smartphone and took the train. And this really worked out quite well for me. I'm still amazed how easy that was. Honestly.*

*Interviewer: Can you describe a little more how you used the smart- phone during the trip? […]*

*Mrs. Deborah: I have tried out everything. What is its name again? [Mentioning the names of a mobility platform and of Google Maps]. Without the experience with the smartphone I never would have dared to travel there.*

Her excitement about her successful journey is evident, seen as "a little adventure" and as a great success story ("really worked out so well"). Further, her statement: "I'm still in amazement" shows her astonishment at how simple it turned out to be. We can hazard a guess that elderly people are often nervous about journeys of this kind. Confidence, or its lack when traveling towards new and unknown places, is certainly an important issue for Mrs. Deborah. The participants often addressed such first time-visits as challenging and problematic. Issues such as access to a place, walking constraints to be expected or how much walking needs to be done, the height of borders and the availability of lifts were also spoken of as significant. In that regard Mr. Moore mentioned that the last time he had used public transportation was in 1990 in Taiwan. He did not explicitly mention that he does not make use of public transportation because of such uncertainties, but did say that he always uses his car because it feels known and familiar to him. Further, Mrs. Johnson stated that she once had a bad experience with a wide gap at a train station. From then on, she preferred train stations where she knows that the gap is manageable. In those cases, lacking knowledge about the environment can lead to uncertainties that can even lead to the avoidance of travel. Accordingly, Schaie (2003) argue that elderly people in general are less keen to explore new places and to change their usual environment even if they have very strong reasons and motivations for doing that, partly at least because of anxiety. Hence, Mrs. Deborah was positively surprised that the navigation to her destination proceeded without any complication. As a reason for that positive experience she mentioned that her competence in smart- phone usage provided her with confidence ("without the experience with the smartphone [she] never […] dared to travel in the unknown city"). The interviewer continued by asking for her reasoning:

*Vignette (#2')*

*Interviewee: Why was the smartphone so important for you in that situation?*

*Mrs. Deborah: It was just that the city was so foreign. I already told you the story when I travelled to my mother with the train. I had my plan and everything. But then, suddenly, the train had a big delay and I missed my connection. I had only a paper map with me and tried to figure out the right connection. Then I met another older woman with the same struggles and*

*we considered our plans together. We felt totally lost at that station till a young man helped us out. […] I think we, two old ladies with a big paper map looked a little weird and he felt compassionate [speaking while laughing]. […] So, finally, we made it, but it was not so easy and took a lot of time. […] That cannot happen to me again with a smartphone. Now I know how to navigate and find the next train. It feels as if I can't get lost so easily any more. […] It is always the same, no matter where you are.*

The value of smartphone app usage is exemplified by a contrasting example. In one reported situation she was on an even longer trip visiting her 96 years-old mother by train. However, she missed a connecting train during her journey by accident and thus, it happened to her that she felt "totally lost" at an unknown train station. Her comment: "I had only a paper map with me and tried to figure out the right one" demonstrates the previous difficulties she had. Navigation in or to- wards unknown places is, it seems, much easier with her smartphone, because it helps her to orientate: "It is always the same, no matter where you are". Using mobility assistance ICTs can (partly), it seems, compensate for missing local knowledge. Thus, it would follow, we think, that the more richly populated with additional local information, the more useful Smartphone apps are likely to prove in fostering a confident attitude to journeys of this kind. Generally, being able to go to new places is described by many gerontologists (e.g. Mollenkopf et al. 2005; Ziegler and Schwanen 2011; Schwanen, Banister, and Bowling 2012) as an important component of elderly people's wellbeing. If, as we believe, anxiety about unfamiliar circumstances is particularly prevalent among older people, trustworthy and relevant local information embedded in smartphone apps could alleviate anxieties about getting lost or about unexpected difficulties. This means not only trans- port information, but also additional information about environmental access such as about walking constraints, kerb heights, the availability of lifts and railings and practical advice about how to manage such matters as crossing from one platform to another (in the context of rail journeys) or the nature of the streets one is likely to encounter.

### 5.4.4 Way-finding in ridesharing cooperation

The third identified practice relates to mobility in cooperative set- tings. In vignette (#3) Mr. Wilson, who was interviewed together with his wife, described a regular joint journey with their friends to play cards together. We looked on a map that showed a lot of movements back and forth. Mr. Wilson described the case as follows:

*Vignette (#3)*

*Mr. Wilson: So, I'm only here [he points his finger on the map in front of him]. From my place, I drove into Ludwig Street first, to Berleburg. This is Ludwig Street here. Then I went back and forth a bit, picked up a friend, then went up to Netphen, to Berleburger Street and there I picked up another friend. And then we went to (= area). So, see, Ludwig Street, Berleburger Street then up the Giersberg hill to play cards here. [Longer chat about the rides-haring arrangement and ways to deal with deviations]. However, it is some- times quite com-plicated to plan such an arrangement, when a routine is broken and someone drops out or when we have to switch turns.*

Mr. Wilson pointed out the tour of the streets as a series of units from "Ludwig Street first, to […] up the Giersberg hill to Berleburger Street and […] to (= area)", while he followed the drawn path on the map with his finger. He mentioned that, without even looking at the map, this time it was their (his wife's and his) turn to give their friends a lift. The other card-playing members 'homes were mentioned as an itinerary of pick- ups. Based on a turn taking system of differing drivers, the tour always differs slightly according to whose turn it is in the car-pooling arrangement. Seamon (2015, pp.54-6), calls such collaborative activities "place chore-ographies" or "place ballets" that he defined as "an interaction of many time-space routines": "The place ballet can occur in […] streets, neighborhoods, market places, transportation de-pots, cafes." According to him these interactive "dances" consist of "rhythmic" patterns of "continual human activity" that also have the potential to foster "a strong …sense of place" (ibid, p.56). Based on the complexity of such coordination arrangements, the travel routine is more fragile "If someone drops out or we have to switch the turn" big parts of the shared travel routines have to be re-arranged for each card-playing member. Thus, upcoming changes and uncertainties need to be communicated to them. Then, without any enquiries from the interviewer, Mr. Wilson proceeded with the benefits of networked communication on such occasions, as with:

*Vignette (#3')*

*Mr. Wilson: It is sometimes quite complicated to plan an arrangement; it often takes a lot of communication by telephone. It would be much easier to use WhatsApp. I really prefer WhatsApp. Also, in comparison to ridesharing tools - even if they are explicitly built for shar-ing rides, and I know WhatsApp is not. It really seems less work and effort to me to offer a*

*ride or ask for one. It is also more direct. I can directly ask the people who share that event. [Short pause]. It is really a pity that none of my friends outside of our group uses WhatsApp or have a smartphone.*

He continued with complaints about the difficulty of (re-) organizing ridesharing arrangements, stating that they are "sometimes quite complicated to plan […] with a lot of communication by telephone". Hence, to give some context information, in the wider project, different ridesharing ICTs available on the market were tested and discussed with the participants. Bearing this in mind, it was quite interesting that Mr. Wilson criticized such tools as inappropriate for dealing with recurring events. For those he "really prefer[s]" the WhatsApp messenger to organize trips. He explained the advantage of group communication with having a shared understanding of the contextual setting in which the arrangement takes place. Formalized (ridesharing) tools, for him, mostly do not support such informal communication and regular cooperation. Hence, such cooperative traveling is not necessarily straightforward, even with familiar and habitual travel routines, as it became evident in this vignette. In further data material we found a number of similar cases. Beside these regular arrangements we found examples of spontaneous ridesharing arrangements to do with joint events. For example, Mrs. Brown identified a path on the map as the pick-up route towards the village where Mrs. Anderson lives and back to the city where they went to "a nice café" in town. She was picked up by Mrs. Brown because she has no driving license and lives in a more rural part outside the town with unreliable bus connections. In another example Mr. Lauder identified a ride towards the weekly schooling sessions at the University. He remembered, based on the lines on the probe, that in that week, Mrs. Davis picked him up because his wife needed the car to get to her dialysis. We found that routine-based as well as spontaneous cooperative ridesharing arrangements were quite important as facilitators of social inclusion for elderly people, as suggested by Altman et al. (2013), Bucher (2005) or Andrews and Phillips (2004). They argue that particularly diverse sets of social events are, for elderly people, often the central anchors for keeping them engaged in social life. Schwanen et al. (2012) even shows that about half of all car trips that are conducted by elderly people over 65 take place with more than one person. In addition, the analysis suggests that sharing trips is frequently tied to mutually shared events like going to the cinema, the theater or a city landmark. Way-finding in this context, then, is very much part of a nexus of shared activities and events.

### 5.4.5 Way-finding towards a place of a specific kind

The fourth context is about going to places of a generic kind. That means that the location of a place is less specific than in the previous examples, because such places, like a super-market, a car wash, a café or a restaurant can be found in multiple locations. A typical example of such a scenario is given in vignette (#4). There, Mr. Smith (72) re- ported on his search for a pharmacy during a trip to the city center. He lives with his wife on the outskirts of the nearby city and describes the following situation while looking at the mobility probe:

> *Vignette (#4)*
>
> *Mr. Smith: This is where I went to a pharmacy [saying this, while looking on the map]. Interviewer: Do you always go to this one?*
>
> *Mr. Smith: No. I don't. Of course not. [Laughing]. I go to one that is close by, because it does not otherwise matter for me which one. I'm not interested in a particular one, but only in the medicine I can get there.*

In his description, the indefinite article of 'a' pharmacy indicates already that he was not searching for a particular one. He further pointed out that he did not go to the same pharmacy all the time, but to "…one that is close by". Hence, unlike in the previous examples the location of the chosen place is not given in advance. He simply aims to find a convenient location "because it does not matter for [him to] which one". Therefore, one can say that he addressed a pharmacy as one out of many others –as a specific kind of place. Mr. Smith continued his explanations with the further description of his journey to find a pharmacy "nearby":

> *Vignette (#4')*
>
> *Mr. Smith: And I only remember that I was there because I used my pharmacy app for that. I quite often use it just to have a look which pharmacy is nearby.*
>
> *Interviewer: Are you also looking for other things nearby?*
>
> *Mrs. Smith: Yes, I do. I also keep an eye open for some nice things, like locations for food and drink nearby, or to see interesting offers to shop. If I want to buy one particular item, I take a look to see where I can find it nearby. […] I do not want to waste my time with searching. It should not take too much time and should be easy to reach.*

As a pharmacy can be potentially found at multiple locations (instead of one specific one), the access to that place becomes central to choosing the location. Further questioning, if issues of reachability be- come important for him, Mr. Smith agreed that the accessibility of places plays a big role for him ("It should not take too much time and should be easy to reach"). Hence, in another part of the interview he stated that the length of the walk and other reachability factors could become highly important in choosing a suitable location:

*Vignette (#4")*

*Mr. Smith: […] Further, of course things are getting harder, and I like to know the distance. You know, like how long do I have to walk to go somewhere. Now, for us elderly people other things become important, too, like the weather, is there a toilet available or a bench for a short rest when the ways are getting too long or hilly.*

Further, many other interviewees stated great interest in issues of environmental access. In that regard Mr. Moore reported for instance that he aimed to avoid situations where he was insecure about the walking distance, or places where he knows that finding a parking space nearby might be difficult. Also, Mrs. Miller reported on examples in that she avoided walking for long time in cold or windy weather, because she "easily gets a cold". Thus, if the weather is bad, she liked to move in familiar areas where she knows cafés or places where she might warm up. In respect of such issues, Altman et al. (2013) suggest one should consider complementary aspects such as the environmental complexity, environmental certainty and uncertainty, crowding, privacy, place identity or the feeling of safety to characterize the positive and negative place affordances that can keep elderly people away, or support their confidence to conduct journeys.

### 5.4.6 Way-finding towards to beloved places

The last distinct way-finding practice that we identified is illustrated in vignette (#5) and deals with travelling towards to 'beloved' places. In the example, Mrs. Cliffords, a 76 year-old woman who lives on her own close to the city and loves to drive around, reports on a Saturday where the mobility probe shows a lot of zig-zagging lines in a smaller radius in the inner city:

*Vignette (#5)*

*Interviewer: That is the next day. It's last Saturday.*

*Mrs. Cliffords: Yes, well, here where I'm just driving about willy nilly, this zig zagging on the map. That happens when I think to myself let's just have a look what's going on around here. I'm quite twitchy, fidgety, as you can see here [laughs]. I was probably just having a look around to see who's close by, to phone them and call around. I'm always on the lookout for interesting new things –where are some restaurants or cafés that I would love. Or I say to myself 'Man! Where can you go? 'Maybe a friend is around. […] There's always a few things I like to do when I'm in the city and then I have a look out for possibilities and what suits me at that particular moment.*

When Mrs. Cliffords reports she was "just driving about willy nilly, this zig zagging on the map" and, "(t)hat happens when I think to myself let's just have a look what's going on around here. I'm quite twitchy, fidgety, as you can see here", she clearly had no specific destination in mind when she started her journey, nor any specific route. Interestingly, she located her search with the word "here" as if she was referring to a precise location, although the map showed a quite diffuse area in which she is on the "lookout for interesting new things". In that area she aimed to find the 'right 'place, the one "that [she] would love". Her search can be characterized in accordance with Downs and Stea (1977) as a "general longing to explore the world and to see it with new eyes". Hence, even if the local area is not new at all for Mrs. Cliffords, she aimed to explore a familiar place with "new eyes" to discover something new. The search for a special place, one that "could be loved", whether it is just to have a seat, to eat, or to meet other people is based on very personal preferences, but might be more prevalent among elderly people, who have the spare time already referred to. Hence, in the interview material we found many examples in that participants reported about similar longings: e.g. Mr. Taylor claimed, "when I was younger I used to go to the tea dance, where young and old come together". Mrs. Miller determined, based on her personal experiences: "Now as an old person it feels much harder to find places where young and old come together", and Mr. Thomson reported: "many places closed during the last ten years that I used to go". Thus, many participants claimed they lacked opportunities to go out as elderly people, or to have places where they feel welcomed. In those examples it becomes evident that respondents feel increasingly left out or like strangers to their own city, experiencing a changing infrastructure that would mostly address young adults 'needs but not theirs. Others mentioned changing personal preferences that might come with age, like Mrs. Wilson: "it is difficult to find nice cafés to meet other people at my age. This was different when I was younger, but it is really, really hard to get in contact with others, even

if I'm an open person and like to communicate. But sometimes I don't know where to go". Those who were living alone particularly showed a great interest in discovering new places that provide opportunities to connect with others. Following the above, the interviewer asked how Mrs. Cliffords made use of mobile media in such situations:

> *Vignette (#5')*
>
> *Interviewer: In these mentioned situations, when you search for nice places, are there some services that you use? Services that support you?*
>
> *Mrs. Cliffords: Yes, sure.*
>
> *Interviewer: Which ones? Can you give examples?*
>
> *Mrs. Cliffords: Yes, of course I can do. I use the event guide [a local app] and Foursquare. I hope to find some interesting things there, but [short pause] it's not so easy to use for me.*
>
> *Interviewer: why not?*
>
> *Mrs. Cliffords: It is [she opens the apps and shows the interface] not that clear whether a place would suit me and if it is close by. Can I go there by foot? Some are very close, but here, look, this one is really far away. To go there I have to make a big plan. […] And I have to use other maps again to find the best way to go there.*

She used the smartphone "to find some interesting things there". However, it was quite interesting that Mrs. Cliffords claimed that current assistance ICTs did not support her way-finding in an adequate manner. She pointed out that it is hard to anticipate, if a place is suitable: "it's not so easy to use for me. It is often […] not that clear whether a place would suit me and if it is close by". Further, as the way-finding practice towards places of a specific kind indicate, issues of reachability and accessibility ("Can I go there by foot?") became highly relevant, too. Thus, becoming older might mean to experience a feeling of alienation towards formerly familiar places. Way-finding in this context entails an awareness of the changing nature of the social landscapes, and it appears that, at present, there are few ways in which applications can lend themselves to this evocation of time passing, or historical and biographical relevance. Mobility assistance ICT could be used to provide customized information about such places (Chon, Kim, and Cha 2013).

## 5.5 Discussion

In this paper we develop a methodological framing to study the everyday way-finding practices of particular user groups. In particular, we aimed to draw a more nuanced picture of elderly people. Therefore, we asked the following two questions: (1) What are the daily way-finding practices of elderly people? And (2) how can these practices be better supported by mobility assistance ICT? In the following we will first summarize our findings. Second, we will discuss the value of the chosen perspective on way-finding practices, indicating what insights that approach can bring to the table.

### 5.5.1 Designing for mobility contexts of elderly people

In the analysis we identified five way-finding practices, which constitute typical patterns of everyday mobility of young elderly people. We summarize them as follows: (1) Way-finding towards habitual places: A large part of the journeys conducted by elderly people were based on weekly routines geared to sport clubs, charity work, visiting friends, caring for children and grandchildren, or other activities like visiting an Internet café. We found that travel routines of this kind were of great importance for elderly people in their post-retirement lives, as they can provide stability and structure for their weekly planning. They can be understood in accordance with Massey's (1995; 2010) concept of 'open places'. Thus, as those habitual places are of particular importance for the user group, we suggest they should be better supported in mobility assistance ICTs. From a design perspective, Google Now is a nice example of such an 'open 'concept of place, by making the departure and arrival times with the preferred travel modes visible. However, this application currently only supports two places: going home and going to work. Instead, of 'work 'other places like 'sport', 'voluntary work 'or 'grandchildren' would be more fitting for elderly people. Further, there are unused opportunities to support the often multiple weekly activities of elderly people; to connect, as it were, the possibilities, such that the contingent variations we have spoken about above are more easily seen and managed. (2) Way-finding in first-time journeys: Less often, we found journeys that were conducted towards unfamiliar places. In those cases, the location is given, but the route there is not known from former visits. These first-time visits are characterized by Nordbakke and Schwanen (2014) as often highly critical, particularly when (as most) elderly people do start to experience smaller impairments, e.g. regarding their eyesight, the ability to walk over longer distances, motor issues or balance. We might add here that issues of confidence and trust also seem to be extremely

important. Our findings revealed that trustworthy information about those un- familiar places could counteract emerging anxieties to do with getting lost or being confronted with difficult, unexpected mobility situations. Therefore, assistive ICTs could be used to re- place missing local knowledge with information about environ- mental access, about the particular character of railway stations, of streets and of surrounding traffic. We should note here that much of this local information could be visual. Pictures of relevant environmental factors, user tags of critical incidents, or (eventually) augmented walk though in train stations or other confusing places would, we feel, be of enormous value. (3) Way-finding in ridesharing cooperation: The findings revealed the importance of ridesharing arrangements for elderly people in both regular, recurrent journeys or in spontaneous, serendipitous situations. In both cases those mutual arrangements can foster social relationships and support those who have fewer mobility opportunities. To better support regular ridesharing arrangements, communication and awareness features could be useful. Messaging groups around shared locations or events can support stable ridesharing habits. These can not only be used to make better arrangements, but also to share related information, pictures or memories. Most ridesharing solutions on the market neither support regular journeys, nor particular groups. Moreover, there is a particular lack of serendipitous ridesharing tools that al-

low elderly users to create more spontaneous cooperation around events. In that regard one can think about the usage of an integrated event calendars as suggested by Stein et al. (2017). (4) Way-finding towards a place of a specific kind: These addresses occurred where the user wants to visit a place that can be found at multiple locations, like a supermarket, a restaurant, or a pharmacy. Google Maps already supports users to find the nearest place in relation to several categories, but it lacks additional in- formation that might enable users to identify the most accessible locations. We should stress, this is not a matter of treating elderly people as a special category of 'disabled 'people, but simply recognizing that they begin to experience more restrictions on their capabilities around the age of 60 or later. Again, the integration of additional information on the availability of different mobility modes and related information about environmental access (e.g., like the constraints on walking like pavement obstructions, height considerations, the height of kerbs or the availability of an elevator) would not be especially difficult. It could be supported in a number of different ways, both through more detailed information, with pictures or video vignettes. As yet, information of this kind is in short supply in transport information systems. We currently lack adequate information about the various

ways in which elderly people experience their environment and how environmental conditions impact their quality of life. It is evident that personal fitness and other considerations are not the same for every person, but can vary considerably. Therefore, the tagging of additional information by elderly for elderly users might be beneficial and also the offer of selective settings to make sure that each user is supported with the needed information. (5) Way-finding towards to beloved place: The last context is about finding the 'right 'place or places 'to be loved'. We found that place preferences can change when people get older and attitudes towards them are inflected by biography and by acute aware- ness of the changing environment. Like younger people, they want to find places that they like and that fit with their different preferences and criteria. Exactly, what preferences and criteria might be relevant, however, for elderly people remains under- researched. One constantly mentioned issue in our sample was the interest in, and the absence of, adequate information about appropriate meeting points. Personal tags of special places by the peer group could, especially if associated with some sense of what it is that makes such places 'special' for the individual, help to get a livelier picture of certain locations and what makes them 'pro- social' places.

### 5.5.2 Studying way-finding practices of elderly people

In this section we discuss the value of the practice perspective on daily way-finding. That was predicated on the view that many existing works on mobility tends to focus on particular transportation modes or on navigational issues, instead of how users 'orientate and experiences their mobility. In the particular case of elderly people, we found that the strong focus on single transportation modes supported to a greater or lesser extent a 'deficit 'oriented model, centered around the bodily and cognitive declines that might reduce the abilities of elderly people to make use of the different transportation modes (J. Lee et al. 2016; Montuwy, Cœugnet, and Dommes 2016). This is evident in approaches to preventive measures, such as exergames (Ogonowski et al. 2016; Skjæret et al. 2016), or to car-based support which often stresses monitoring services, automation processes or corrective features. Others aimed to improve the accessibility of public transportation information systems that focus e.g. on better guidance to ease accessibility for elderly people (Krainz et al. 2016). Navigational issues were often addressed in the course of cognitive disabilities like dementia (Wan et al. 2014; Alsaqer and Hilton 2015). Thus, we developed a methodological framework to study elderly people's way-finding as practices to get more detailed insights on their daily occasions and particular needs. The chosen method,

one which entailed using map- ping applications as 'probes' into ordinary way-finding, demonstrated a number of sometimes subtle elements. In particular, we found three issues of major importance: social, biographical and health related ones. On the social level our investigations highlight the significance of concerted activities in fostering social alignments such as collaborative forms of mobility. Furthermore, we show the dynamic aspects of aging, by recognizing changed preferences around loved places. The findings indicated that, like younger people, business travelers, or families, young elderly people have their own preferences for meeting points and activities, preferences that reflect what appear to be some typical lifestyle factors. Supportive mobility assistance ICT should enable them in identifying such places, events or activities, too. On the bio- graphical level we found that by entering retirement, elderly people are the only cohort that is not necessarily part of an institution such as school, university, work or even kindergarten. The point is that institutions like those provide for most people's fixed weekly structures and so, in their absence, there is a need to establish new ones. The analysis showed that elderly people of our user group started to create new rhythmic mobility patterns. Those were developed in relation to frequented, habitual places and the serendipities that sometimes intervene. ICT solutions could be used to support these patterns. Further, such a support could also revalue those self-selected patterns on a personal level. Regarding health-related issues, we have been at pains to discount the 'deficit 'model of elderly functioning, but the study showed that also minor health issues and concerns do impact on young elderly people's way-finding choices. According to Richards et al. (2012) and Durick et al. (2013) individuals around age 60 increasingly start to experiencing such small health changes. We showed that the absence of information on reachability and environmental access could lead to in- securities and might even prevent such journeys. Hence, given that a good access to places is of course important in all contexts, it turned out to be particularly relevant in cases where destinations are less well known for one reason or another. While this is not especially surprising, ICT support for mobility in such contexts does not seem to reflect these specific needs yet. Addressing them might support the young elderly in developing new confidence and trust in planning trips to as yet unknown places, whether far away or not. Our findings are consistent with the idea that mobility is more than the sheer capability to use the diverse transport systems avail- able. Rather, this study gives detailed insights how mobility assistance ICTs can be adapted to the way-finding practices of a particular user group and also its potential to reshape their mobility experiences. It is important to mention that we understand the research on way-

finding practices not in opposition to the existing works but as complementary. It provides, we suggest, a better understanding of certain user groups, which might otherwise be less well understood or simply not reflected. Moreover, we see the practice-based lens, facilitated by the mapping probes, as an additional perspective on diverse way-finding practices.

## 5.6 Conclusion

The starting point of this paper was the lack of empirical research in HCI on daily mobility to support particular user groups. Addressing this issue, we suggested a framework for studying way-finding as it occurs in daily life –namely as a practice –and outlined two fundamental challenges: The first one is a methodological question of how way- finding practices can be understood and conceptualized. We answered with Tuan's (2004) conception of 'senses of place'. As with Harrison and Dourish (1996) and Dourish (2006), for Tuan "place …is more than 'location', while that more is related to the personal orientation towards places" that is rooted in the very personal experience of moving in and towards those places (Tuan 1977). The second challenge was a question of method; how users can be supported to better express their experiences of moving around. We have used what we feel is an instructive method for mapping of daily activities to ease the talking about certain situations and also, more importantly, the rationales that people bring to their activities by using a probing approach. More advanced approaches of digital mapping might even provide more dense and detailed insights. Hence, an advanced probing approach might also serve as a starting point for further elaborating understandings of way-finding as practices. The study we conducted had also some limitations. Notably, the participants came in the main from a small town. The sheer complexity of journey possibilities in larger cities is something that needs further investigation since it may prompt other considerations. Similarly, many elderly users may not be as comfortable or in tune with mobile smart- phones as those in our sample. Thus, future work should also focus on ability-based design and the adoption of such services. Further, when addressing age as a continuum, there is an obvious need for comparative analyses with other discrete user groups. Again, understanding the specific needs of a variety of user groups, for instance for newly arrived immigrant populations, for people with different kinds of disabilities, for people for whom safety is especially critical, and so on, would be a more than worthwhile exercise to foster aspects of social inclusion.

# 6 Social Dependency and Mobile Autonomy - Supporting Older Adults' Mobility with Ridesharing ICT

**Abstract**

Alternative mobility modes for older adults are increasingly important for economic, ecological and social reasons. A promising option is ridesharing, defined as use of the same vehicle by two or more people traveling to a common destination. In particular, mobile computer supported ridesharing provides a promising way to enlarge older adults' mobility choices in addition to private driving and public transportation options. In order to understand the opportunities and obstacles of ridesharing from the point of view of elderly people, we conducted an interview study in order to examining ridesharing experiences. It turns out that 'mobile independence' and 'decisional autonomy' are key issues for mobile wellbeing. This partially conflicts with common ridesharing concepts. Hence, we further analyze older adults' strategies dealing with these conflicts and show that these strategies offer departure points for the design ridesharing solutions, which are better suited to the demands of older adults.

## 6.1 Introduction

In 2000 about 13% of the total U.S. population were over the age of 65. By 2025, the number of older Americans will have more than doubled, so that nearly every fourth person will be over the age of 65. In Europe, China or Japan this effect will be even more dramatic, because migration is not as high as in the US. All but the most fortunate senior citizens will be confronted by an array of medical and other constraints on their mobility even as they continue to seek an active community life (Mollenkopf et al. 2005). Many older adults drive but still face mobility barriers, or suffer from physical or medical problems (Rosenbloom 2004). Then there is a large number of elderly people who live in regions that are underserved with public transportation infrastructure (Mollenkopf et al. 2005). Debates on providing transportation for the elderly in gerontology, transport studies, health research and urban studies do not always capture the complexity of their situations. Based on the complex and diverse mobility situation and needs of the elderly we suggest a ridesharing system that is flexible enough to address the heterogeneous contexts of older adult mobility. Ridesharing provides not only an alternative

mobility infrastructure, but also includes a social network that allows personal help when needed, or can support social inclusion. Despite its great potential, ridesharing presents quite a new topic for gerontological mobility research and we know little about developing ridesharing ICT for the elderly. This provides motivation for a qualitative study on 21 older adults' attitudes and experiences towards ridesharing in a German mixed density area consisting of rural and urban spaces.

In the following we will draw a detailed picture of the mobility situation of older adults and we will give reasons to focus on ridesharing solutions for this particular user group (section two). Then we will provide an overview of related work on ridesharing systems in HCI research (section three), followed by a discussion (section four), arguing that research about ridesharing for the elderly is under-rehearsed. After outlining the methodological framework (section five), findings will be presented. Ridesharing needs, problems and strategies for coping with challenges of older adults provide innovation seeds for design implications that will be outlined at the end (section six).

## 6.2 Improving older adults' mobility with ridesharing

According to Ziegler et al. older adults' mobility can be understood along three dimensions in gerontology, transport studies and health research of western societies (Ziegler and Schwanen 2011): (1) as quantified movements through space and time, (2) as dependent on preconditions like the available infrastructure and (3) as subordinate to individual physical mobility status. In the following we will see how these dimensions address ridesharing and how it supplements older adults' mobility.

### 6.2.1 Measuring mobility

The first research dimension deals with counting mobility trips on a daily or weekly basis, measuring the distances the elderly cover and the transport modes they choose (e.g. Fobker and Grotz 2006). Although older adults make 22% fewer trips overall after retirement, studies show that those over 65 make a greater percentage (roughly 90%) of their trips with a car than younger people do (Rosenbloom 2004). Further, older people typically have very active post-retirement lifestyles until they are 85, and take as many as 23% more non-work trips than people under 65. In particular, older adults at retirement often have much more spare time. Older

adults drive often to sports clubs, make visits, go to sightseeing tours, or just go for a walk or undertake a shopping spree. Thus, older adults often undertake activities along with others, and often in informal ridesharing arrangements. Studies show that about half of all trips are done in cars with at least two persons, the driver and at least one passenger (Schwanen, Banister, and Bowling 2012). In addition, the percentage of trips in cars made by those over age 65 without a license is almost as high as licensed drivers. This means that informal ridesharing is already a very common and also very important transport mode among the elderly, that supports that older adults who do not drive (Scheiner 2006).

### 6.2.2 Mobility preconditions

The second research string addresses the unequally distribution of options for older people in relation to different transport modes (Mollenkopf et al. 2005). As the majority of older adults in western countries will increasingly live alone in suburban or rural communities, access to public infrastructure becomes increasingly problematic for this cohort. Thus, the private car becomes crucial to sustain individual mobility. In addition Fobker and Grotz point out that incomplete knowledge about public transport services is a significant barrier preventing older adults from using alternative transportation modes as well (Fobker and Grotz 2006) and explains why a good social network becomes of great importance to compensate for the absence of a car. Coughlin, for instance, discovered that older adults who are embedded in a good social network are more likely to give up driving because informal ridesharing opportunities exist (Coughlin 2001). In this context Lord emphasizes the adaptation of lifestyle through 'mutual aid' and 'community based' help (Lord, Després, and Ramadier 2011). Again others argue that such structures should be institutionalized to increase the benefits (Dumbaugh 2008; Silvis 2008). One way of doing so could be a ridesharing system based on existing social networks.

### 6.2.3 Mobility and health

Existing research tends to focus on bodily or cognitive impairments in later life, causing difficulties in undertaking the basic mobility activities of daily life (Beswick et al. 2008). In particular Rosenbloom criticizes the fact that most research on older adult mobility focuses on those with the most obvious and severe disadvantages, those who do not drive or who are severely disabled (Rosenbloom 2004). She shows that disability rates have in fact been falling among all cohorts of the elderly for decades, caused by a combination of good nutrition, improved health

care, better education, and higher incomes. Most elderly people, she argues, will be in overall good health until they reach age 80 or older (apart from smaller problems, like vision problems at night, problems of carrying heavy bags or coping with crowded streets) (Rosenbloom 2004). Thus, life from 60 to 80 can no longer be regarded as *residual life* time, but is characterized by *late freedom,* posing new challenges, and creating new development tasks and design options. However, driving is still the easiest physical task for older adults. Long before they lose the ability to drive, older people may be unable to board or ride public transit, or to walk to a bus stop. Thus, it is not surprising that the fear of losing the driving license is widespread among older adults (Schwanen, Banister, and Bowling 2012).

In summary, ridesharing practice is a common and deeply established mode in the elderly's daily travel. In particular, ridesharing can address the needs of those who have never had a car or a license, as well as those who have driven well into their senior years, but now are unable to do so and have poor access to public transport.

## 6.3 Supporting Ridesharing

Ridesharing systems became popular in the 1970s to cope with the challenge of increasing environmental awareness, oil prices and transport collapse. People at that time joined together in ridesharing communities using slip-boxes in order to exchange offers and demands (Handke and Jonuschat 2012). Since that time ridesharing research in information systems and HCI has undergone a change in perspective, shifting from logistical concerns towards questions of social acceptance.

### 6.3.1 Matching demands and offers

The precondition for matching a driver with one or more passengers is that their mobility patterns are as congruent as possible, given travel time and route convergence. The prevalent research focus emphasizes the challenge of finding appropriate algorithms for matching rides. While there is no standard method to determine the best ride-matching method, several approaches have been developed along different foci of activity-based behavior (Steger-Vonmetz 2005; Teodorović and Dell'Orco 2008). Meanwhile agile and real-time matching became key components for a successful ridesharing system. Location aware Internet-enabled mobile phones allow very short notice or even en-route notification. This constitutes the technical

basis for flexibility among spatial, time, role and route dimensions (Handke and Jonuschat 2012). Another factor for intelligent matching operations is to improve the modal choice of transport (Steger-Vonmetz 2005). Increasingly, attention is being paid to the question how the use of online social networks can contribute to solving problems of meeting potential sharers, coordination, and logistics (Ghelawat, Radke, and Brereton 2010; Mirisaee, Brereton, and Roe 2011).

### 6.3.2 Reducing transaction costs

Reducing costs has been a major element in ridesharing research since its onset. In HCI, the focus has widened to include transaction costs. In the case of commuting, transaction costs are very low, because commutes are based on routinely established practices that do no longer need a lot of coordination work (Handke and Jonuschat 2012). However, with the arrival of more flexible, agile ridesharing systems, handling transaction costs, becomes a much more challenging issue. For example Hansen et al. (2010) focus on community based-toolkits and ICT as means to reduce transaction costs by lowering the complexity of the selection of and the navigation to meeting points. Largely in line with this perspective is the work of Xing et al. who take meeting points into consideration and call for 'multi-modal travel planning systems', including information about public transportation to offer optimal meeting points (Xing et al. 2009). Several approaches, such as those presented by Brereton et al. (2009) or Wash et al. (2005) focus on the improvement of communication processes, comparing informal and formal systems.

### 6.3.3 Accounting for social acceptance

The arrival of dynamic and flexible ridesharing systems precipitated a discussion in HCI research on issues of social acceptability. Pioneering work was done by Brereton et al. (2009), Allen (2009), and Ozenc et al. (2011), who argue that ridesharing systems can reach a wider mass of users if social challenges concerning personal preferences of commuting choice and social interaction are solved. They point out that it is necessary to understand that riding, meeting with people and participating at an event are related activities and hence a broader view of the social situation in which people travel and meet is needed. Further Brereton et al. and Ghelawat et al. (2009; 2010) pinpoint that agile rather than static matching programs need to arrange ridesharing based on extended social networks. Wessels et al. (2011) show that online

social networks provide users with the ability to share daily travel activities by publishing information using a personal profile and have the additional function of showing relationships between people. Thus, designing for participation in local social ridesharing has to deal with the question of designing networks of relations between people in order to understand how to better support ridesharing relations. Yet in using social networks systems and further using tracking and data mining technologies in combination with personal information, concerns about issues like *trust*, *privacy* and *security*, which are situated in social practices, are raised (Mirisaee 2010; Radke et al. 2011; Wessels et al. 2011).

Hence, with the arrival of agile, flexible ridesharing systems, design decisions can no longer be addressed separately from concrete social and cultural perspectives. However, increasing interest in social issues like trust, privacy, safety or social interaction has not addressed ridesharing specifically. Mobility behavior is still considered as a derived demand, based on the spatial and temporal characteristics of the performed activities.

### 6.3.4 Discussion

Economic pressure on the public sector and the low incomes of older adults create a need for developing new mobility options in the near future. Currently, supporting elderly people to use ridesharing is a blind spot in gerontology and HCI research: While gerontology articulates the challenge of supporting independent living, it has yet missed to investigate new opportunities offered by mobile and ubiquitous computing. In contrast, while transportation and mobility research gains importance in HCI research, the elderly are not thus far addressed and hence their interests are typically neglected when it comes to the design of mobile ridesharing systems. This blind spot might result from the stereotyped view that older adults are not technology savvy: a largely unwarranted assumption given that mobile phone users are getting older (Mollenkopf et al. 2005).

Further, our literature review shows that understanding older people's mobility is mainly framed by a transportation perspective. The dominant topic is the overcoming of mobility barriers through increasing the numbers of mobility activities, providing infrastructure, and improving the health situation of older adults to enhance the ability to move from A to B in physical space. Others, however, argue that this view does not guarantee mobility without problems or an increased quality of life. For instance, authors like Ziegler et al. (2011), Kaiser

(2009), and Steg (2005), stress that we need to take subjective meanings of mobility more into consideration. In this new understanding, mobility is more than just a means to reach destinations but contributes significantly to older people's wellbeing and quality of life. In addition, we need to consider social and cultural factors which act as barriers to choice for older adults when they examine viable means of travel (Scheiner 2006; Dumbaugh 2008).

This new understanding implies that HCI research on ridesharing for older adults should not focus on transportation issues only. Instead we should broaden the investigation to the elderly mobility experiences, wellbeing and subjective attitudes to ridesharing. Although existing literature draws a realistic picture about older adults' mobility activities, patterns, and transportation mode preferences, qualitative research which takes values, fears and desires into account and uncovers current mobility practices is still lacking (Fobker and Grotz 2006). Sensitized by the above-made arguments, the research question of how ridesharing is experienced by older adults is our primary research issue.

## 6.4 Methodology

Addressing this question, we conducted an interview study. Interviews can provide detailed insights into the subjective life-worlds of individuals and therefore were chosen to investigate subjective attitudes, meanings and interpretations towards mobility in general and daily ridesharing in particular.

We chose problem-centered interviews (Witzel and Reiter 2012) for the data collection, because they aim at focusing on experiences, perceptions and reflections in relation to specified issues. On the basis of a question guide, therefore, we asked interviewees to reflect on and expand our themes in any way they chose. The semi-structured interviews were accompanied by a short questionnaire with the function to complement the study with additional biographical and socio-demographic background information about the interviewees. The questions asked were loosely structured around a topic list about the living arrangements within daily mobility routines and the way they dovetailed (or not) with available infrastructure like possessing a car, using public transport, or other forms of mobility like ridesharing. We were further interested in mobility choices, preferences and habits.

Asking questions in a problem-centered interview provides some structure, but also provides for an open, iterative, and reflective response by both parties to the interview. Interviewers

relied on reflective questioning and probing, prompting participants to provide additional detail, clarification and exemplification. Hence, we kept interviews as open as possible in order to gain individual insights in the issue of older adults' ridesharing experiences. The interviews were conducted in participants' homes by one of the researchers, audio-recorded and transcribed verbatim afterwards. The duration of interviews was driven by interviewees, and thus varies in length from 45 minutes to two and a half hours.

The initial contact with participants was made through various local senior organizations. We selected a heterogeneous group of seniors (N=21) in relation to gender, age, local infrastructure, and in the transport systems typically used, in order obtain a wider spectrum of ridesharing and mobility experiences. Table 5 provides an overview of the interviewees according to relevant categories. Pseudonyms are used to ensure participants' anonymity and confidentiality.

The region that participants come from has about 100.000 inhabitants in western Germany. One characteristic of this area is that it includes both urban and very rural areas. The only public transportation option available is bus, or train (mainly for inter-city travelling). The bus service is very limited, especially in rural areas. Additionally, the landscape is very hilly and diverse; meaning that travelling from one location to another can mean very indirect journeys. Thus, the focus in this study lies on an area with limited public transport system, that is close to the real-life context of most older adults.

All interviewees were still mobile and take actively part in social events and life in general. They agreed to participate on a voluntary basis and no financial compensation was offered. Further, all of the interviewees committed to collaborating in a three-year project, commencing with these initial interviews. The overall project aim is to develop a mobility platform for older adults that follows a participatory design approach (Wulf et al. 2011). Participants from the outset were aware of the research aim of building a ridesharing platform customized for older adults needs and are overall positively positioned toward mobile ridesharing solutions.

In the analyzing process we used MAXQDA[4] software. First, interview transcripts were organized into different content parts to organize the data with the help of different code groups. Second, the data was analyzed under three leading question headings: first, what makes daily mobility actually a valuable experience; second, how is ridesharing experienced; and third, what

[4] http://www.maxqda.com/ (last view: 01.01.2014)

are the strategies people use to organize their ridesharing practice? In the following we will report on our findings on these issues.

**Table 5: Characteristics of interview participants (N=21)**

| Category | Characteristics | Number of Respondents |
|---|---|---|
| Sex | Male | 5 (26%) |
| | Female | 16 (74%) |
| Age | 58-70 years | 11 (53%) |
| | 70-80 years | 10 (47%) |
| | (Average: 69 years) | |
| Material Status | Married or living with a partner | 12 (58%) |
| | Widowed/ single/separated | 9 (42%) |
| Housing tenure | Owned | 13 (63%) |
| | Rented | 8 (37%) |
| Self-rated technical competence | More good | 6 (26%) |
| | More bad | 15 (74%) |
| Population density | Low density | 11 (53%) |
| | High density | 10 (47%) |
| Travel Modes (Multiple answers are possible) | Own Car | 17 (84%) |
| | Public transportation | 5 (21%) |
| | Walking | 8 (42%) |
| | Regularly involved in Rides-haring | 9 (47%) |

## 6.5 Findings

Two categories turned out to be of particular significance for the experience of mobile wellbeing in older adults' lives: *independence* and *decisional autonomy*. However, both dimensions were viewed as constraints on ridesharing arrangements, but constraints, which nevertheless could be overcome with the adoption of various strategies.

### 6.5.1 Mobile independence and decisional autonomy

Participants consistently raised two issues, which we call 'mobility independence' and 'decisional autonomy' in relation to their daily experiences of mobility. Every interviewee referred to at least one of the two issues, but in most cases both arguments were referred to several times. Both arguments are illustrated in the following in more detail.

### Maintaining independence from others

Every participant mentioned mobility independence at least once during the interview. The following quote provides an insight into a typical answer given by one interviewee to the question of what mobility means to them:

> *'It (mobility) means being very independent and able to go to places. The bus services up here are really good and I'm really happy and that is important. You don't need anybody because the (bus) connections are excellent and you can get anywhere you like really quickly. That is very important for me. Yes, this is really very important to me', (Mrs. Thomson, 76).*

For Mrs. Thomson, who lives in a single-household in a suburban area without a car, her mobility experience is directly interwoven with her understanding of mobile independence. Hence, the mobility she mentions is concerned with the ongoing maintenance of her individual independence. Thus, by independence she means being able to manage her daily mobility by utilizing her own resources in accordance with her abilities and without depending on others. It is this understanding of independence as 'doing things alone' on the basis of one's own physical and cognitive abilities that turned out to be the dominant meaning of independence. Hence, our interviewees point out that it is not just about reaching the destination but 'managing to get there', re-affirming their own capacity to do so. This issue of desired independence is well attested to in the gerontological literature. Plath (2008), for instance, argues that the high value placed on independence can be understood against the backdrop of a society that is strongly influenced by liberal, individualist values, and is incorporated on the individual level. For older people, their status is a negotiated one. Declining physical prowess may mean that they are seen to be more dependent by others but on the basis of our evidence they are also fiercely determined to maintain independence.

### Maintaining decisional autonomy

Although decisional autonomy relates to mobility independence, it is distinct from it. Quotes like following clearly express this position:

> *'Yes, a great deal [mobility means] everything. Everything… the decision too, just the thought of it even I CAN go, if I want… that is so important, you know? Even if I might not actually go anywhere but just… yes, just to know that if I wanted to go anywhere, I can just go to the*

*garage, get in my car and drive off… and yes, I am scared of the day when that might not be the case anymore', (Mrs. Martinez, 77).*

Mrs. Marinez lives with her husband and two cars in a more rural area. Mobility is important for her as a means of maintaining and enhancing travel opportunities, rather than the travelling itself. In this way mobility is seen as a means of being autonomous in and through the capacity to make decisions about where, when and how to travel on one's own. Decisional autonomy refers to the way in which older people seek to maintain and maximize their choices. This issue of autonomous decision-making is in line with the findings of Sheller and Urry (2003), or Urry (2007) who show that decisional and executional autonomy are key aspects of our perception of freedom and that more mobility is widely considered a symbol and facilitator of that freedom. However, many of the interviewees stated fear of an uncertainty about the future:

*'Well, err, I mean it's always just a question of time isn't it, how long you might still be able to drive a car. It might be over really quickly, you never know do you. It's something I think about of course; of course, not all the time, but it is an important point', (Mrs. Harris, 75).*

Mrs. Harris lives with her husband in a very rural area with two cars and demonstrates in this sequence her awareness about potentially rapid change in their mobility situation. Hence, while decisional autonomy is in general an important factor in mobile wellbeing, most participants also stated a fear of losing that autonomy in older age. Although all of the participants are still more or less satisfied with their current mobility, they also see it as endangered. Maintaining decisional autonomy 'while one can' seems to be tied up with making the most of current capacity in the knowledge that it may well be diminished in the future.

### 6.5.2 Independence and decisional autonomy in different transport modes

The concepts of *independence* and of *decisional autonomy* are interwoven but can be separated from each other on an analytical level. Their relative importance depends on the various transport modes being used.

#### Using private resources

People usually depend on a variety of resources to support mobility, including the car, bike, motorcycle or any other kind of vehicle that is appropriate for the person's surroundings. In

our case the examples deal mainly with car usage. The 80-year old Mr. Moor who resides in a very low-density location area describes the advantages of car driving like this:

> *Interviewer: 'And you still drive don't you?'*
>
> *Mr. Moore: 'Of course, I always drive by car. It means a lot because it means I'm able to get out when I want. Although the bus stop is right before our house, the bus stops only twice a day when we are lucky (smiling). You need a car in order to do all the daily errands or if you want to get out in an emergency or anything like that, or go out to the theatre', (Mr. Moor, 80).*

The car affords self-reliance in respect of both decisional autonomy and independence. In using the car, this interviewee can go to places he would not be able to reach by foot or by bus anymore. Thus, in keeping with Ziegler et al. (2011) and Schwanen et al. (2012), cars can function as 'compensation tools' to protect individual independence when physical functioning declines. Interestingly, Mr. Moor explains how he uses his 'car driver' capacities to occasionally extend a courtesy to older adults who cannot drive and whom he picks up when he sees them on his way. Thus he refers to the widespread belief that cars are the only transport mode that can provide people with the mobility and autonomy required to live a late modern life (Urry 2007), and refers to the inequalities of having a car or not. In his understanding ('*You need a car in order to do all the daily errands')* it is necessary to offer rides to those who cannot otherwise manage their errands. Multiple studies – mostly set in car-dominated societies such as the USA and Australia – point out that being able to drive in later life is strongly related with self-reliance and independence (Allen 2009). On the other hand losing the driving license raises the prospect of a dependency which most older people strongly resent and wish to avoid (Adler and Rottunda 2006). Thus, as Mr. Moor describes, car driving brings a responsibility with it for the others who have no car or cannot drive (any more).

Decisional autonomy connects to one's ability to plan for oneself how to undertake journeys of whatever kind. Hence, decisional autonomy is highly connected with possessing a car. Driving means having the option of being mobile whenever one wants or needs (Urry 2007). This is in accordance with studies that examine driving cessation, where older people construct driving cessation as a loss of executional spontaneity (Adler and Rottunda 2006). Although decisional autonomy is also an important value for the younger ones, driving the own car can be particularly important for the older adults who more often live in low-density areas or have

problems using public transportation. This is also stated in the interviews, when addressing the car as a *sine qua non* of mobility autonomy:

> *'I've got to have the feeling I can get in and drive off. […] but I don't really NEED my own car, I don't use it every day. But I want it to be there, waiting in front of the door so it's there when I need it', (Mrs. Jackson, 64).*

Mrs. Jackson who lives in a more urban location with good transport links sees the car as a symbolic representation of decisional autonomy. Further many participants stated that the car is the only transport mode, which allows translating immediate wishes into actions without the need for any detailed travel planning. Thus, the car is perfect for autonomous decision-making. The car allows the 'ageing car driver' spontaneity, independence and sense of control that cannot be replicated by other transport modes.

### Using public transportation

With regard to public transportation, some interviewees also see independence in using buses, as is stated in the following:

> *'my mobility… as long as I can still walk to the bus stop, use the bus, I'm happy. It's my independence. I'd like to remain independent actually. And for me that means the bus. Not the car, because I don't own one', (Mrs. Martinez, 77).*

Mrs. Martinez refers to the car as the transportation mode of choice but clarifies that taking the bus allows her to feel independent as well, since there is no need to ask for support. Interestingly, public services of this kind are not perceived as autonomy reducing, but as an infrastructural 'right'- a service that are all entitled to use and - given the fact that one pays to use the service- which confers no particular sense of obligation. By and large, our interviewees had no difficulty in planning journeys in such a way that they fitted in with timetable constraints. They often reported noting or accessing information about return journeys on the back of the hand, in short notes, or by using route leaflets, so they could refer to them as needed and react more flexibly to contingencies. Thus, decisional autonomy is restricted in the case of public transportation because timetables and routes restrict the flexibility of people's mobility. Regardless, mobility depends of course very much on people's residential location and its traffic connections. This pertains not only to the distance to the nearest bus stop, but also the frequency of buses during different times of the day and days of the week.

## Using private resources publicly – Ridesharing

Ridesharing, by definition, entails a degree of mutual dependency. Driver and passenger depend on each other in several respects, for instance, in matching logistical concerns like time of departure, pick up places and return. Further, people have to cooperate by negotiating some agreement about the 'intensity' of interaction - is one expected to talk? How much? Laurier, for instance, showed that both parties have to find a way defining and negotiating their mutual relationship (Laurier et al. 2008). Further, Sherlock compares the roles of passenger and driver with the roles of being a good 'host' and a good 'guest' (Sherlock 2001). Thus, while guest and host are background 'politeness' categories to driver and passenger they are resources for moral assessment of each person's conduct during the journey. These kinds of relationship are, of course, not those found between family members or between longstanding, good friends. There, such issues are more or less settled as habitual. Hence, there does appear to be some asymmetry of decisional influence depending on these roles. The following sequence gives a good glimpse in typical statements about the 'guest' and 'host' role:

> *[Talking about sharing regular rides with her neighbor and going to a particular bar] 'Of course I depend on the driver. If the driver wants to go to Xbar, drinking a coffee, I have to follow if I want or not. I don't like the Xbar. And in return when driving on Saturday to the market I would not go to Xbar. Then people can decide whether they want to go to Xbar or drive back home with me', (Mrs. White, 58).*

There seems to be a mutual understanding that passengers as good guests have a duty to orient towards driver's habits as Mrs. White states who lives in a single household and possess her own car and often practices ridesharing as driver and as co-driver. She explained further that she would expect to accommodate driver wishes in respect of start times for instance, and would not expect equal consideration from the driver. Hence, there is a mutual understanding that passengers should make few demands on drivers largely because there is a sense of having been 'invited'. Drivers, in short, are perceived as having more rights in negotiating the arrangements.

Further, several interviewees expressed personal issues within decisional autonomy in ridesharing situations. Since the ride opportunity is not entirely predictable with respect to time, route, etc., the potential passenger has to deal with a considerable amount of uncertainty. Relying on someone else means lining activities up with the schedule of others, at least to some extent.

The following sequence illustrates an issue that was stated by participants quite often and can be seen as a result of the passengers' loss of decisional autonomy:

> *'[With ridesharing] you've just got to follow suit, no matter how or when she's driving. I have to watch what anyone's doing, I can't look (when shopping) where I want and how long I want and what I want. Thus, I prefer to do it alone, you know […] That's all those things, no, well it is (on my own) more independent', (Mrs. Williams, 73).*

This respondent practices ridesharing regularly, but shows an awareness of this unequal relationship. The passenger has to adjust to the driver without even knowing what exactly s/he is adjusting to. In contrast to public transport, decisional autonomy is reduced for passengers because they are less able to plan independently. Thus, and in summary, the analysis has shown that ridesharing is characterized by participants with attitudes that fit uneasily with basic needs of mobile wellbeing: namely independence and decisional autonomy.

### 6.5.3 Organization of ridesharing practice

As we already mentioned above, however, ridesharing is quite popular among older adults and frequently used. This is because they adopt a range of strategies to cope with these demands that makes sharing rides a more pleasurable travel mode.

#### Preserving independence

As already mentioned above, the 'guest' and 'host' analogy in ridesharing practice, including gratitude, can cause a feeling of dependence on the driver, in contrast to using a bus, or renting a car. However, interviewees reported about a practice that can be described as 'lift giving' and 'gift giving', that can lower the experience of dependence.

> *'To square things you can take some flowers or a plant to say thank you now and again. They (the drivers) don't want anything but just to say thank you, you can get some flowers. Just a little plant. But I don't do it so often because they don't want you to. Like they say, it doesn't matter whether three people are in the car or four', (Mrs. Thomson, 64).*

This woman lives in a single household directly into the city center. Although she possesses her own car, she regularly practices ridesharing with a woman who picks her up for errands and other routine chores. Giving a little gift like a flower or spending money on a coffee in-

volves gift giving (Mauss 1990), and hence constitutes a form of reciprocity. Informal gift exchange economies are sometimes romanticized as being more social than the 'cold' value exchange economies, where one acquires a commodity or service by paying the price. However, gift exchange economies do not come for free, but involve quite complex and unspoken rules, governing timing, appropriateness and emotionality. The aforementioned roles of 'host' and 'guest' establish a particular kind of reciprocal social relationship, different in their implication from those of family member or paid service provider. The statement from Mrs. Thomson shows that people are aware of this underlying reciprocal paradigm of ridesharing and in consequence develop strategies in order to maintain their independence. Concerning this, Nicolini (2013, p. 62), for instance, pointed out that 'reciprocating a gift too soon is bound to look like a payment, therefore negating the disinterested nature of the original act and creating embarrassment; conversely, delaying the reciprocation too much is bound to be understood as ungratefulness'. Establishing reciprocity needs to be socially negotiated and is difficult to establish in such ambivalent circumstances. Given the central importance of the moral order in these arrangements, it is obvious that the relation between driver and passenger can vary across a number of dimensions. The degree to which one can impose on another will depend to extent on the degree of familiarity both parties share. Sons, for instance, have a different set of obligations towards mothers than they do towards their drinking buddies. Casual friends are very different in status from 'good' friends. In each instance, the kind of reciprocity that might be entailed is very different.

As already stated, there is, in some circumstances, a great reluctance to impose someone when asking for rides. In particular, the intricacies of asking relatives and friends for rides were discussed with regard to the increasing level of dependence caused by asking for a ride too often. In particular it turned out that the interviewees are very careful when family members are involved. Statements like the following are frequently found in our sample:

> *'No, no, no, no, no, no, no! I don't want to pester anyone if I can help it. I always see to it that I can manage by myself, if possible', (Mrs. Gracia, 78).*

Mrs. Gracia, one of the more 'fragile' users who lives with her daughter in a remote rural area and has no driving license, nevertheless expressed an aversion to asking family members for a lift. She further indicated that this was because she wished to avoid exploiting 'obligations' and preferred asking friends because some form of reciprocity was easier to negotiate. This wish

not to impose is fairly consistently expressed in our sample. In sum, interviewees stated two strategies that provide some relief from the sense of dependency in ridesharing situations. This is to make use of the principle of reciprocity and to establishing a flexible economy that can be adapted to the specific kind of relationship between driver and passenger.

### Preserving decisional autonomy

An aspect of ridesharing that is surprisingly common is that in many cases ridesharing arrangements are predicated on a common activity, such as club visits, going to the theater or cinema, or visiting friends. Ridesharing arrangements connected through a shared activity have the advantage that participants can more easily orient to the obligations entailed in an activity like shopping, club visits, going to theater or cinema or visiting friends. Hence, there are two kinds of activities that are particularly well suited for ridesharing: regular activities and spontaneous ridesharing invitations. In the first case travelling together not only enhances the experience in these circumstances, but has a pragmatic element, as well. The coordination of ridesharing within regular activities is much easier because it is based on similar, anticipated, commitments, as the following quote from Mrs. Thomson reporting about her ridesharing experiences, illustrates:

> *'Well yes, they're fixed… well, there's a group of us who do things together… sometimes we drive to the cinema … and erm yes, then you just ask do you want to go this evening or maybe tomorrow and then one person says, yes, listen I'll drive or [someone else says] I'll drive…That's what it's like', (Mrs. Thomson, 64).*

Hence, there are some trips that are more suitable for ridesharing than others. However, in the case of regular mutual activities the activity has fixed borders. No negotiation about start and end time is necessary and there are few uncertainties caused by different interests (as long as all parties agree to limit the trip to the joint activity). Interviewees like the Mrs. Thomson report on developed routines for coordinating regular shared rides, such as meeting points and times. Thus, while single trips have to be coordinated with all parties in detail, regular ridesharing trips can be planned on a long-term basis and thus do not have negative impacts on decisional autonomy. The second kind of activity, spontaneous invitation, also has no negative consequences. Such unforeseen ride offers are valued as a win rather than a loss of decisional autonomy. In summary, constraints on decisional autonomy are reduced in ridesharing situations

when certain kinds of activity are in question: Spontaneous ride offers that can provide a welcomed opportunity, or regular rides providing a long-term and routine planning opportunity.

## 6.6 Conclusion

This focus on the experiences of older adults' mobility and ridesharing, we argue, provides new insights into the ridesharing practices of this particular user group and can inspire ridesharing design.

### 6.6.1 Elderly ridesharing practice

Although the interview study was conducted with a heterogeneous group of older adults that differ in age (from 58-80 years), gender, marital status, or population density, they all have a positive attitude towards ridesharing and think that a mobile ridesharing system would improve their mobility situation. Like the literature suggests (Scheiner 2006) informal ridesharing is a common and frequently used travel mode. In our sample of 21 older adults about the half of the interviewees make regularly use of ridesharing, but all are experienced with this particular kind of travel mode, more or less frequently.

In our study we followed authors like Ziegler et al. (2011), Kaiser (2009), and Steg (2005) who emphasize the need to take subjective meanings of mobility into consideration, but specifically in relation to older adults' ridesharing experiences. One of the major observations was that although ridesharing can be a good transportation alternative either for the older adults who live in low-density areas, or have problems using public transportation, or the car, it seems not to be motivated by such issues. Hence, lacking infrastructure or a bad health condition does not primarily cause the indigence for a lift. Moreover, ridesharing takes place when people share the same destinations and particularly when undertaking joint activities. Further, findings show in accordance with the literature that mobile independence and decisional autonomy are central values for older adults' mobility experience (Lord, Després, and Ramadier 2011). However, it was astonishing to see, that particularly ridesharing is problematic because of these points, but is a quite popular and common transport mode at the same time. This gives reason to search for strategies older adults use to organize their ridesharing practice.

We discovered that interviewees regularly indicated negotiated, delicate ways in which principles of reciprocity are mediated in the driver-passenger relationship, and that this is used as a

means to maintain independence in ridesharing contexts. This delicacy, contrary to the existing ridesharing literature on payment systems (which tends to the view that the main issue is providing adequate motivation for the driver (Allen 2009)), suggests that a much more careful analysis of motivational elements is needed when dealing with older people. Establishing a balanced reciprocity between both parties of the driver and passenger is based on their relationship and the kind of ridesharing conducted. Further passengers are more likely to accept ride offers instead of asking for one, in order to keep their independence.

Like the desire for mobile independence, decisional autonomy, understood as flexible movement, turned out of special importance for the older adults, too. It means having the capacity to make decisions about where, when and how to travel on one's own. This makes the car, where possible, a preferred option that allows the older driver spontaneity, independence and sense of control that cannot be replicated by other transport modes. Although ridesharing creates some difficulties in relation to decisional autonomy, as we have seen, there are circumstances where autonomy is subordinate to other factors. Two in particular seem to outweigh this need. Firstly, spontaneous ride offers are easily accepted and secondly long-term ridesharing arrangements based on a regular and organized schedule are welcome.

Although we have no comparison with younger reference groups, there are some suggestions in the data that older adults interpret independent mobility and decisional autonomy in their own way. Hence, our interviewees point out that it is not just about reaching the destination but 'managing to get there', re-affirming their own capacity to do so, as long as they are able to do so. For the older adults' independence and decisional autonomy are values that may be diminished in the near future, and thus, gain of importance.

### 6.6.2 Insights on ridesharing ICT

Our analysis demonstrates that HCI research on ridesharing for older adults should address ridesharing as a social practice rather than a transportation mode shifting people from place A to B. While ridesharing turned out to be a desirable objective in general, its practical implementation depends on a set of social issues, which relate to decisional autonomy, and to independence. These issues should be applied in ridesharing design additionally to issues discussed in literature already like trust (Mirisaee 2010), privacy (Radke et al. 2011), or security (Wessels et al. 2011).

It would be naive to imagine that such insights lead directly to design decisions. Rather, we see these conclusions as aiding in the construction of the design space. That is, they point to the kinds of issue that need to be considered both in terms of possible constraints on design and in terms of avenues to explore. Thus, and for instance, an examination of the concept of 'independence' and what it means for older adults has implications for the kind of payment system we might envisage. In most existing platforms, reciprocity is established exclusively via financial balancing. Among older adults, the issue of reciprocity and its concomitant obligations is nuanced, not only with respect to what payment might be negotiated as appropriate but also to when such payments might be made, if at all. As we have intimated, older people have a range of experiences in respect of their social networks, patterns of friendship and family relations. These subtle arrangements should be addressed by the design, giving the users the right to determine the kind of ridesharing conducted and what kind of reciprocity should be conducted. Beside classical paying systems, one can think for example on regular ridesharing journeys with an alternating driver where the system might remember users on the joint activity and the driver.

Further, there is a self- evident demand for mobile autonomy in our sample, but this is mediated by particular kinds of social activity with particular kinds of people. Joint activities which implicate friends and others in existing networks and which are geared to regular, repeated and routine activities are likely to be facilitated by ridesharing arrangements. Of course, to function adequately, such systems would need to provide a simple means for older people to delineate and limit who ride offers might be made to and in what circumstances. Additionally, such facilities enable participants to solve the issue of return journeys and to lower coordination effort in general, since people attend the same event and time and destination are usually tied to the event itself whilst at the same time supporting existing social networks and minimizing uncertainty. Otherwise, spontaneous ride offers can provide a welcome opportunity for traveling. In this case the design should be orientated towards easy and fast design solutions for offering rides and the design should incorporate features that help to create awareness about offers.

Lastly, ridesharing should be integrated into a pool of other mobility opportunities that do not exclusively depend on private ridesharing arrangements, but are integrated with public transport and other infrastructures that assure certain reliability. Ridesharing is of limited value to older passengers if it does not allow them to plan for contingent circumstances or changed

plans. Such an integrated multi-modal platform would be of most value if it provided information not only about ridesharing opportunities but also about other modes of transport. Ridesharing, in this perspective, is one part of an enlarged mobility option that maximizes independence and decisional autonomy.

In sum, the focus on older adults' ridesharing experiences originates in joint activities, and offers orientation, reciprocity, and multimodality as design inspirations. Findings show that matching demands, transaction costs and social acceptance should not be addressed separately, but are related to each other in and through the social practice of ridesharing and the social situation in which people travel and meet.

# 7 A Wizard of Oz Study on Passengers' Experiences of a Robo-Taxi Service in Real-Life Settings

**Abstract**

Autonomous driving enables new mobility concepts such as shared-autonomous services. Although significant research has been done on passenger-car interaction, work on passenger interaction with robo-taxis is still rare. In this paper, we tackle the question of how passengers experience robo-taxis as a service in real-life settings to inform the interaction design. We conducted a Wizard of Oz study with an electric vehicle where the driver was hidden from the passenger to simulate the service experience of a robo-taxi. 10 participants had the opportunity to use the simulated shared-autonomous service in real-life situations for one week. By the week's end, 33 rides were completed and recorded on video. Also, we flanked the study conducting interviews before and after with all participants. The findings provided insights into four design themes that could inform the service design of robo-taxis along the different stages including hailing, pick-up, travel, and drop-off.

## 7.1 Introduction

Autonomous driving (AD) has the potential to radically change the mobility landscape. With autonomous vehicles (AV) the future of automobile commerce might no longer lie in selling cars to private customers, but in offering mobility as an on-demand service (Pakusch, Bossauer, Shakoor, et al. 2016). The preparations for this scenario are already moving ahead. Recently, major automakers such as GM, Ford, Fiat Chrysler and Mercedes-Benz parent Daimler have partnered up with tech companies such as Google, Bosch and other transportation network companies such as Uber and Lyft to test and provide an autonomous mobility service in the coming years (Carson, B. and Muoio, D., o. J.; Chafkin 2016; Leadem, Rose 2017).

Such an advance in AD technology is expected to transform the current transportation system into one in which shared mobility is more prevalent and may give rise to various types of new business models and services (Stocker and Shaheen 2017). Conventional taxis and carsharing services are expected, in this view, to be combined into shared autonomous vehicle services

(SAVs). In the case of public transportation, autonomous shuttle buses are anticipated to operate on certain routes, whereas SAVs for private transportation, referred to as *robo-taxis*, are expected to be route-independent (Litman 2017).

Although uncertainty on various levels exists, the scenario of AVs appears to be a near-future possibility. According to a recent prognosis, AVs may become available in many urban areas during the 2030s and 40s (Lipson and Kurman 2016; Litman 2017). Rather than delivering autonomous vehicles to individual customers, however, there are good reasons to think that cooperation between the automotive manufacturer and service operators could enhance standard levels of service and maintenance in pre-defined areas that need to be digitally mapped (Litman 2017; Tussyadiah, Zach, and Wang 2017). Thus, the basic function of such services will be to enable their customers to order robo-taxis and take them to the destination requested (Hars 2015; Stevens et al. 2016).

We will argue that there is little current research which explores SAV-services in real life settings to explore and understand the different obstacles that can occur in everyday situations. To address this gap, we ask the following questions: (I) How do passengers experience a robo-taxi service that is simulated by a WoZ approach in their real-life environment? And (II) How can the findings help to inform the interaction design of possible robo-taxi services? As robo-taxis are currently not available, apart from in very restricted test runs, there is little opportunity for any orthodox observational work. For this reason, we conducted a Wizard of Oz (WoZ) study that imitated a robo-taxi service (Pettersson and Ju 2017). For this purpose, a field study with n=10 participants were conducted in Germany. The participants could hail and use the robo-taxi service for their own purposes over a week. As passengers, the participants were completely relieved of the driving task. Further, we concluded the trial with pre- and post-interviews that were conducted with each participant.

We found out that the participants orientated their interaction with the service along a punctuated trajectory, including hailing, pick-up, travel, and drop-off stages. Each of the stages provided important anchor points for the passengers to interact with the robo-taxi service. We further gained insights how the participants appropriated the service, the ways the passengers get actively involved when using the service, how they experienced the journeys and how they dealt with smaller breakdown situations. Based on these findings, opportunities for possible interaction design solutions of prospective robo-taxi services were identified and outlined.

## 7.2 Related Works

As services of SAVs gain more and more importance in the automotive branch, research about its basic functions to enable passengers to order robo-taxis and take them to the destination requested increased, too. Hence, quite some work has been done recently in laboratory predefined settings. However, research is still missing that is centered on rea-life settings of passengers to explore the interaction with robo-taxi services in every-day situations.

## 7.3 General discourses on AV and SAV

Regarding the National Highway Traffic Safety Administration classification from 2016, we can distinguish 5 different levels of autonomous driving, ranging from no automation (level 0) to full automation (5). Levels 1-3 list different forms of assisted driving where a human must still monitor the driving and intervene if needed. Levels 4 to 5 classify cars with 'high' or 'fully automation' and can operate unmanned (NHTSA, o. J.). Many HCI studies on AV have focused on level 3, focusing on the various conditions under which control passes to and from the human driver (McCall et al. 2016; Mok et al. 2017; Walch et al. 2015). Works focusing mainly on the driver often emphasize negative effects of AD, such as the experience of losing driving pleasure, or the experience of losing control and competency, as well as the feeling of being at the mercy of technology (Meschtscherjakov et al. 2015; Kun, Boll, and Schmidt 2016a; Riener, Boll, and Kun 2016; Lorsignol 2016). Hence, SAV only becomes possible at level 4 and 5, where high to full automation takes place.

At the moment, the extent to which SAV will replace the private car is unknown. However, the coexistence of both private AVs and SAVs is plausible, especially because self-driving technology offers various advantages for both forms (Pakusch, Bossauer, Shakoor, et al. 2016; Pakusch, Stevens, et al. 2018). Level 4 and 5 vehicles promote the convergence of different, separately considered service areas, such as car-sharing, car renting, carpooling, driving services, as well as for the taxi business (Pakusch, Bossauer, Shakoor, et al. 2016). According to the report by McKinsey & Company in 2016, new business models driven by shared mobility, connectivity services, and feature upgrades, could expand automotive revenue pools by 30%, adding up to USD 1.5 trillion by 2030 (Gao et al. 2016).

Given the current non-existence of such services, simulation studies have proven useful. Shen & Lopes (Shen and Lopes 2015), for instance, demonstrated in a simulation study that replacing

taxis by AVs would reduce the waiting time of passengers by 29.82%. Burghout et al. (2015) found out that only 5% of currently existing cars would be needed in Stockholm, if an SAV service was implemented. Kang et al. (2017) showed that, in Ann Arbor, an autonomous electric vehicle sharing service would greatly reduce greenhouse gas emissions as well as the social cost of carbon.

However, SAV services also have their disadvantages. For instance, AD raises new moral and legal questions. One concern is about what happens when AVs cause an accident (Tussyadiah, Zach, and Wang 2017). Furthermore, social questions arise when algorithms decide which passenger can be picked up and for what price. Also, rebound effects can be caused when and if not only car owners, but also public transportation users shift their preferred transportation mode to SAV. Such services could also cause many job losses in the mobility service sector (Pakusch, Stevens, et al. 2018).

## 7.4 AV and SAV in HCI discourse

In recent years, research on AV and SAV with fully automated vehicles (levels 4 and 5) has become substantially more prominent in HCI discourses and now has a lively presence as a research topic (Kun, Boll, and Schmidt 2016b; Pfleging, Rang, and Broy 2016; Stevens et al. 2016; Guenes, Hottelart, and Reilhac 2018). The research discourse can be separated into three main research fields:

First, research with a passenger-centric perspective: Such studies often highlight the positive effects of being relieved from the driver task. Pfleging et al. (2016), for instance, studied what kind of activities passengers want to carry out while traveling in AVs and how such activities can be supported by car interior design. Following this, Stevens et al. (2019) explored the implications for the interior design of the car and better time management for passengers. Concerning the potential to create a productive work environment, Pollmann et al. (Pollmann et al. 2019) compared three configurations of a car interior, conducting a neuro-ergonomic study. Furthermore, Sirkin et al. (2016) explored dialogs between driver and speech-based robot vehicle interfaces in a driving simulator, identifying concerns, confusions or curiosities over and above navigation or other traditional driving-related tasks.

Second, research that focus on road-interactions: Those research works address a shift in communication from 'human road users-to-human road users', towards 'AV'-to- 'human road users'. Research themes within these studies center on feasible interaction concepts for communication with other road users such as pedestrians or cyclists (Rothenbücher et al. 2016), or other car-drivers (B. Brown 2017; B. Brown and Laurier 2017). Some studies concentrated on very particular communication requirements when a vehicle is in automated driving mode. Chang et al. (2017) explored the communicating of the automated car when it needs to signal a turn, slow down or stop and Lagström et al. and Lundgren et al. (2015; 2017) researched how to give pedestrians or others a sign to draw their attention to danger.

Third, research on passenger interaction with SAV services: Many studies have been done about the acceptance of, and interaction, with automated shuttle buses (Distler, Lallemand, and Bellet 2018; Eden et al. 2017; Nordhoff et al. 2018; 2019; Wintersberger, Frison, and Riener 2018). Nordhoff et al. (2019), for instance, conducted interviews with people using such service in a real-life test phase. They identified speed and waiting time as crucial factors for a positive attitude towards using such a service. The study by Eden et al. (2017) further revealed that users attach importance to comfortable and safe seats as well as ample space for transporting luggage and shopping. Detjen (2019) further touches on the challenges of how passengers can interact with SAVs when no (taxi-) driver exists anymore. The findings outline new research topics like for example how the passenger can communicate the destination, the preferred route, making a stop, or explaining to the SAV what driving style is preferred.

## 7.5 Methodological challenges and own perspective

In this paper, we deal with the third research field. From a methodological point of view, several studies deal with the challenge of studying the everyday experiences of using (not-yet-existing) SAVs. Coping with that, Földers and Csiszár (2018) and Strömberg et al. (2018) postulated different design methods such as Wizard of Oz (WoZ) methods, small-scale scenarios, design metaphors, enactment, and peer-to-peer interviews. Baltodano et al. (2015) introduced a methodology for simulating an SAV on open public roads. They developed the Real Road Autonomous Driving Simulator (RRADS) and used it to evaluate prototypes in a between-participant study design. A broadly similar study to our own in terms of goal and methodology

is the study by Kim et al. (2019). They explored the interaction between SAVs and its passengers to envision challenges and design concepts for resolving them.

All the above-mentioned studies outlined the WoZ approach as their method of choice to study passengers' interaction with SAVs and related services. WoZ, in general, is a technique for prototyping and experimenting dynamically with the functions of a system. In this way, a technical system's performance is simulated and controlled by a human operator – a so-called wizard (Steinfeld, Jenkins, and Scassellati 2009; Wang et al. 2017). However, all of these works used the WoZ approach in laboratory settings with predefined scenarios to drive from a place A to a place B. Thus, no research into SAV-services in real life settings to explore different obstacles that can occur in everyday-situations have been conducted. To address this gap, we ask the following questions:

I. How do passengers experience a robo-taxi service that is simulated by a WoZ approach in their real-life environment?
II. How can the findings help us inform the interaction design of possible robo-taxi services?

## 7.6 Method

In order to address these questions, we applied a WoZ approach in real-life situations with 10 passengers who were free to use the robo-taxi service based on their personal demands over one week. We aimed to observe how the participants would integrate the service into their daily life, hence minimizing 'study' effects. Therefore, we aimed to allow the participants relative freedom of choice when, where and how to use the robo-taxi service. The trial was further accompanied by pre- and post-interviews.

### 7.6.1 Set-up of the WoZ robo-taxi service

Ideally, in a WoZ scenario, the participant should experience the WoZ as much as possible as a 'real' robo-taxi service. That included different components that were supported, including: (A) the taxi-hailing; (B) timetable coordination; (C) the robo-taxi; and (D) robo-taxi-passenger communication.

(A) The robo-taxi-hailing process was supported by a simple mobile application. To order and to pre-order the robo-taxi the passengers needed to insert a starting time and address, as well

as the address of the destination. Further, we added a blank field where passengers could insert additional information; like if they needed to arrive at a certain time, if they were in rush or more flexible. Based on this information the taxi-ride was confirmed or declined by one of the researchers. In the case of a confirmed ride, the researcher sent the expected time of arrival for the starting point, the expected travel time and also an estimated price of the ride to make the experiment more realistic. When the car was not available, we declined the request. We also offered the mobile phone number of one of the researchers for more personal and immediate support (e.g. cases of delay or to arrange more detailed information about the pick-up places). In those cases, the researcher was in close contact with the drivers to up-date them with new information.

(B) The incoming requests required timetable coordination. With the help of this document we decided whether we could confirm or if we had to decline a ride. The robo-taxi service was available between 8am and 24pm. We could only manage rides of 30 kilometres at a maximum based on the battery restrictions of the eclectic vehicle. Also, we had to include charging breaks. The document included all relevant information including the pick-up place and time, as well as the destination and the additional information that we gained for a particular ride. The driving was done by three of the researchers.

(C) For the robo-taxi we chose a Mercedes B-Class electric car. Figure 5 shows some details of how we prepared this car to make it look like a robo-taxi. The passengers were asked to sit on the back seat. Further, the driver cabin was blocked with a partition panel made of curtain material. With that solution the passengers could not see the driver, but the driver could still see the outside of the vehicle through the front screen, the side mirrors, and the rear-view mirror, enabling the driver to drive safely. The hidden taxi-driver had access to the driving schedule and all relevant information regarding the rides. During the rides a navigation tool with earplugs supported the driver. For recording, a video camera was placed in the front of the car to record the passengers' behavior.

(D) Further, the robo-taxi-passenger communication needed to be supported for the duration of the rides to address unexpected demands or spontaneous wishes, and address unexpected events. The most efficient way to support the communication between the passenger and the robo-taxi was to simulate voice interaction. To open the conversation, the passengers were

introduced to use the 'wake word' *taxi*, similar to Amazon Echo or Google. The driver was to answer in the way one might expect from such a service.

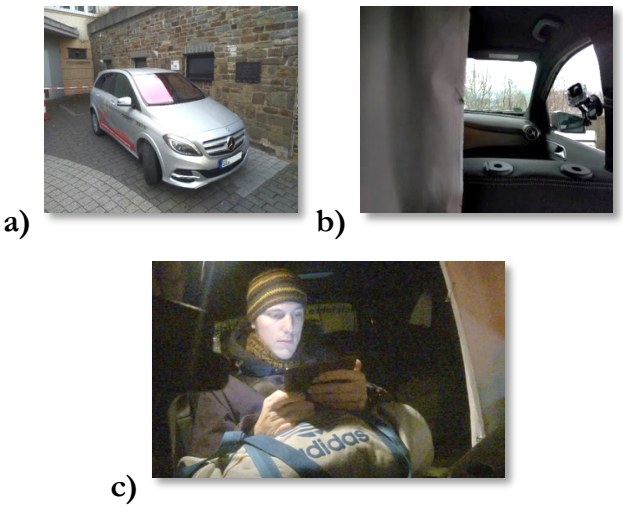


**Figure 5: Inside and outside of the WoZ: a) outside of the car at the charging station; b) view from the backseat showing the camera position and the curtain; c) view from the camera on one participant sitting at the backseat.**

We instructed all participants before the start of the trial that they could individually order and reserve the robo-taxi service for their own purposes and needs, as long as the service was available. We also informed them about the above-mentioned restrictions on availability (e.g. due to the 'office hours' or when the service is occupied), the hailing process, and how to use the simulated voice interaction with the robo-taxi. Subsequently, the participants were informed about the research process, including the present driver of the car, who should be ignored as much as possible by the participants. Hence, even given that the driver was hidden as much as possible, there were some situations where the driver became visible or hearable by the participants. This happened when getting in and out of the taxi or when hearing the voice of the driver during the voice-interaction. Further, all participants were informed about the purposes of the study and that all rides were free.

Overall, 10 participants were invited to use the robo-taxi service for one week (see Table 6). The recruitment was done using local organizations that were related to activities such as sports, computer clubs, a local citizen's forum and personal acquaintance. We paid attention to acquiring a broad spread across gender, age, type of household, lifestyle and preferred means of transport. For practical reasons, however, we offered the service only in one city, and therefore recruited only participants from this city. All participants were genuinely interested in the topic

and open-minded enough to try out the new service. The participation was voluntary and they were not offered any financial reward, other than free rides.

**Table 6: Overview of participants: PT = public transport**

| No. | age | gender | household | Life-style | Mobility |
|---|---|---|---|---|---|
| **P1** | 25 | female | Shared flat | Student | Walking, PT |
| **P2** | 33 | Male | Living as a couple | Working | Walking, Car |
| **P3** | 37 | Male | Living in a family | Working | Car, Carpooling |
| **P4** | 64 | Female | Single flat | Retired | PT, walking |
| **P5** | 80 | Male | Single flat | Retired | Bicycle, car |
| **P6** | 63 | Female | Living as a couple | Working | Car |
| **P7** | 26 | Female | Single flat | Studying | Walking, PT |
| **P8** | 30 | Male | Living in a family | Working | Car, PT |
| **P9** | 22 | Female | Shared flat | Studying | Walking, PT |
| **P10** | 72 | Male | Living as a couple | Retired | Car, taxi |

## 7.7 Data collection and analyses

The data material is assembled from (1) the pre-interviews; (2) the documentation of the participants' interaction with the robo-taxi; and (3) the post-interviews.

(1) The pre-interviews were conducted with all 10 participants before the trial started. The intention was to gain an initial understanding of the participants' everyday mobility habits and their individual expectations towards the robo-taxi service. The guideline included questions about daily mobility routines and the preferred means of transportation. The participants were further asked about their attitude towards autonomous driving, and their expectations as to how they might feel during their first ride in a robo-taxi. The interviews were semi-structured, but questions were extended individually to sharpen the participant's profile or to discuss interesting aspects in more detail. Each interview took about one hour.

(2) The participants' interactions with the robo-taxi were all video recorded, resulting in 33 videos. The recording was done in picture and audio with a small camera that was placed at the front-seat passenger's window (cf. Figure 5). This ensured the capture of the participants' activities at the back-seat, their facial expressions and their voice interactions during the rides. Further, we asked the passengers to fill out a short survey about their experiences after each ride. In addition, all rides and observation notes made by the driver were documented on the timetable.

(3) The post-interviews were also semi-structured. They focused on the service and related experiences. The guideline included questions about the context of use and the reasons for ordering the service. Furthermore, the participants were asked to compare their expectations before the study took place with their actual user experiences. We also asked them to describe positive and negative experience with reference to specific situations that occurred. Other questions included, for example, how to improve the in-car experience and, if necessary, how to support the customer service during the ride. Both interviews before and after the field study were fully transcribed.

The analyzing process included data material of all three data sources (1-3) and followed a reconstructive, documentary approach (Bohnsack 2014). We started the process by selecting certain cases that described the experiences of robo-taxi interactions that were mentioned during the rides or in the interviews. Thereafter, we focused on various details that were described, such as expectations, uncertainties, challenges and suggestions. The analyzing process itself was carried out in three steps: First of all, sections were selected in which the participants described their experiences and the subjective relevancies. These sections were examined concerning 'what' was said and they were then thematically annotated. In the second step, we reconstruct the frame in which a topic was dealt with. At this point, the focus was no longer on 'what' but rather on 'how' the participants talked about a particular experience. Finally, the different experiences were compared and contrasted in order to uncover common themes. In the end, we arrived with certain main themes, which are presented below. For the purpose of better readability, the statements used below were shortened from time to time (marked with '[…]'). Since the interviews were originally conducted in German, the quotes are translations into English.

## 7.8 Findings

The robo-taxi service was used 33 times in total. Participants used the service on average three times during the week, with once being the least use (by P7) and five times the most (by P5). The shortest distance was about 1.5 kilometres, while the longest amounted to 15.5 kilometres. The journey time varied from about 7 min up to 27 minutes. The rides involved quite heterogeneous environments ranging from urban traffic to more rural roads and the motorway. Nine rides were conducted in pairs. Further, the robo-taxi was mostly ordered in situations where using a car over a bus was thought to be an advantage, such as returning from the supermarket

with full bags, visiting places that are not easily reachable with public transportation or for evening events, when a taxi driver would be more convenient.

### 7.8.1 Awareness about routes and stops

We identified several situations where awareness about routes and stops became highly relevant for the passengers, sometimes prompting intervention.

In that regard, some participants called us before a planned ride and asked questions, such as: *"Can I bring a friend"* (P 1), *"Can we make an extra stop?"* (P9) and many others.

During the hailing-phase, we noticed that a mobility guarantee for the return was sometimes crucial for the first order placement, as was mentioned by P6 in her post-interview:

> *„This affected those trips that included events where I really depended on it for getting back, too. For instance, I had wanted to book a ride to get to my choir, but that's in [Name of a place] [10 kilometres from her home]. If the taxi doesn't pick me up, I'm screwed. […] That was too big a risk." (P6)*

Regarding the pick-up place, the activities of the taxi and the passengers needed to be coordinated, as P8 noticed in the post-interviews:

> *"How can I know which car was the right one, I had no clue. I stood there and I was like oh gosh, at [my] street passes a car every three seconds. […] I'm still wondering today how does Uber do it? Ten million people, three million Uber-drivers." (P8)*

The lack of information about where to find the correct car caused a moment of insecurity for P8. This was particularly problematic in crowded places with many cars, or when the local parking opportunity was limited. Such situations were often only solved by additional communication. In the reported case by P8, a call by the driver was necessitated. Another case is reported by P1:

> *"[PB7] and I […] waited right up front, cause we thought, well, our taxi surely comes from this direction, since only official taxis and buses are allowed to pass there and that's why didn't we didn't see it […]. So, I texted [Name of one of the researchers] […] so, we figured it out. But I, well, it's pretty hard to find the car at such places. When a lot is going on, many cars and stuff, you have no idea where to wait." (P1)*

During the rides, we noticed that, for most participants, awareness about the actual route was important for them to relax and feel comfortable. In that regard P9's first ride experience was instructive, for instance. She felt uncertain as to whether the vehicle would indeed take her to the desired destination and checked the potential route on Google Maps in order to check the route against what she expected. This initial distrust could have been avoided, if the vehicle had provided an overview of the route to the participants.

> *"In the beginning, I was curious and inspected the interior, there was this basket with sweets, pretty nice [laughs]. Then I looked out of the windows to figure out where we were going since we took a route, I didn't know yet. So, I checked it [on Google Maps] to make sure that the car takes the same route as shown on the map. Then I unwound pretty soon. I arranged some stuff for my pending ride with [Name of long-distance bus] and wrote a few messages, made a to-do list, you know. Actually, I was pretty calm during the ride, you could read and stuff. That was lovely." (P9)*

In the pre-study interview P9 had described herself as a mainly skeptical person and dismissed the idea of relinquishing the operational control to an AV completely. She showed some signs of distrust at the beginning of the ride, because the robo-taxi took her via an unusual route. However, after she was sure that the taxi was on track, she reported that she relaxed and focused on non-driving related activities.

Similar situations occurred with different participants. Many reported in the post-interviews that they checked the route of the robo-taxi during rides. P5 even corrected the robo-taxi twice during a ride, because he knew a better route than the one that the robo-taxi aimed to take. Normally, of course, taxi drivers ask passengers whether they have a preferred route, and this response to or anticipation of preferences is something that needs to be addressed in an interaction design.

In another example P6 suggested that it would be nice to know the likely arrival time, the traffic situation, and so on in order to adjust travel plans accordingly:

> *"Let's say I'm in an unfamiliar environment and the car stands in a traffic jam, then it'd be nice to know where am I right now? Do I have the opportunity to change and take another transport mode that brings me faster to my destination?" (P6)*

As she pointed out, it could make sense to change the means of transport under certain circumstances such as traffic jams. Other transportation modes could be more suitable in changing circumstances but support for such multimodal mobility chains would need clear communication of alternative affordances.

Finally, the drop-off situation entailed some insecurities, too. In that regard P3, P4 and P9 claimed that they missed more detailed information about where exactly the taxi would stop, since it is common for passengers in a normal taxi to ask to be dropped at specific points. Thus, it did seem that the kinds of information typically provided by modern navigation tools are, overall, seen as useful for passengers.

### 7.8.2 Passenger-robo-taxi interaction

We identified several examples where the participants felt insecure about how to interact with the robo-taxi. The basal need of an interaction mode became obvious in an example with P5 who greeted the robo-taxi whenever he opens the door with *„Hello car!"*. He also said goodbye whenever he left the car (*"Goodbye car!"*). Although, that was not a common behavior among the participants, it signaled the need to frame the interaction with the robo-taxi with a clear starting point and a concrete ending.

The insecurities in the robo-taxi interaction also became visible in the way the passengers handled their luggage and bags. Passengers placed their luggage and bags always either on their knees (as it can be seen with P2 in Figure 5), or on the back-seats, but nobody used the luggage compartment. For instance, P10 asked during the drop-off *"how much time do I have to get out?"*, while he was struggling to sort out the shopping materials he had left in the back seat and which had fallen over. Another example is given by P3, who transported a crate of beer to a party and back. During both rides his friend occupied the seat next to him, so he placed the crate on his knees during both journeys. In the after-interview he explained the situation and stated that he felt more "*secure*" with the crate beer on his knees, because he *"did not know how to tell the vehicle 'please hold on, I want to pack something into the luggage compartment'"*. In the case of a real taxi, such insecurities are not the norm, because the driver probably would have identified a need and likely would have assisted.

Further, we observed a bunch of examples in where the passenger wanted to make spontaneous changes from the original route. For instance, P1 stated in the post-interview that she did not

know how to communicate to the car that she wanted to make an intermediate stop to catch up with her friend. She claimed that she felt nervous, and did not know if her request would be acted upon. She also felt *"anxious"* how long the robo-taxi would wait till her friend got in.

Some participants started to talk very intuitively to the car. In that regard, P7 suggested that it would be nice if the robo-taxi would have greeted her:

> *"Or [...] something like 'Hello, welcome to the mobility service. The ride from there to here, Is that correct?'" (P7)*

She suggested that such a form of interaction probably would have implied a change in her perception. Instead of sitting silently in the robo-taxi, waiting uncertainly for the robo-taxi to start, she would then have a fixed, clear starting point for the journey ahead. Moreover, she stated that she would have liked to confirm her destination when sitting in the taxi to reduce concerns about whether the destination and route are actually what both the car and the passenger understand.

It is also not unusual for human taxi drivers to ask which route is preferred, in particular when there are different possibilities. All in all, P7 reckoned that such bits of conversation might be enough to build some kind of rapport. She further suggested:

> *"Maybe asking first how you are [...] 'Do you want some music?' […] But I'd find too many questions annoying, too; or it could say 'We'll arrive very soon' […] maybe in the end it could say 'take all your belongings with you' [laughs]." (P7)*

While such a proactive behavior is sometimes appreciated by the passenger, the frequency of inquiries and other interactions needs to be carefully managed so as to avoid irritations. The simplest and most obvious way of doing this is to ensure that, other than greetings, interactions are limited to a question/answer format.

### 7.8.3 Media usage

In the following section, we elaborate in more detail the preferred media formats of the participants and outline their strategies for managing space and time during their rides. In the post-interviews we received the general feedback that the participants enjoyed the private, calm and relaxed atmosphere in the robot-taxi. However, many participants requested better equipment in the car that could support them in their activities. Some of the participants (P1, P2, P3, and

P8) suggested additional screens that could display navigational information or could be used for entertainment and work-related activities.

Most often, participants demanded access to entertainment, like listening to music, radio and podcasts, or watching a movie. In fact, missing options for entertainment were requested for nearly every second ride in the feedback sheets. Many asked, if it would be possible to connect with their streaming providers like Spotify or Netflix to have access to their personal music. During one drive P1 and P7 claimed that *"Ocean was missed"*. When we asked them about that comment in the post-interview, P1 revealed a personal insight on a certain driving habit that she used to have with P7. She said:

> *"That's a trance song and me and [P7], we always listen to it as soon as we get into my car." (P1)*

Thus, they missed that song when driving around in the robo-taxi.

However, during the rides we observed a lot of different activities beyond media consumption, such as sleeping, eating, working, writing emails or doing phone calls took place. (P3) described her activities during her rides as a mix of different activities:

> *"Well, to be on my own was quite boring, because there was no music […] That's why I was just busy with anything […] checking e-mails on my mobile and surfing around and writing to anyone." (P7)*

It is noticeable that many participants described the experience within the robo-taxi as different from an ordinary taxi ride, because of the particular feeling of privacy engendered, sometimes shading into feelings of isolation. This was for instance stated by P8:

> *"You rather feel like you're on your own, I'd say privacy in every case. [Advantages:] For example business call, ehm phone calls in general. You may feel less inhibited […] probably it's also a matter of one's own feelings, one feels less observed." (P8)*

Other participants confirmed P8's feeling of being in their private sphere. For instance, P1 mentioned that she felt like she could talk openly with her companion since no taxi driver was listening. As many participants used the robo-taxi service in pairs, their conversations sometimes also included quite personal topics. In that regard P1 and P7 joked that it would be easier to make out in a robo-taxi than in a traditional one with a taxi driver. Thus, the apparent absence of a driver opened up a space for a degree of social intimacy. Participants otherwise

commented on the occasions where a degree of social awkwardness was present with a taxi driver, sometimes because drivers talked rather more than was wanted or, on occasions, played loud music. While in regular taxis the driver is the one who usually determines the media content in the car, the passenger in the robo-taxi can choose their preferred content, much like a passenger in a train or airplane. P9 even explained that some of her female friends are afraid to take a taxi at night at all. For her the driverless taxi feels safer.

### 7.8.4 Adjusting routes and stops

In the study we observed many contingencies that challenged the robo-taxi service. These examples showed that the robo-taxi service needs to react flexibly on passengers' requests and needs to better cope with unexpected travel situations.

That need was e.g. stated in an example with P5, who ordered the robo-taxi to go from his home to the supermarket and to return again afterward. The vehicle was close to the supermarket, when P5 asked for a different route be taken, because, as he said, he knew a shorter way. Where drivers in control of their vehicles can, of course, alter their routes on the go, this remains an open question for robo-taxis, as to whether passengers should be able to alter planned routes during a ride.

The case described, implied that the passenger may have habitual routes, which they, as P5 does, might favor over the one selected by the robo-taxi. Anyhow, it is not possible to draw conclusions on how important this specific issue is to them and how often it will occur. During P5's visit to the supermarket, the robo-taxi awaited his return, which took less than five minutes. However, there are no regulations covering what waiting times are acceptable and expectable:

> *"If the taxi shall wait after the ride and return directly... should we say it at the end of the ride or book it and hope it gets us or reserve it?" (P1)*

P1 raised the question of how a passenger could communicate the wish that the robo-taxi should wait. On the way back from the supermarket, P5 had an unexpected request. He asked the robo-taxi to follow a circuitous route to withdraw money from his bank account. This would not have been possible, if the robo-taxi had not accommodated the participant's request spontaneously. P5 was not the only participant with such requests. P10 had a similar experience. During the study, he was preparing to move apartment. He had booked a ride to his

former apartment, but decided spontaneously otherwise, when he got into the vehicle and asked to go to his new apartment to arrange some things. This shows that people are generally used, when driving themselves or using a taxi, to being able to go whenever they want, wherever they want. They demand similar levels of flexibility from the robo-taxi.

> *"What if I want to pick somebody up on my way? So, I'm wondering if my route planning has to be so complicated that it'd be easier to drive on your own." (P1)*

The interaction patterns of the passenger with the robo-taxi, we suggest, should include the option to let the user change the destinations "on-demand" too.

In another instance, P2 ordered the robo-taxi service to go to a sports field to play soccer. Unfortunately, there was a problem, because said sports field had no house number. Therefore, he put in a house number of a private house that was the closest to his destination. When the taxi arrived at the location, P2 explained to the robo-taxi where the actual destination was.

Participants also addressed also different scenarios regarding in which the passenger and the car would need to communicate.

> *"The first time I took the [robot] taxi, my coat's belt got stuck in the door and it hung out [laughs]. Then I laughed a lot and told P7: 'Oh shit, now my coat gets some fresh air.' […] Anyway, the driver reacted and stopped." (P1)*

P1's story showed that some unexpected situations might occur where the car needed to react appropriately. In her case, she just needed the car to stop momentarily.

### 7.8.5 Dealing with emergency situations

No accidents occurred at all. In fact, the large majority of all rides passed without any critical incident. P1 and P7 did, however, had one rather negative experience during one of their rides. On the way to an animal park, the robo-taxi overtook a bicyclist at a roundabout without much room:

> *"I only noticed something, cause the car pulled a bit aside and a bicyclist started swearing. […] If you're not driving by yourself, you're not really attentive and if something happens all a sudden, you don't really have an overview. 'Okay, so what's the matter?'. And if you're obligated to act right…. That's difficult… I'd say. Sure, you can make an emergency call, but anyway, you probably have to get out of the car and figure out what just happened." (P1)*

Since the passengers were not responsible for driving they noted the incident only incidentally. Nevertheless, participants felt responsible in some way and reflected on what the circumstances would like in the event of, for instance, an accident. Participants were unclear about whether they were merely bystanders or were somehow involved.

P2 was the participant who seemed most enthusiastic about AV in the pre-study interview. Nevertheless, he mentioned in the post-interview a situation in which he had reservations, when he heard a siren:

> *"Sirens of a fire engine truck. I was unsure, if the car would drive to one side." (P2)*

Whether, for him, the vehicle reacted in ways which were appropriate very much depended on circumstance, and circumstances of this kind are largely unanticipated by our participants. Apart from this incident, P2's general impression confirmed the positive attitude expressed prior to his rides.

> *"I felt happily excited. I thought, nice, let's see how it goes, alone regarding the electric car arriving that silently […]. I was wondering, no manual gearshift, what about the acceleration? […] Actually, I didn't really think about that autonomous driving situation. […] It probably worked that well. […] So, when I sat there, I wasn't like oh please, let it work. Rather like yup it runs, now you're inside, just a sec and you'll arrive." (P2)*

P1 also remarked in relation to safety:

> *"I couldn't tell what the car would have to communicate if something serious happens. Let's say I recognized an accident and it made an emergency call automatically or so, no clue!" (P1)*

In fact, if necessary and desired the vehicle could also provide an instruction on how to give first aid.

## 7.9 Discussion

Our WOZ study about the everyday usage of a robo-taxi revealed a fuller picture of passengers' experiences with the service at the different stages of hailing, pick-up, traveling and drop-off. In particular, the study gave insights into four design themes that are not typically addressed in literature so far. The first theme addressed short-term domestication, the second theme relates to the active passenger, the third refers to the passenger experience of the journey, and the fourth theme deals with breakdowns.

### 7.9.1 Short-term domestification

There are various scenarios in the literature discussing whether robo-taxis make the concept of ownership obsolete in future mobilities (Pakusch, Bossauer, Shakoor, et al. 2016). Our study drew attention to the fact that the concept of ownership in SAV services must be thought differently. Instead of owning a car for a long period of time, using a robo-taxi means to own a shared space for a short period of time.

By making use of the robo-taxi within a short amount of time, we labeled this first category '*short-term domestication*'. It highlights the desire of the participants to appropriate the space of the robo-taxi during their (short) travel time. Silverstone and Haddon (Silverstone and Haddon 1996) described domestication as the process, where households and individuals adapt and adopt pre-formed technology to invest them with their own significance. This concept was also taken up in urban sociology to analyze the appropriation of public spaces. Deinet (Deinet 2014), for example, described the appropriation of McDonalds as a social space by young people.

Pfleging et al. (2016), for instance, pinpointed that future cars must be designed as places involving more than driving. In a similar vein Stevens et al. (2019) uncovered in co-design sessions that people envision personalized AVs that should feel something like a second home. They explored preferences for using personal space in the light of activities preferred in AVs, like sleeping, drinking coffee, etc. Our study showed that the robo-taxi participants mentioned quite similar activities such as listening to music, podcasts, and radio, or watching movies. Others wrote emails, telephoned and wished for better support to work, while some would prefer to relax in a comfortable position. There was also a great desire to feel unobserved in a save, private space, where privacy and safety were judged as highly important features. In order to support the various in-car activities, different approaches might be adopted, such as providing entertainment equipment, as well as streaming services like Netflix or Spotify. Working activities can also be supported with fold-out tables and seats to lean back comfortably. In contrast to private cars, a robo-taxi presents a private space only temporarily. Equipment must be quickly to prepare and put back, so it can be used by others afterwards. Future study could explore in more detail how a fast and a temporary limited domestication of a robo-taxi could be supported. The using of shared spaces privately also demands new privacy concepts.

Further, the absence of the driver promotes the impression that one is unobserved. In particular, our study showed that participants quickly forget that they are observed through the camera. However, this should not be exploited. On the contrary, creating a private atmosphere in robo-taxis demands a respectful handling of the passengers' personal data. As Gowda et al. (2014) mentioned, there might be some design trade-offs for data privacy. On the one hand the passengers might be interested in some permanent settings, such as the right alignment for the most comfortable seating, playing the user's preferred music automatically, or preferred settings for the voice interaction. On the other hand, sensitive data should be kept private. How different privacy and security concepts are to be appropriated in such settings requires further study.

### 7.9.2 The active passenger

A dystopic picture is often drawn, suggesting that, through autonomous driving, humans degenerate into passive passengers who can only be served (Meschtscherjakov et al. 2015; Kun, Boll, and Schmidt 2016a; Riener, Boll, and Kun 2016; Lorsignol 2016). Such a view mainly focused on what is lost, such as driving pleasure, the loss of control, or the loss of driving competency. This view, however, neglects those competencies that are needed as a passenger. So, instead of focusing on the passive passenger, we observed what can be labeled the *'active passenger'*.

Hence, we should focus more on the benefits that result from relief from the driving task. This foregrounds themes, such as designing for comfort and non-driving related activities. Also, in our study many participants appreciated the doing of non-driving related tasks and experienced being a passenger as a potential stress reducer. As we have seen, they also enjoyed their free time.

However, although the passengers enjoyed their 'free' time, the study made us aware of the 'work' passengers needed to carry out, such as preparing the robo-taxi as a private place, and putting it back to its original state. Moreover, we found that the passengers undertook a quite active role in being controllers of the robo-taxi, and frequently checked the performance of the robo-taxi.

Passengers on trains or buses sometimes need reassurance that their expectations are met. Buses and trains offer e.g. monitors and voice support to announce the next exit. Furthermore,

mobile applications offer more detailed information about the journey that also allow checking of real-time data. This makes it easier for the travelers to feel 'in control', ensuring one is still on the right track and on time. This need was also often mentioned by our participants.

However, in contrast to buses, trains, as well as autonomous shuttle services, robo-taxis do not operate on fixed tracks. This makes life easier for passengers as routes do not need to be controlled at each stop. The freedom to ride with the taxi wherever you want creates new possibilities, but also new needs for interaction. During our study, for instance, situations occurred where passengers wanted to modify and adjust the route in emergent ways, such as waiting for a friend who sought a lift, or the need to return because keys have been left behind. Further, we noticed that the participants wanted to be informed about the traffic situation and delays as well as about precarious or unsafe situations.

Designing passenger-centric information systems should take these needs into account. In addition, as Pakusch et al. (2016) have already pointed out, SAV services could foster intermodal mobility. Hence, information systems should bear this in mind supporting passengers to switch between different mobility modes almost seamlessly. In this way, there are opportunities for robo-taxi services to work as a supplement to long-distance train rides, supporting the 'last-mile' and taking its passengers seamlessly from the train station to the final destination.

### 7.9.3 Passenger experience journey

A customer journey illustrates the steps (also called touchpoints) the customer goes through in engaging with a service (Richardson 2010). The aim of the customer journey design should be to ensure a coherent and consistent customer experience across all touchpoints (Nenonen et al. 2008). With regard to the passenger experience of the journey using a robo-taxi service, we identify in our study four key touchpoints where a coherent and consistent interaction design must be ensured: *hailing, pick-up, traveling and drop-off*.

All touchpoints have different focal points regarding the right media choices. Hence, while the smartphone is probably an appropriate way to do the hailing, the pick-up and drop-off need to involve the connectivity of the car, too. In our study, the question was often asked, how can the right car be identified. Uber, e.g. also worked on this question and chose an identification by color-coding on the mobile app and the car (Perkins, Chris 2015).

For the hailing it is unclear yet if the planning is more comfortable when the participants insert a concrete address or book the service for a certain amount of time, to keep the highest amount of flexibility. During the traveling, different interaction channels were suggested by the participants. To have the relevant information about the journey ready at hand, an integrated screen could be a useful device. Further, the participants could use it as their entertainment system or use it as a second screen for the smartphone or computer. Therefore, support for connectivity between the screen and the users' personal media devices is worth investigating.

For better support during the pick-up and the drop-off many participants requested voice interaction. Also, Ramm et al. (2014) argued that the interaction with the car via voice feels the most natural and intuitive for passengers. They argued that voice interaction could be particularly important for passengers who are less technically experienced, since voice is a natural communication method. They found that 'wake words' like 'Alexa' for Amazon Echo, or 'Ok Google' for an Android device could be an option to avoid too much interference with the vehicle, an observation supported in this study. However, the AV does not always need to respond by voice, it also can respond to action, such as manipulating something on an integrated screen. Further, Sirkin et al. (2016) explored the dialog between the driver and the speech-based robot vehicle interfaces to improve the navigation and other driving-related tasks. However, still further research in relation to voice interfaces in robo-taxis and the contingencies which occasion it.

Hence, the findings showed the importance of supporting consistency over the different stages, as well as a better support for coherence between the different media formats that are engaged. Until now, we still know very little about how the different interaction systems based on the personal mobile application, the voice interaction, screens and connected car IoT could be integrated in the best possible way and how best to support the different stages of a robo-taxi drive in an optimal way.

### 7.9.4 Dealing with breakdowns

Fortunately, there was no car breakdown or accident during the test phase. For this reason, however, we could not investigate how passengers behave in such situations. In the past, some studies have investigated how drivers perform while presented with information on automation

uncertainty and failure (Koo et al. 2015). However, these studies focus on drivers not passengers. In comparison, further research is needed to explore which information would be helpful for robo-taxi passengers in case of emergencies such as accidents or technical breakdowns. After all, taxi and Uber drivers seek to engage their passengers, too. Explaining and reasoning actions could be an important factor in the design of a better driving experience.

## 7.10 Conclusion

In this paper we asked the question, how do passengers experience robo-taxis in real-life situations?, to inform the interaction design of such services. Therefore, we conducted a WoZ study where 10 participants had the opportunity to use the simulated SAV service during a one-week period. The findings gave a rich picture about the different stages of hailing, pick-up, travel, and drop-off in real-life situations. Further, we developed four design themes out of the findings to inform the interaction design in robo-taxis. These motivate to design for short-term domestication, for the active passenger, for the passenger experience journey, and the right way of dealing with breakdowns. As we have outlined in the discussion, these themes can inform future works in HCI on robo-taxis.

A limiting issue of this study is that the participants could use the service for free, though it would have been more realistic if they had to pay for it. However, payment had been considered beforehand, but was rejected, since it would have left the number of rides more uncertain. Further, findings were influenced by the fact that participants knew all the time that a human was driving and that they were actually not alone in the car. This had in some cases a trust building effect on the driving and safety experiences of some participants, as they reported on in the interviews. There is also an unknown difference between the communication with a 'real' robo-taxi and the communication with the WoZ. We reflected on that difference directly in the findings and the discussion section.

It is important to mention that the goal of designing SAV services that are as user-friendly as possible inevitably raise questions about their influence on adoption and changes in user behavior. If robo-taxi services are designed to meet the needs of users for comfort and affordability, there is a risk of rebound effects in the form of an increased consumption of individual mobility instead of public transportation. Therefore, the design of SAVs should always be part of a holistic sustainable traffic concept.

# 8 Bridging Location-based Data with Mobile Practices – Introducing a Framework for Mobile User-Studies

**Abstract**

Increasingly, mobile services are using location-based information provided by GPS sensors. Especially HCI research deals with a growing interest in how people make sense of location-based information while on the move. Mobile user-studies can help to address this black box and provide the opportunity to combine location-based data with context related content of the mobile practices being performed. In this study, we address this relationship and ask how spatial information should be visualized in order to explore mobile contexts. We conducted a qualitative study to learn about the usage and interpretation forms of spatial information and further translated these findings into a basic framework for mobile user-studies, concluding with an evaluation.

## 8.1 Introduction

Nowadays, mobile phones accompany most of us every day and everywhere we go. They have opened up new possibilities for the investigation of human behavior (Vergunst 2011). In particular, mobile, intelligent, and GPS-enabled smartphones allow for and demand an integrated view of location-based information and the mobile contexts in which the particular mobile practices are performed (Hasan, Zhan, and Ukkusuri 2013; Kracheel et al. 2013). HCI research has is greatly interested in how people make sense of location-based information while on the move. Currently, more and more mobile user-studies are being conducted to answer this question e.g., (Jon Froehlich et al. 2007; Meurer, Stein, and Wulf 2014). However, the relationship between spatial information and mobile practices is still underexplored.

In order to shed light on this question, we ask in this paper how spatial information and mobile practices (and their relationship) should be addressed in order to support mobile user-studies in an appropriate manner. The challenge herein is to map the geo-location data (referring to time, longitude and latitude) with the cultural and meaningful dimension of space to inform a framework for mobile user-studies. To do so, we conducted a context study with 19 users who allowed us to track their movements over three weeks. At a later date, we provided them with

GPS-based paths of their own movements, which enable them to follow their movements on a map over the time. This alienated mobility data triggered narrations about mobility, i.e. the users were encouraged to report freely about the mobile contexts they identified. These mobility narrations allowed insights into how spatial information was used, referenced and interpreted when reporting on mobile practices. In particular, we discovered three main requirements from the interviews to inform mobile user-studies: (1) the visualization of movements, (2) the visualization of paths and places and (3) the integration of interpretation spaces. We continued by building a framework for mobile user-studies around these identified findings. We then evaluated the framework and concluded with a discussion regarding future enhancements.

## 8.2 State of the Art

In the following, we introduce current tools for mobile user-studies that can be clustered into three groups: (1) *experience-based studies*, (2) *location-based studies*, and (3) *integrated studies*. We will discuss the current approaches with regard to their ability to explore how people use location-based information, and state the necessity for a framework that allows this question to be addressed.

### 8.2.1 User-Studies in the mobile contexts

Fostered by the rapid dissemination of mobile devices and their ever-increasing role in our everyday lives, the field of HCI has yielded new approaches to capture people's behavior and actions with regard to location-based data by observing the use of mobile devices.

#### Experience-based studies

Early on (mobile) diary studies (Bolger, Davis, and Rafaeli 2003), as well as the experience sampling method (Consolvo and Walker 2003) were viewed as appropriate methods for capturing users' behavior directly in a specific situation (Kahneman et al. 2004). Both facilitate user-driven reporting of one's own behavior in mobile contexts. In diary studies, users– based on previous instructions by the researchers – decide when and which information is worth reporting. Forms of voice-based diaries or photo-based diaries (B. A. T. Brown, Sellen, and O'Hara 2000) as well as combined methods have been designed for specific mobile contexts

(Dörner, Heß, and Pipek 2008). In all these studies, the diary entries have to be reported manually (Church and Smyth 2008). Brandt et al. (2007a) present variations called snippets, which are short diary notes recorded in specific situations and which allow the users to complete the entry later. These traditional paper-based diary studies include fields for writing down the location of an activity and are comparable to the experience sampling method, the main difference being that in experience sampling, participants are given a signal at a specific time to report details about his/her current situation. One Shortcoming of both diary studies and experience sampling is the effort needed to document the relevant data. Further location-data is not systematically addressed as a basis for interpretation, and as a result users lack proper support to reflect on locations (Liu, Liu, and Wang 2010; Kracheel et al. 2013).

### Location-based studies

Beside these more qualitative approaches, quantitative logging approaches are being used increasingly to gather detailed information on mobile behavior. Life-logging is one such approach which aims to record user behavior automatically via "the continuous capturing of personal data, such as photos from one's field-of-view, location, audio, biometric signals and others, with the aim of supporting the later recall and reflection on one's life events and experiences" (Gouveia and Karapanos 2013). Data logging in general means that usage data, which would otherwise be very hard and time-consuming to capture, is automatically collected by a device with no user interaction whatsoever (Jon Froehlich et al. 2007). Due to the fact that mobile devices have become highly personalized tools for virtually everyone, they are more or less present and on hand at any time and place (Fortunati 2005). Mobile-data logging therefore represents a significant part of life-logging, allowing users' spatial footprints to be traced. Hence these services do not offer the integration of the user's-perspective.

### Integrated studies

Further, approaches that combine experience-based studies with automatic data logging are coming increasingly into existence. The current stance of literature is dominated by a space-related understanding of mobility (Hjorth 2013). One characteristic of this research stream is strong sensor orientation which allows mobility patterns, like routines and mobility modes to be discovered (Kose, Incel, and Ersoy 2012), thus enabling mobility systems to be improved (Raubal et al. 2007), or sustainable mobility behavior to be fostered (Lathia and Capra 2011;

Broll et al. 2012). One example is given by driver logbooks that allow drivers to report information about certain journeys Meschtscherjakov et al. and Kracheel et al. (2011; 2013), or Froehlich et al.'s (2007) system that combines the logging of phone data with mobile experience sampling by triggering surveys at specific moments of interest. They show that the acceptance of such a mobile system in everyday life requires both robust performance and non-intrusive data collection. Liu et al. (2010) argue that such mixed methods are required to gather appropriate information about users' behavior. A major challenge of this research line is identifying encounters for temporal and spatial mobility patterns (Kostakos et al. 2010), and interpreting this data as forms of mobility activities. This can be addressed by using location-based data collected from social media applications (e.g. Foursquare or Twitter) (Hasan, Zhan, and Ukkusuri 2013), or mixed-method research using questionnaires, surveys or interviews that aim to describe the purpose of the activities, the means of transportation and personal details (Christensen et al. 2011; Jones, Drury, and McBeath 2011). However, these complex frameworks do not look in detail at how location-based data is actually interpreted by users in particular mobility contexts.

### 8.2.2 Motivating a framework for mobile user-studies

We showed that researchers can benefit from the new options to capture, track, simulate, mimic and shadow the many interdependent forms of people's intermittent movement (Sheller and Urry 2003). Hence, we do not move in an empty space but through streets and places. We go home, to work, to a restaurant, visit a friend or the sports club. Often, we have a special preference within the selected transport mode, the company we choose for our journeys, types of coordination, or the selected route. In order to focus on such issues, we cannot refer to locations as being stated only objectively. Moreover, we have to ask how users can be supported in interpreting spatial data to re-construct the specific meanings of places that influence our movements and daily mobility (Meurer, Stein, and Wulf 2014). Hence, mobile user-studies should not only take the objective spatial dimension into account but should also support the user in an appropriate manner to reflect on the actual mobility (Harrison and Dourish 1996; Cici et al. 2014). Yet there is very little going on in terms of trying to understand the role of real world context in relation to understanding, building or evaluating interactive mobile user-systems (Kjeldskov and Paay 2012; Meurer et al. 2014). This leads us to the challenge of finding

new ways to support people with their mobile phones to not only track spaces, but to allow the users to remember and interpret concrete mobility situations.

## 8.3 Context Study

In the following, we introduce the study conducted in order to discover how users make use of and interpret spatial data.

### 8.3.1 Method

We conducted an empirical study with 19 users. The user group was selected from a wider project, aimed at assisting elderly people with modern mobility support systems. The initial contact with participants was made through various local organizations for senior citizens. We selected a heterogeneous group of socially active seniors (N=19, 14 female and 5 male), in relation to age (between 57 and 80 years old, and an average of 69 years), local infrastructure (10 in high density areas and 9 in more low-density areas), and also in relation to the transport systems typically used. The idea behind this selection was to obtain a wide spectrum of mobility experiences. We worked with the seniors in a participatory design-orientated Living Lab setting (Meurer, Stein, and Wulf 2014). We provided all users with a modern smartphone and guided them in its usage. In regular schooling sessions that took place weekly over a period of about two years, the users improved their technological skills and increased their knowledge of mobile mobility services. Hence, although we were dealing with older adults, at the time of investigation all interviewees were skilled in handling mobility-related application services.

Mobility narrations were conducted in an interview-like manner with each of the 19 users. We asked them to interpret the prepared maps with the outlined GPS tracking data of their movements over the last two weeks. We provided all users with a Google account, which allows us to obtain GPS data produced by the participant's mobile phones in order to track their movements. Mobile behavior was recorded automatically by the Google service Location History. During the trial, the participants led their daily lives routinely while the GPS mobile sensor was constantly tracking their outdoor movements. After two weeks of tracking we re-visited each participant and prepared the collected data for presentation. We used both paper-based as well as computer-based representations of the tracked mobility behavior as shown in Figure 6. The

picture shows the data of one day, as provided by the Google service. The digital version enables users to check the detailed travel times on demand and to zoom the map in and out. These forms of presentation provided information about the spatial movements in units of space and time gained from the mobile GPS sensors. With these representations, we triggered mobility narrations that led us back to elementary travel stories. These stories provided insights into how people read and make sense of their personal location-based data.


**Figure 6: Material provided to the users**

Our study was conducted in a region in western Germany which has about 100,000 inhabitants and includes both urban and rural areas. All the workshops took place in participants' homes and lasted between 56 and 153 minutes. Pseudonyms have been used to ensure participants' anonymity and confidentiality.

## 8.4 Identified Elements of locating practices

In the following we outline the empirical findings from our study. The mobility narrations provide insights into how users align their mobile practices along the presented spatial information of past journeys. Three key elements which especially supported the users were (1) visualization of movements, (2) visualization of paths, and (3) interpretation spaces.

### 8.4.1 Visualization of movements

We started by asking users what they could see on the personalized maps lying in front of them. We made sure to ask open questions that leave participants space to explain using their own reference system. We obtained answers like the following example sequence #1:

> *Sequence #1: [locating mobile contexts]*
>
> *I: So let's take a look at the details on the map.*
>
> *A: Yes, okay. It (the internet page) is just setting up. Goodness, that's amazing! What's this? Whereabouts was I then? Right here! I was in the internet café yesterday. As clear as day! Wow! […] And here. er. here I can see my way to my brother over there.*

In this sequence the maps are addressed as an important tool to help participants remember and identify their own past mobility practices as it is emphasized with expressions of joy: #1: *It (the internet page) is just setting up. Goodness, that's amazing! […] As clear as day! Wow!* Further, the geographic visualizations of their own GPS data was often used for orientation, to identify where the participants had actually been. However, although the users only see spatial references as red-lined GPS marks of their movements, they do not state purely geospatial descriptions. Instead, people refer to their mobile practices as if one could actually *see* them on the map ("*I can see what I have been doing*", or in "*I can see my way to my brother over there*" (#1)). Hence, people literally bridge the geographic data lying before them with their mobile practices. Coincidentally, both dimensions are connected through the narrative elements of "here" or "there" as their locutionary seat. The map with the referenced GPS coordinates was disengaged by the users in an interpretative process that turns geographic space into a meaningful area. Although the spatial character still exists within the indexical reference of the particles "here" and "there", the emphasis lies not on the geography but rather on the mobile practices performed. In other words, mobile contexts are easily identified by the users with the help of the maps and the referenced GPS locations, as the two examples (along with many others) show.

### 8.4.2 Visualization of paths

Additionally, it turned out that the visualization especially of paths supports the identification and interpretation of mobile contexts, as illustrated by the following sequences #2- 3:

> *Sequence #2: [categorizing located contexts]*

*I: Perhaps you could describe what you can see on the map?*

*D: Well, for example, that's where I took the bill to Alfons. In the garden centre. It is only a short walk, I went on foot, because it is right here in the neighborhood.*

*Sequence #3: [categorizing located contexts]*

*E: when I'm mobile I go to the gym, I go shopping, or go swimming with my neighbor, as you can see here below."*

In these sequences not only the indexical character of the elements like "here" and "there" are addressed, but rather its deontic character that refers to a particular mobile practice. In sequence #2 it is paying a bill in a shop in the neighborhood, or in sequence #3 it is going home. Ascribing content to locations in this way is different from simply naming streets or areas of the city as it connects familiar meanings to the paths shown. In the excerpts, users refer explicit to these paths as "making sense". Within these ensembles, users are able to inscribe particular knowledge to the "geometrical" or the "geographical" space which makes it meaningful and socially readable. Thus, the paths drawn on the map work as preconditions to transform users' mobility practices into a legible form along the path that can be identified and described easily.

### 8.4.3 Integration of interpretation spaces

Further, in the course of the interviews it transpired that users locate their mobile practices within particular paths and places, as illustrated in the following sequence #4:

*Sequence #4: [reading located contexts]*

*C: So I'm only here. From my place, I drove into Ludwig Street first.. This is Ludwig Street here. Then I went back and forth a bit, picked a friend up then went up [name of a village] to Berleburger Street and picked up another friend. And then we went to Giersberg (= area) to play cards here.*

The user point out a "tour" of paths as a series of units (*Ludwig Street first, to. […]to Berleburger Street and […]to Giersberg (= area)".* Although the drawings on the map outline not the "route" (there isn't one) but the "log" of people's journeys – users interpret the outlined marks as footprints of the successive events that took place in the course of the journey. In sequence #4 the speaker refers to an event which happened at a particular place. Within the stated mo-

bility context of *playing cards* the related mobility practices are expressed within certain preferences. Hence, although we are dealing with an objective tool – the map - the reference to this tool is quite selective and subjectively motivated according to the stated mobility practice of playing cards. Therefore, the conducted mobility is stated in a particular manner, namely as a regular activity that is shared with friends. If the user had talked about the workplace or the home, these descriptions would probably have been different. We can imagine for example that the way-finding would be much more straightforward without picking up friends, or would rely on using public transport. Hence, the map is not used in order to reconstruct the prior paths and visited places but to reconstruct particular activities and events from mobile practices that can be located or related to paths and places. We could further observe that users start to annotate the maps, what identifies paths and places as useful units providing users with spaces in which to describe and exaggerate their journeys.

## 8.5 Conceptional Framing

The three identified elements of (1) visualization of movements, (2) visualization of paths and places, and (3) integration of interpretation spaces turned out to be basic needs, necessary to make use of and interpret spatial information. The study especially reveals that designers should provide users' starting points to empower them to make sense of geo-location data. We found out that designers need to understand how users refer to their performed mobility and provide an appropriate basis for the interpretation of mobile contexts.

This motivates the creation of a framework for mobile user-studies that empowers users to actively make sense of the mobile practices they performed. Hence, we identified the following issues that go along with the three findings (see also the overview in Table 7):

(1) "Visualization of movements" refers to the need to collect spatial movements in situ.

(2) "Visualization of paths and places" can be translated as the users' need to be supported in identifying journeys places within performed trips.

(3) "Integration of interpretation spaces" refers to the need to allow users' annotations on the performed trips.

**Table 7: Design implications and for mobile sensing tools**

| No. | Identified Issue | Design Challenge | Technical Implications |
|---|---|---|---|
| 1 | Visualizing GPS/ time data on a map | Collecting spatial movements in situ | Users' mobile phones need to continuously log position and time |
| 2 | Visualizing the GPS/ time data as paths | Identifying trips and destinations as the points of beginning and ending a performed activity | Based on available sensorial data the system needs to be able to determine the start and end of trips |
| 3 | Integration of interpretation spaces | Collecting information within the performed journeys and places | Based on the recorded trips the system needs to provide features to annotate trips and to select context information |

## 8.6 A Framework for mobile user-Studies

In the following, we introduce in more detail how the identified requirements are translated into a framework for mobile user-studies. This framework allows studying in rich detail how users make use of and identify mobile contexts while on the move.

### 8.6.1 Addressing the challenge to locate mobile contexts

Collecting spatial movements in situ requires location data from the phones' sensors to be acquired. GPS immediately comes to mind as the most important sensor, but other sensors like wifi or Bluetooth signals can also be used to determine a users' location. In order to identify trips and destinations, it is necessary to analyze this data. In long-term studies, large amounts of location data are gathered which leads to high demands of computational power to process this data. E.g. we tested processing 1000 locations on a modern smartphone with clustering algorithms like DBSCAN. The computation of clusters took about 10 seconds. Yet for in-situ recognition of places and routes, such approaches are not suitable for processing a complete data set.

Thus, these calculations need to be repeated at very short intervals to ensure in-situ recognition of trips. Further, the intensive workload on the devices would make them unusable due to battery drainage. Moreover, combining the GPS data with other sensor inputs like wifi or Bluetooth signals is problematic when using this approach. Thus, we decided to gather location data and process the incoming stream according to predefined rules. This approach allows the researcher to define under which circumstances data should be stored and/or can be shown to users to ask for qualitative input like collecting information about a trip or destination.

We used a complex event processing approach (CEP) to implement a rule system on the client side. This has several advantages compared to performing statistical analysis of the collected location data. Firstly, using a CEP Engine (CEPE) allows the data to be processed stream-based. Thus, only relevant, incoming location data is processed. The CEPE automatically filters relevant data (e.g. locations that were received within a given timeframe) based on the rules that were defined previously using a special event pattern language (EPL). Secondly, these rules can be (de-) activated or swapped easily without modifying the code of the application itself. Using CEPE on the mobile client allows on-the-fly modifications of data collection (e.g. triggering a questionnaire when a user leaves a spot that has been identified as relevant during the running study).

In our case, we used the Esper complex event-processing engine. Esper is an open source CEPE that has been ported to Android and is only about 6MB in size. Further we used the Funf framework to capture sensor data from more than 15 sources including location, wifi and running apps. This data is then sent to Esper. The patterns, which have been defined on the server, are downloaded via a REST API as soon as they are available. This API provides a JSON file, containing the EPL and the id numbers of the actions it should trigger, which in our case are surveys initially linked to particular places. To create such EPL patterns, knowledge of EPL syntax is required. To eliminate this necessity and to enable researchers without technical training to define EPL rules that allow for categorization locations, we created a graphical editor that is described in the following section.

### 8.6.2 Graphic rule definition to support categorization

As pointed out earlier, one of the main challenges is the collection of spatial information, and to react to this data e.g. by running questionnaires based on the user's mobility. Thus, we developed a web-based editor that is based on the EPL and allows researchers to define events using a graphical user interface (GUI). The editor (cf. Figure 7) ensures that researchers formally define the situations which are relevant for the study in order to make them unambiguously recognizable by mobile devices equipped with the appropriate sensors.

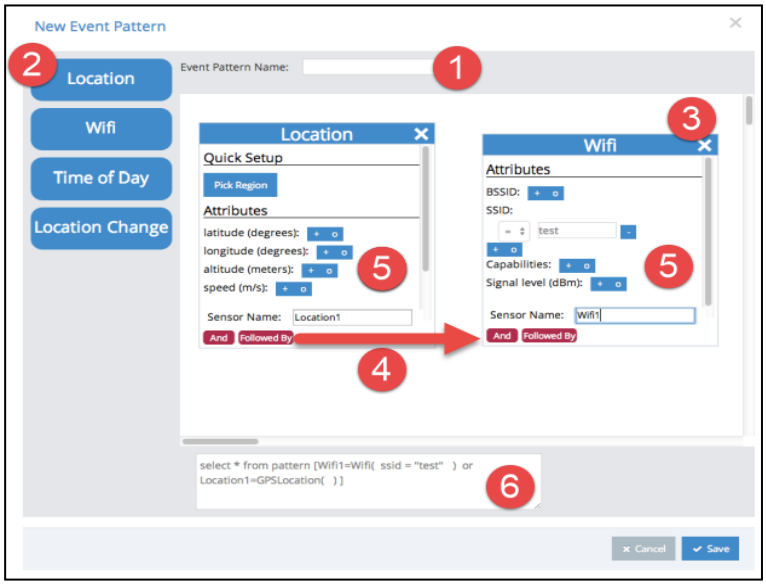


**Figure 7: Web-based editor for event-definition**

This example shows how researchers can create event patterns that support the categorization of the participants' devices. Firstly (1) researchers name the patterns they are going to create. From the list of sensors (2) they can drag and drop different location-related sensor events to the canvas (3). The available sensor events are:

*Location:* Probably the most basic sensor event for location detection. This event will be triggered every time the device receives a location. This can also be specified in more detail by providing bounding areas of relevant locations (e.g. specifying that a questionnaire should be triggered when users are at a specific location, e.g. at university).

*Time of Day*: Basic sensor event to define a time. This event can be used to define rules that should only be matched at a given time of day (e.g. specifying that a questionnaire should be triggered at 3 PM on a Wednesday).

*Location Change*: This event detects a change of the geographic location without the need to specify a concrete GPS position. The researcher needs only to provide a time span and a distance. If there are location measurements in this time span that are further apart than the provided distance, the event is triggered.

*Wifi*: This can be used to determine if a user is connected to specified (or indeed any) wifi. This sensor can be helpful to detect if users are in a specific building (e.g. triggering a questionnaire when users connect to their home wifi).

Further, the framework allows these sensor events to be connected through "AND", "OR" or "Followed-by" connections. Per default, events are connected by "OR"; "Followed-by" and "`AND" connections are established by dragging lines between the events.

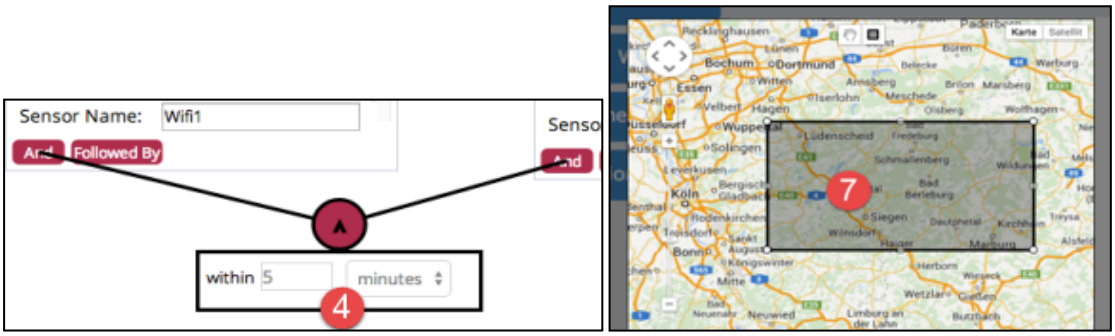


**Figure 8: Output of the event orchestration - Left: Connecting two events - Right: Setting location attributes using "quick setup"**

"AND"-connections imply that the criteria for the event is fulfilled simultaneously, e.g. the participant is at the specified location and connected to the specified wifi. "OR"-connections imply that one of the specified events has happened, e.g. the participant is connected to the specified wifi but is not at the specified location (or vice versa). "Followed-By"-connections refer to a sequential order, e.g. the participant happened to be at the specified location but left and connected to the specified wifi afterwards. For "AND" and "Followed-By" connections researchers can specify a timeframe for the occurrence of the involved sensor events (cf. (4) in Figure 7). For each of the sensor events, attributes can be determined (5) to further specify events. E.g., using the attribute SSID for wifi-events implies that events will only be triggered when the participants connect to a specific wifi network. It also demonstrates the "quick setup" of the location sensor to define attributes based on a selected geo region (7). The output of the event orchestration is shown below the canvas in Figure 8 (6). Here the generated EPL-snippet is shown. The snippet and the canvas are synchronized, thus any changes in one will be reflected in the other representation. These event pattern can be connected to actions (in our case triggering questionaires) that are executed when the event occurs. These EPL-snippets are pushed to the mobile devices along with their corresponding action. Principally this enables the researcher to specifiy or adapt his definition easily and to push it to the participants' devices immediately without changing any source code or adjusting settings.

### 8.6.3 Interface design to support the analysis of location data

After a survey has been started and data has been received from the users, researchers have to be able to view and analyze the collected qualitative and quantitative data. To enable this, we built a web-based route viewer (cf. Figure 9), which allows researchers to inspect the routes, the participants' names for those routes, and the respective surveys. This enables researchers to comprehend the participant's thoughts on those routes, as participants name locations according to what they mean to them personally. The locations are managed in the route viewer. The route viewer provides a list of participants as shown on the lower left. If a participant is selected, all routes for this participant are listed to the right with the name designated by the participant. If a participant gives the same name to several routes, these routes are grouped together, thus facilitating the categorization of locations.

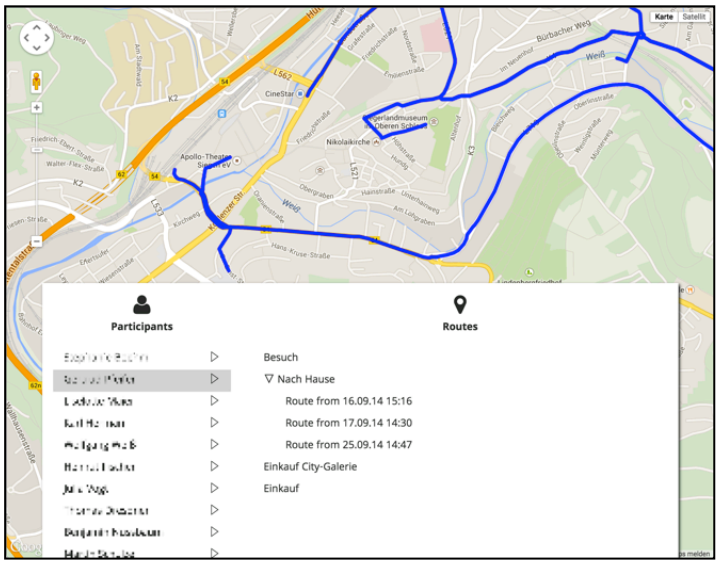


**Figure 9: Web-based route viewer**

## 8.7 Evaluation

In order to evaluate the framework, we first conducted a test to check the its functionality by defining different events and testing whether the respective action is triggered. Secondly, we tested the web frontend with researchers to find out whether the identified issues were included properly.

### 8.7.1 Technical evaluation

Within the technical evaluation we equipped four students with mobile devices and pre-installed our framework. After this we defined several event patterns in the backend system. The first pattern was expected to trigger when the students were on campus. At first, we did not take into consideration that this event would be triggered each time a new location measurement is added to the CEPE. This resulted in two cases of students being prompted to fill out the same survey several times while they were present at the university. This was fixed by changing the event pattern definition slightly, so that it only triggers once a day. Next, we defined a more complex event, intended to trigger when the student's phone detects a certain wi-fi network and switches on the screen of his phone. This was used as a way to detect precise in-door locations. This enabled us to define a survey which was triggered when the student was in the proximity of our offices and using the mobile phone. The problem with this approach was that the survey notification was triggered directly after the screen was turned on - a time when users usually want to accomplish a certain task. It would be possible to add a pause time after the event triggers in the CEPE, but our visual editor has not supported this feature yet.

### 8.7.2 Content evaluation

We further conducted a first content-orientated evaluation with five researchers from the field of information science and mobile media studies. Having introduced them to the framework, we let them use the described functions and conducted an interview afterwards that lasted about 30 minutes on average.

The participants confirmed that: (1) the implemented framework collects spatial movements in situ and visualizes them on a map; (2) Visualization of paths and places helps to identify journeys and important places; Further, (3) the participants used the annotation feature within the journeys performed in order to provide more detailed information about the trips conducted.

The five participants did however also name some critical issues: (1) Three of the users stated they would appreciate the option to annotate routes later, without the need to do it while being on the move. Participants pointed out that situations could potentially arise when one is pressed for time and therefore it would be more convenient to categorize trips later; (2) Further, we gathered initial insights into preferences concerning how to visualize trips on the map in order

to support users in remembering and interpreting their mobile practices. Most of the participants strongly recommended visualizing single trips instead of cumulated routes. The clustering of trips where are annotated with the same categories was recommended; (3) Finally, participants stated that a time line is important for them, to help remember particular trips better. Two of the researchers stated their wish to view trips in a chronological order and to view trips of selective categories on the same timeline.

## 8.8 Discussion and Concluding Remarks

In this paper, we argued in favor of mobile user-studies as a great approach to foster our understanding of mobile behavior. However, current services mostly address spatial information as fixed and restricted to longitude and latitude information. We showed that location-based information is highly interwoven into sense-making processes and mobile routines. Therefore, mobile user-studies are needed to provide answers to how people actually use and interpret their performed mobility while actually being on the move.

In order to inform the design for a framework of mobile user-studies, we started with a context study to discover ways in which users make sense of spatial information in daily mobility. We especially gained insight about three requirements that were translated for building the framework: (1) visualization of movements, (2) visualization of paths and places, and (3) integration of interpretation spaces.

The evaluation showed major research issues for the future. The organization of trips was particularly stated to be a major issue. A future version should therefore be designed so as to assign collected content information within performed trips on maps that can be seen by both researchers and users. Moreover, the route viewer and the questionnaire editor are implemented as two separate applications. Currently, questionnaire data cannot be shown in the route viewer although it has the same access to the API. Hence in future we plan to integrate those two applications seamlessly.

The framework is openly and flexibly designed to allow researchers manifold options of collecting data on the move. Our challenge in the future is to find appropriate ways of integrating and making use of empirical data like questionnaires, open questions, photos etc. that can be selected in connection with a particular trip. Hence, we have laid the basic groundwork that allows how people actually interpret their performed mobility to be studied, as well as making

use of location-based information while on the move. But to answer this question in more detail, our second step has to be to build a graphic editor that visualizes what the framework can already achieve (by using the event pattern language): the integration of routes with user-interaction mechanisms.

# 9 Opportunities for Sustainable Mobility: Re-thinking Eco-feedback from a Citizen's Perspective

**Abstract**

In developed nations, a growing emphasis is being placed on the promotion of sustainable behaviors amongst individuals, or 'citizen-consumers'. In HCI, various eco-feedback tools have been designed as persuasive instruments, with a strong normative appeal geared to encouraging citizens to conduct a more sustainable mobility. However, many critiques have been formulated regarding this 'paternalistic' stance. In this paper, we switched the perspective from a designer's to a citizen's point of view and explored how people would use eco-feedback tools to support sustainable mobility in their city. In the study, we conducted 14 interviews with citizens who had used eco-feedback previously. The findings indicate new starting points that could inform future eco-feedback tools. These encompass: (1) better information regarding how sustainable mobility is measured and monitored; (2) respect for individual mobility situations and preferences; and (3) the scope for participation and the sharing of responsibility between citizens and municipal city services.

## 9.1 Introduction

Throughout the western world, a (neo-) liberal agenda has arguably been placing a greater burden upon individuals as 'citizen-consumers' to both consume for the sake of the market whilst accepting responsibility for the sustainability of their actions (Clarke et al. 2007). Private transportation currently accounts for about a quarter of global CO2 emissions. Given current trends, this value is set to increase by roughly 50% between now and the year 2030 (Banister 2008; Banister and Button 2015). Hence, studies have shown that even small changes in people's individual behavior can lead to significant reductions in carbon emissions (Holden 2012; Saboori, Sapri, and bin Baba 2014). For example, Divetz et al. (2009, p. 18452) estimated that "the adoption of easily implementable actions on a household level (e.g., changing one's driving behavior by slower acceleration and adhering to speed limits) can save 123 million metric tons of carbon per year, a figure that equals 8.4% of the EU's national carbon emissions". As indi-

vidual behavior can have such a significant impact on sustainability, eco-feedback tools to encourage sustainable behaviors amongst citizen-consumers have become very popular in HCI research (B. J. Fogg 2007; DiSalvo, Sengers, and Brynjarsdóttir 2010; Brynjarsdottir et al. 2012).

In general terms, eco-feedback has some similarity to the quantified self-movement as it uses mobile phone data (MPD) to close the 'attitude-behavior gap' (Jariyasunant et al. 2015) by motivating behavior change. Hence, eco-feedback tools are less about the health of an individual and more about promoting a sustainable lifestyle. However, measures aimed at changing individual behavior can face very low levels of uptake, complex constraints and even resistance (Mont, Neuvonen, and Lähteenoja 2014). Critiques of these approaches often point to the normative stance of assuming sustainable mobility is the only 'good' mobility, which risks being unintentionally paternalistic and behavioristic (Brynjarsdottir et al. 2012; Huber and Hilty 2015).

In this paper, we aim to challenge the normative top-down pressure upon citizen-consumers to adopt more sustainable mobility practices. Instead, we chose to examine the perspective of citizen-consumers themselves and explore what it would take for eco-feedback tools to support their own interests. To this end, we conducted an interview study with 14 citizens in a medium-sized city in Germany. To ground the study in their own everyday practices, we used an eco-feedback tool as a probe that captured their daily mobility habits and their sustainable character. In this way we sought to make them familiar with eco-feedback technologies and to elicit their reflections upon their limitations and the possibilities to support a more ecofriendly mobility.

The study showed, in accordance with the literature, that eco-feedback tools with a strong normative positioning can easily be perceived as restricted. We found that such a stance was not always compatible with individual mobility situations, needs and local mobility resources. In particular, we found a range of limiting factors as well as a number of possibilities for design that might have the potential to either lower or raise the acceptance of eco-feedback tools. Design in this space, it would seem, needs to find ways to: (1) support citizen's understanding of how sustainable mobility is measured and monitored; (2) respect individual mobility situations and preferences; and (3) support participation and shared responsibilities between citizens and municipal city services.

## 9.2 Related Work and Theoretical Framework

Over the last decade the sustainable HCI community has seen papers presenting interactive technologies that variously aim to support, inspire or persuade people to adopt pro-environmental behaviors (e.g. Blevis 2007; DiSalvo, Sengers, and Brynjarsdóttir 2010; Dourish 2010; Pierce et al. 2013). A central feature of them has been the provision of eco-feedback, which has become an increasingly active field of research in its own right (cf. B. J. Fogg 2007; DiSalvo, Sengers, and Brynjarsdóttir 2010). A core assumption here is that the right kind of information about one's behavior and its environmental effects will encourage more environmentally-friendly and sustainable habits (Jon Froehlich, Findlater, and Landay 2010). Over recent years, the concept of eco-feedback has increasingly entered people's homes, addressing their recycling habits (Thieme et al. 2012), their food consumption (Zapico et al. 2016) and their electricity consumption (Strengers 2011; Pierce and Paulos 2012).

Several kinds of persuasive strategies, relating to private transportation, have also been developed. An early example was the work of Froehlich et al. (2009). They aimed to influence individual mobility behavior through 'emotional' feedback. This was symbolized by the fate of a polar bear, visualized as a virtual pet standing on an ice floe. Others have used 'gamification' to make the desired behavior more enjoyable and to sustain the interaction by challenging users to compete with each other, e.g. EcoPath (Ross et al. 2010) or the Green Daily Guide (Bliznyuk 2011). 'Socially normative' feedback approaches that seek to motivate users through comparisons or rankings, have also been used. These are often embedded in social networks such as Facebook to show rewards for fulfilling sustainability challenges, like the platform Tripzoom (Gabrielli et al. 2014). An extended version of this can be found in MatkaHupi (Jylhä et al. 2013), which aimed to stimulate users through personalized challenges. Finally, 'awareness-related' eco-feedback approaches aim to catch user's attention by using different means of information visualization and route recommendations (Spagnolli et al. 2011). Examples here include the Quantified Traveler (Jariyasunant et al. 2015) or EcoMobil (Meurer et al. 2016), both of which are good examples of providing users with detailed information about their mobility behavior and personal eco-footprint.

Although, there are some indications that persuasive ICT can have a positive effect upon sustainable behavior, long term evaluations in real-life settings are missing. Furthermore, persua-

sive approaches have recently been subjected to fundamental critique (see, for example, (Brynjarsdottir et al. 2012; Huber and Hilty 2015). This critique hinges upon issues such as "turning the problems of environmentalism into questions of personal moral choice" (Dourish 2010 p. 8), focusing too much on individual consumers (DiSalvo, Sengers, and Brynjarsdóttir 2010) and using persuasive technologies that have a narrow focus on individual behaviors (Brynjarsdottir et al. 2012). The same authors instead see opportunities to support environmental movements (Dourish 2010), address things at a collective, regional or national level (DiSalvo, Sengers, and Brynjarsdóttir 2010) and shift the focus from behaviors to practices (Brynjarsdottir et al. 2012). In particular, these critiques seek to address what is seen as a patriarchal top-down perspective regarding how sustainable mobility should be pursued, ignoring the fact that daily mobility habits have often developed over lengthy periods of time and are deeply rooted in everyday routines and situated reasoning.

Against this, some work has highlighted the importance of daily habits in relation to everyday mobility choices and has suggested that just providing information about alternatives may not be enough for people to change their habits (Barr and Prillwitz 2014; Hasselqvist, Hesselgren, and Bogdan 2016). In this regard, some studies have noted the importance of travel context and have shown fundamental differences in transport preferences between every-day, leisure and holiday mobilities (Barr and Prillwitz 2012; Nyblom 2014b). Many studies also indicate the importance of attitudes and lifestyle choices (Banister 2008). Thus, it has been suggested that travel planning tools should provide not only information about the time and cost of different alternatives, but also about convenience, comfort and privacy (Chorus, Molin, and Van Wee 2006; Stein et al. 2017). There is also a strand of work that considers the importance of values. Egbue and Long (2012), for instance, have shown that values relating to sustainability and the environmental benefits of electric vehicles (EVs) have a major influence on EV adoption, but also that these values can be deemed less important than cost and performance. Some have also suggested a need to focus on sustainable values that extend beyond the design of technology itself and into the design of the physical infrastructure (Watkins 2018). There is also commentary upon the impact of other environmental factors, such as the weather (Prost, Schrammel, and Tscheligi 2014) and uneven distribution of transportation access (Banister 2008; Meurer, Müller, et al. 2018).

It can already be seen just from this overview of the literature that many more factors influence upon the adoption of sustainable mobility practices than those currently being addressed by

eco-feedback tools. Often, such tools neglect the complex interplay of how mobility is entwined with social practices and personal preferences, e.g.: how practices of (un)sustainable mobility are related to others; the structure and organization of physical environments; and how solutions for sustainable mobility are supported by the local infrastructure.

To tackle these challenges, we suggest a change in perspective. Instead of using a top-down persuasive approach, dictating what sustainable mobility should look like and how citizens should behave, we questioned how citizens would adapt eco-feedback tools to support sustainable mobility practices promoted in their city. Here, the goal was to examine the limitations and potential for eco-feedback tools to sustain a more environmentally sound mobility in cities. Thus, a special focus was placed on the use of MPD as a central element of feedback tools in general.

## 9.3 Methods

To explore the above issues, we conducted interviews with 14 citizens. Within these interviews we aimed to explore the potential of eco-feedback tools while addressing the interviewees "as analysists of their own and others' practices" (B. Brown, Reeves, and Sherwood 2011). Mobility practices exhibit people's orientation towards what Tuan (1977) calls a *sense of place*. This can be defined in the following way:

> *"[A]sense of place is inevitably dual in nature, involving both an interpretive perspective on the environment and an emotional reaction to the environment.... A sense of place involves a personal orientation towards place, in which one's understanding of place and one's feelings about place become fused in the context of environmental meaning"*

Thus, one's orientation towards a sense of place is constituted in and through the act of moving in space. Note that mobility practices are not only shaped by given infrastructures, but also shaped by people's interactions and movements. Exploring mobility as a practice therefore means exploring people's spatial movements and experiences (Meurer et al. 2015; Pakusch, Bossauer, Meurer, et al. 2016). To ground this endeavor, we followed the example of (Meurer, Stein, et al. 2018) and recorded people's spatial journeys, enriching geo-location data with users' qualitative reports of their own personal experiences.

In this case, we used an eco-feedback prototype to track daily mobility activities. The tool functioned as a probe to show the interviewees a practical example of how MPD might be collected and visualized. The prototype itself provided an outline of users' journeys and associated modes of transport. We recorded the movements of all interviewees over a set period prior to the actual interviews. During that time, we gave the interviewees time to think about the limitations and potential of the prototype and how they would like to enhance, modify and elaborate on such a tool. The goal was to offer a creative incentive for the articulation of new ideas and social innovations (Wallace et al. 2013). To that end, the prototype offered some simple visualizations to sensitize them to the possibilities of MPD selection and how it might be visualized (cf. Figure 10).


**Figure 10: Collected travel information (left) and sustainability measurements (right). These designs were subsequently slightly modified to improve readability.**

As we wanted to engage with 'ordinary' citizens, we had to allow for a potentially very broad target group, which had to be rendered manageable in some way. One strategy was to interview only people who were individually or jointly responsible for the organization of mobility in their household. We also paid attention to acquiring a broad spread across gender, age, type of household, rural or urban place of abode and preferred means of transport. A detailed overview of the chosen participants is provided in **Table 8**. We selected a total of 14 participants, living in a medium-sized German town. People were recruited using local organizations that were related to activities such as sports, computer clubs, a local citizen's forum and through personal acquaintance. All of them, regardless of age, had sophisticated smartphone skills. They were

also all genuinely interested in the topic of sustainable mobility and were open-minded regarding the use of new media and MPD. Participation was on a voluntary basis and they were not offered any financial reward.

The study began with a kick-off meeting where we introduced the study procedure and installed the prototype on the participants' own smartphones. From then on, we passively recorded their daily mobility for a period of about four weeks. During this period, participants were able to inspect the visualizations of their mobility behavior (cf. Figure 10), as well as adjust wrongly classified modes of transport, to ensure the stored information was accurate. Afterwards, we conducted individual interviews at the participants' homes. The interviews were divided into three sections: First, we asked them about their mobility background, previous mobility experiences and their personal mobility biography. Descriptions were elicited through questions such as:

> *"I am interested in your personal experiences as a mobile person and mobility participant. Perhaps you can start by telling me about the time when you moved out of your parents' house and then, had to decide for yourself about your mobility and how it continued until today. "*

Secondly, once the interviewee had arrived at the present, s/he was asked to look specifically at some of the recorded instances of mobility in their data:

> *"It would be great if you could report in more detail about the concrete mobility situations that were recorded, the mobility modes you used, the way you organized your travel and why you decided to do it that way."*

Thirdly, we asked the interviewees about shortcomings and opportunities of the eco-feedback tool in more detail:

> *"Lastly, we want to ask you about your experiences of using this tool, the limitations and potentials. If you imagine a complete re-design what characteristics would be important for you to foster sustainable mobility in your city?"*

During the interviews, we aimed to secure an open narrative to gain individual insights. The interviewers relied on reflective questioning and probing, prompting participants to provide additional detail, clarifications and explications. The interviews lasted for between 30 and 90 minutes, were transcribed and anonymized, then analyzed.

Analysis was based on a reconstructive, documentary approach (Bohnsack 2014). We started the process by subjecting some cases to intensive examination, while other cases were only used to provide supplementary material. Relatively quickly, it became apparent that some interviews documented concrete potential for how eco-feedback tools could be developed further from a citizen's perspective. Other cases gave less information, depending on the nature of the questions and the willingness, knowledgeability and enthusiasm of the participants. The analysis process itself was carried out in three steps: First of all, sections were selected in which theoretically interesting aspects and the subjective relevance systems of the interviewees emerged with particular clarity. These sections were examined with regard to "what" was said and they were 'immanently' or thematically annotated. In the second step, we sought to reconstruct the frame in which a topic was dealt with. At this point, the focus was no longer on "what" but rather on "how" interviewees talked about a particular topic. Finally, depending on how the limitations of eco-feedback tools and ideas for their development had been handled in concrete statements, they were compared and contrasted to other statements in the material to formulate concrete themes. In the end, we arrived at three main themes, which are presented below.

**Table 8: Overview of the participants. SH = single household; FH = family household no children; FH+n = family household with n children; SA = shared apartment; C = car; PT = public transportation; B = biking; eB = electric bike; W= walking.**

| No. | Age | Sex | Household | Area | Transport |
|---|---|---|---|---|---|
| #1 | 28 | m | SH | urban | PT; B; W |
| #2 | 24 | f | SA | rural | C |
| #3 | 64 | f | SH | rural | C |
| #4 | 60 | f | FH | urban | C; W |
| #5 | 74 | m | FH | rural | C; PT |
| #6 | 55 | m | FH+2 | rural | C; W |
| #7 | 21 | m | SA | urban | PT; W |
| #8 | 32 | f | SH | urban | C; PT; W; B |
| #9 | 61 | m | FH+1 | rural | C; eB |
| #10 | 81 | m | FH | rural | C; W |
| #11 | 24 | f | SA | urban | PT |
| #12 | 43 | f | FH+2 | urban | C; PT; W |

| | | | | | |
|---|---|---|---|---|---|
| #13 | 34 | f | FH+3 | rural | C |
| #14 | 67 | m | SH | urban | C; PT; eB; W |

## 9.4 Findings

The analysis showed clearly that, although all participants spoke at some point during their interviews about the positive value of sustainability, the value was not considered a driving factor in and for the organization of their daily journeys. Moreover, we found that daily mobility was deeply rooted in everyday practices that often conflicted with what one might understand as sustainability. In accordance with other studies mentioned above, eco-feedback that aims to persuade people towards more sustainable mobility was mostly regarded as too far removed from people's actual mobility needs, individual situations and available resources. However, aside from these limitations, the interviewees also mentioned other concerns (or themes) that they felt eco-feedback tools needed to address. These themes encompassed: (1) better information regarding how sustainable mobility is measured and monitored; (2) respect for individual mobility situations and preferences; and (3) supporting participation and the sharing of responsibility between citizens and municipal city services.

### 9.4.1 Measuring and monitoring

This theme relates to the expressed wish of many participants to understand sustainable mobility better in general and individual sustainable mobility in particular. Although, most participants obtained information about sustainable mobility from the daily news (via print, online media or the television), ways to measure, monitor or define sustainable mobility had not previously been encountered by many participants. We also found that participants lacked any point of reference to get a better understanding of their own sustainability behavior. These points are discussed in more detail below.

#### Measuring sustainability mobility

The interviewees often expressed uncertainty about the units adopted to measure sustainable mobility in a quantitative manner. Some participants even stated that they felt "*insecure*" (#11), "*irritated*" (#14) or even "*helpless*" (#7) when trying to understand how the $CO_2$ balance for their everyday mobility was measured. Mrs. Brown (#12) expressed it like this:

*"When I throw garbage on the roadside, I can directly SEE that my behavior is causing pollution. That is different with my mobility. / Interviewer: Why, why do think so? / Because It is harder to see a direct effect of my behavior. […]. A plastic bag is a plastic bag, but 53 grams of $CO_2$ is (pause) I think we have still so much to learn about how our environment is affected by our daily mobility."*

Her explanation shows that she lacked ways of making $CO_2$ pollution more directly accountable in experiential terms. However, some felt they needed more detailed information about the exact calculation of $CO_2$ values per mode of transport and how the guiding values were calculated. The units of measurement for $CO_2$ in kg often remained only abstract values that were difficult to understand. Mrs. Henry, (#3) was particularly explicit on this point:

*"The first-time hearing of kg it didn't ring a bell. I always have thought it's just blown out and that it doesn't have any weight. For me 1kg conforms to 1kg flour. So, one can't imagine that easily."*

This quote is an example of how difficult understanding measurements of sustainable mobility can be for a non-expert. If the participants were not used to reading the measuring units they had problems understanding the balance sheet of $CO_2$.

We also found that participants struggled to interpret their data in a qualitative way. For instance, knowing whether your own $CO_2$ values were high or low was articulated as quite difficult by most interviewees. So, Mr. Edward (#10) asked:

*"I know how much or little 100 Euro is, but I have no clue how much or little 1kg $CO_2$ is. What does make sense in that case?".*

To illustrate his difficulty, he compared $CO_2$ with money and argued that he is used to understanding the value of money, but understanding $CO_2$ values is something new for him. While we are used to putting a value to money, we have never learned to value $CO_2$ balances and to experience it as a kind of 'lived' data rather than abstract information. Many insecurities about how to handle environmental data, it would seem, are due to a lack of knowledge, proper information and practical experience.

### Monitoring sustainable mobility

Another important aspect was the monitoring of sustainable mobility. In the prototype we used a benchmark that raised for many participants the question of how sustainable mobility was defined. Mrs. Brown (#12), for instance, asked:

> *"Who is actually defining that benchmark? I mean is it an official one? I really would like to know where these values come from. […] Also, I wonder what happens when my $CO_2$ consumption level is below or above the benchmark."*

These questions address critical points, such as the lack of an official benchmark for sustainable mobility. For our prototype we decided to use data from our project partner, the Wuppertal Institute for Climate, Energy and Resources, who developed the sustainable backpack.[5] Its underlying model is built upon the level of $CO_2$ consumption per person required to stay below the world climate goal of less than 2°C of global warming. Of course, private mobility is only one factor in the model out of many others that might cause global warming, including housing, household consumption and nutrition or taking holidays. Thus, the benchmark for sustainable mobility can only be understood as an average proportion of $CO_2$.

Further, positive incentives for sustainable mobility were requested by many of the participants (#3, #6 and #13). Mr. Mahoney (#4), for instance, said:

> *„It would be great to see the effects of our mobility behavior. I mean does the effort make any difference, and if so, in what way? It would be great to see if it raises the air quality or has any other advantages."*

In this example, Mr. Mahoney is not talking about just a data visualization of $CO_2$ consumption, but rather about effects that might be experienced in the real world, such as the local air quality. Mrs. Adams also had an interest in more local environmental awareness functions. She asked:

> *"can we see its effects on the local pollution load?"*

While sustainability is often discussed at a global scale, Mr. Mahoney and Mrs. Adams questioned if the effects could be shown at a local level. Citizens might be emotionally motivated by local environmental data that is close to their homes, work or schools. This renders the data less abstract and more open to direct experience. So, just making monitoring models more

[5] https://www.ressourcen-rechner.de/?lang=en

transparent might not be enough. The model also needs to be grounded in local and tangible experiences that can encourage citizens towards more eco-friendly behavior and that can provide concrete incentives to proceed in certain ways.

On the other hand, we did also encounter examples of people who valued the opportunity to monitor their mobility behavior in terms of sustainability. The following example comes from a married couple, Mr. and Mrs. Garcia (#9), who were living in the countryside. Mrs. Garcia first of all said to her husband:

> *"in principle you cannot change anything on your mobility practices. He replied: Yes, but I find it meaningful to raise awareness about this, although it does not change anything or cannot change anything. […] But basically, when I am concerned with it and when I am using it, it stays in my mind. […] You will not think about your transport mode every trip, but the attitude may change. Thinking about the environment and how you can influence it, even with limited possibilities. And for this it is good to have such an app, where I can see how many resources have been used, just to be a little bit more aware that my behavior is actually causing effects."*

Mr. Garcia began by agreeing with his wife that confronting his own habits with sustainability measures was unlikely to cause direct behavioral change. Nevertheless, he saw a potential in eco-feedback tools to make himself more aware of his own behavior. During the interviews, other participants also saw some benefit in behavior monitoring, even if they did not intend to change their behavior because of it. These participants positively valued the learning effects derived from using the prototype because it helped them to get a better understanding and awareness of how mobility could affect the environment.

We also found that people appreciated being able to assess their mobility data by means of comparison. The prototype we developed supported making a comparison between people's own data and the data for an average user. This was described as being helpful for developing a better sense of the import of their own mobility behavior. So, Mr. Taylor (#14) noted that a comparison with his own behavior had led to a more critical review of his own practices:

> *"I first took a look at the distances and then I focused on my car usage in relation to the others and so I figured out something interesting, look at the kilogram-section." Interviewer: "right, you are ahead there, because the other users drive their car mostly with two passengers. They have more kilometers, but are eco-friendlier because of that." Mr. Taylor: "yeah, exactly. The*

*others covered a longer distance but cause less $CO_2$, because they traveled together. You have to learn to understand it."*

It is important to stress that this new insight did not necessarily mean Mr. Taylor would then change his practices. What the data does show, however, is that feedback about one's own behavior can be an opportunity to question old habits. Thus, Mr. Garcia (#9) was surprised that he walked less than the average person and this made him consider walking more often. Similarly, Mrs. Henry (#3) was very surprised when she and her husband realized the enormous impact on their sustainability values caused by their holiday trips with a camping car. The couple were enjoying their retirement by taking regular longer trips away, but this had increased their regular $CO_2$ rates by a factor of 32 in comparison to a normal week. Again, these new perspectives on old habits are by no means a driver for behavioral change or giving up on pleasurable practices.

So, monitoring does not automatically lead to behavioral change. It can, in some cases, sensitize people to what more sustainable mobility might involve for them, thus giving them the means to engage in active and informed reasoning about it. However, in other cases it can lead to frustration and even rejection. In all cases it was important to the participants that their individual mobility situation be considered, as different people have different opportunities to make their mobility more sustainable.

### 9.4.2 Individual mobility situations and preferences

When examining the issues regarding measurement and monitoring, we found that, from the participants' perspective, it was very important that the specificities of managing their own individual mobility be recognized and respected. However, general monitoring processes and rhetoric often clashed with these desires, as we discuss in more detail below.

#### Individual mobility needs

Many participants reported that fitting their mobility routine to their personal needs was of the utmost importance. We identified several different concerns and ideas about what optimal mobility might look like, e.g.: a car's luggage compartment allowing for the easy packing of sports bags or groceries (#2); using rail services to commute because it allows one to "*sit in the train and get work done*" (#1); using public transport to get to the city center (#14) because you *"don't need to care about parking. That saves stress and money"*. These different rationales are highly indicative

of how people arrange and chose modes of transport that fit neatly to their lifestyle and cause a minimum of disruption or hassle. Certain modes of transport were also regarded as being healthier than others. Thus, Mrs. Evans (#8) commented:

> *„A heathy mobility for me means to leave the car once in a while, even if it is less comfortable. Shopping by foot can be a great training (laughter)."*

So, driving can be replaced by walking to achieve a healthier mobility, even if it is perceived as less comfortable or as an 'effort'. 'Healthy' mobility, then, is a disciplinary practice that needs to be actively pursued and valued. However, sustainable mobility does not always go hand in hand with other priorities in people's lives.

Thus, we found a couple of examples where sustainable mobility was characterized as a 'luxury', because it can result in higher mobility costs in terms of flexibility and money. Mr. White (#6) was particularly concerned about issues of flexibility with regard to sustainable transport options:

> *"At the moment, I am unfortunately dependent on the car because I have to do a lot of trips and I'm not able to ride the bike anymore. That isn't changeable. Based on my inner attitude everything should be eco-friendlier. But if I am pressurized and have to be fast and precise, I take the car. To be honest, sustainability is more like a luxury topic for me, of course it is nice to care about the environment and everything, but it should be possible, too. Maybe I'm the wrong person. I'm not a benchmark for sustainable living".*

For Mr. White riding a bike and using public transport do not meet his need to be "fast and precise". Although, he emphasizes his positive attitude towards sustainable living, he excludes himself from the moral imperative by saying "*I'm not a benchmark"*. This illustrates the trade-off between wanting to be sustainable and having to pay for it with a form of mobility that is deemed infeasible. Others, were concerned about the trade-off between sustainable mobility and the high monetary cost of public transport. In particular, they did not see the sense of buying bus or train tickets when they already had a car in their garage. In this situation, bus or train tickets were described as a "*cost on the top*" (#3) or as "*extra costs*" (#13) in addition to the high maintenance cost of cars. Together, these examples show the extent to which personal pressures and preferences shape whether people will choose more sustainable modes of transport. Not only do individual perceptions of sustainable mobility vary greatly according to

different perceived needs, but also it is clear that general monitoring processes fail to address the individual logics of mobility.

### Respecting individual mobility needs

When we took a more detailed look at the concrete monitoring data produced during the trial, many participants felt that the monitoring process did not do justice to their individual mobility behavior. In this regard, Mrs. Adams (#13) claimed that there was little opportunity to change her mobility towards more sustainable modes of transport. So, the monitoring did not result in a behavior change but rather "frustration":

> *"I know that I need to drive more than other people, like those who live in the city. I need my car for everything. I cannot avoid it. So, I do not really want to know how sustainable I am. I know that I'm not. But I do not drive around unnecessarily, just the bare necessities. All the same it is."*

Note, here how she expressed a preference for not receiving eco-feedback about her lifestyle. This is not a preference for ignorance exactly. She says that she is already aware that her behavior is not very sustainable. Instead, she does not want to be continually reminded and called to account for something that she feels powerless to change. When assessing whether their own mobility behavior was sustainable or unsustainable, we found that many participants tended to perceive their consumption in terms of being either 'necessary' or 'unnecessary / wasteful'. In this regard, Mrs. Brown (#12) said:

> *"I'm always on the run and without my car I would be totally lost". Interviewer: "Can you explain that in more detail?" Mrs. Brown: "Well, that's what I NEED. I need to be quick and flexible to manage everything [...] I have to be mobile to go to work, to go shopping and to take care of my family. I'm always saying 'I'm the taxi for my children' (laughing). […] That is just the really basic."*

Mrs. Brown used to live with her family in the city center with relatively good public transport access and with many places in reach. Despite this, she still preferred to use a car rather than public transport to manage the different needs of her family. The expression "*that's what I NEED*" shows her sense of car-based mobility being the only thing flexible enough to meet with the diverse requirements of her family. Somewhat different, Mr. Davis (#6), a father of a

teenage girl who lived with his family in a rural area, described sustainable mobility behavior as the prevention of what he considered to be unnecessary or 'waste':

> *"Sustainability is very important to me (..) I really try to do it as well as possible. [He elaborates further examples regarding how sustainability is integrated into his daily e.g. not buying plastic bags]. It was always important to me that I do not drive around un-necessarily and waste any money. I don't drive around just for fun, or have a big car, just because I could. No. I orientate my mobility on what is really necessary."*

He made it clear that sustainability was an important value in his life, which, for him, meant paying close attention to his personal mobility habits. The over-riding orientation, here, was to only consume as much as was absolutely necessary. This focus on 'waste' drove a perceived need to organize transportation more efficiently, but not necessarily more sustainably. What might be argued to be 'enough' or 'efficient' is subject to enormous variation and can highly differ from person to person, according to individual values, needs, contexts and the local accessibility of different modes of transport. It can also be subject to the situated vagaries of dealing with whatever needs to be dealt with here and now. Although, most of the interviewees expressed positive views regarding the value of sustainable mobility, they were also more than capable of providing good accounts for why they conducted their mobility in the way they did. This is something that needs to be respected rather than set aside.

### 9.4.3 Shared responsibilities

According to different circumstances, needs and available infrastructure, the interviewees had different kinds of mobility lifestyles. As we have seen above, there is not always a choice when it comes to mobility behavior. Another important outcome of this is that people do not always feel completely responsible for their choices and the environmental impact of those choices. However, people are still willing to take on some measure of responsibility. But they feel that local mobility suppliers and local municipal city services should take on some responsibility, too.

#### Individual responsibility

While many participants did not see much opportunity to change their daily mobility habits, they were more than ready to support new mobility services aimed at developing more sustainable mobility. Mr. Mahoney (#4), who lived in a more rural region, said:

*"To establish a more sustainable mobility I think that sharing opportunities offer a nice opportunity. If some offer would be close by, I think I would consider if we really need two cars in our family, or if we could replace one because I use it only occasionally."*

Thus, carsharing services were viewed as a potential opportunity for some participants to scale down their individual car use. Related forms of sharing such as ridesharing turned out to be relevant here, too. Mr. Taylor (#14) commented:

*"If I would know, I could help my neighbors with a lift, I would immediately offer a ride. That is what I understood under a local solidarity. I think that would improve the quality of a neighborhood […] and that also accounts for a sustainable mobility, right?".*

So, offers of sharing could play a part in fostering the formation of a local community identity where part of it is bound up with a collective responsibility for the environment.

Many interviewees expressed the view that sustainable mobility is the shared responsibility of the local community, rather than about individual effort: "*It is a shared effort, not an individual duty*" (#3). However, characterizing attention to sustainability as a 'duty' has certain connotations. It implies seeing it as a personal burden, that is easier to bear when the weight is distributed across a number of shoulders. Others argued that collective attention to sustainable mobility is more efficient (#12):

*„I alone, I don't think that it makes a big difference at all and I don't think it is my duty alone. It's a collaborative responsibility and I'd like to see how OUR actions have an impact."*

This statement makes it clear that people may think their own impact would be quite low, whilst a joint effort might result in more visible change. Another participant expressed it as a feeling of being part of a community of fate. This was clearly articulated by Mrs. Adams (#13), a mother of two young children:

*"I really would like to know what all of us could achieve together to improve our environmental situation […] this needs to be considered for our kids, too".*

Here, sustainable mobility is seen as a collective achievement. In contrast to the previous example, it is not expressed as a collective burden, but as a shared experience ("*achieve together"*). This is more about an investment in the future and, indeed, later in the interview she refers to a collective responsibility to care for the future of the "*kids*".

### Responsibility of the city

Some interviewees expressed a view that caring about sustainable mobility and environmental pollution was being pushed too much onto individual citizen-consumers. This was expressed by Mrs. Williams (#12). She vented her frustration as follows:

> *"Phew! I'm a little torn, because I think that everybody has to do something to make a change, but sometimes I feel that the individual hasn't the ability to do so. Actually, I guess this is because sustainability isn't applied in the big wide world. We're always thrown back to ourselves [...] but I'm just a small cog in a big wheel [...] I mean, what's the point of me walking more, but the car industry is developing stronger motors on and on. I reject that, I say, no, I do not want to take that pressure; you should start on a large scale. That's far more efficient, instead of me, average citizen, starting small."*

In this quote, the overall political system is criticized for not providing a more environmentally-friendly infrastructure that might then facilitate sustainable mobility on an individual scale. Mrs. Williams expressed a need for concrete action to be taken by industrial operators and political decision makers to provide sustainable transport options, thus effectively calling them to account for their inaction. In this regard, Mrs. Evans (#8) wished that the local mobility situation would be taken more seriously by the city services:

> *"If they would know how my daily mobility looks like, they would not ask me to take the bus or to ride a bike". Also Mrs. Davis (#6) stated: "I wish I could clarify my mobility situation so that people know how desperate the public transportation is. Maybe then something would happen, maybe then they would come up with something. (pause)."*

In both of these quotes the interviewees express a desire that their individual issues and concerns might be recognized by the authorities, who were considered to be better-placed to do something about it. There is a demand for what Iris Young calls 'political responsibility' (Young 2010). This concept captures the sense of actors not being solely responsible for issues they have not caused directly through their actions, but where there is a sense of co-responsibility because everyone is structurally entangled in their formation. Responsibility, in this case, is not tied to a question of whom to blame, but rather where the obligations lie.

## 9.5 Discussion

In the above results, we identified three key themes that capture both the limitations and the potential of eco-feedback tools from a citizen's perspective. These encompass: (1) better information regarding how sustainable mobility is measured and monitored; (2) respect for individual mobility situations and preferences; and (3) support of participation and shared responsibility between citizens and municipal city services.

While a lot of research has already pointed to the limitations that attach to reinforcing unsustainable norms, presuming rationality (Brynjarsdottir et al. 2012), or taking a paternalistic perspective (Zhang et al. 2015), less work has examined what other kinds of potential may reside within an eco-feedback approach. An exception here is work that addresses the potential for rendering sustainable behavior more accountable (Schwartz et al. 2013). However, similar studies on eco-feedback systems that aim to support sustainable mobility are lacking.

To address this gap, we argue that understanding how eco-feedback tools are engaged with from a citizen's point of view provides a new perspective on the potential of eco-feedback and how it might encourage more environmentally-friendly mobility. In the following we suggest some of the possibilities that were motivated by our analysis.

### 9.5.1 Understandable and accessible information

Our findings showed that the interviewees were more interested in understanding and learning about sustainable mobility than they were in being confronted with abstract values that did not make concrete sense to them. They all had an interest in information related to sustainable mobility. Most of them were well-informed by the media about topics such as environmental pollution, electric vehicles, new mobility services like car sharing and the more general situation regarding mobility in German cities. However, many of them also expressed uncertainty regarding their own competence and skill to make informed judgements about whether specific forms of mobility were more or less sustainable. When it came to concrete statements about sustainable mobility, their judgements were often quite programmatic and abstract, such as: 'cycling is sustainable' or 'driving is unsustainable'. Although, these statements are not necessarily wrong, they do not capture a very detailed understanding of what sustainable mobility might entail.

Even though many participants struggled to understand the abstract aspects of measuring and monitoring sustainable mobility, they were nevertheless interested in such things. In particular, they wanted to understand how sustainable mobility could be distinguished from unsustainable mobility. However, not every user wants to invest significant effort and time in understanding detailed and complex background information. An official model could help to foster trust in the reliability of monitoring. This model should be easy to understand and accessible to everyone. It would help if information such as the fact that benchmarks are based on keeping an individual citizen's $CO_2$ output below a certain value was better promoted. This could be done in schools, at the workplace, by municipal city services and by other organizations, but also in the different applications that aim to support sustainable mobility.

An important point to mention here is that knowledge and information about how to interpret mobility data should not be simply used for persuasion but rather to support users in developing a better awareness of the consequences of their actions and of the character of environmental pollution in general. In this regard, this study can be thought of as an example of an induced learning process on mobility data related to sustainability. Such learning processes need to be further fostered in different social settings such as, again, schools and workplaces, and in public settings, cars, at train stations and, of course, in the media.

### 9.5.2 Balancing the tensions between individual needs and monitoring

During the interviews we found that transformations of mobility routines were often associated with life-changing events. For instance, becoming a parent had led, in one case, to a new way of thinking about mobility (#6). Getting a new job caused new mobility demands in two cases (#8; #12). We also found that mobility requirements needed to be re-organized in the course of a separation (#12) and, in two cases, when people met new partners (#8; #6). Interviewees reported having somehow 'slipped into' new ways of proceeding with their daily mobility as a result of changes in their living circumstances. This underscores the strong connection between mobility habits and the evolving character of everyday routines that have developed over the course of people's lives: e.g. decisions about where to live, where to work, how to organize the household and its relationship with the outside world; how and with whom leisure time is to be spent; how the grocery shopping is to be done; how to travel to work, and so on. In every case, there are preferred modes of transport that are reasoned about in relation to the particular

situation. Changes in one's social environment often (perhaps inevitably) induce processes of self-reflection and behavior change.

Thus, the provision of information should go beyond abstract sustainability goals that might be considered unachievable, unrealistic or patronizing. Instead, on the basis of our findings we feel that it is important to understand and appreciate daily mobility as it is: a set of practices that have to fulfill different needs and serve different values that might even seem to contradict the broader aims of sustainability. It is unreasonable to expect that users will simply change mobility routines that have evolved over extended periods of time. Intertwined with this is the fact that, where practices are sustainable, they, too, have developed over the longer term. This rather conflicts with persuasive eco-feedback approaches (Carrel et al. 2012; Jariyasunant et al. 2015) that assume that just providing the feedback will result in change. The findings also indicate that eco-feedback needs to be provided in a 'safe' and 'protected' space that provides room for (self-) reflection and learning about one's own mobility habits and the effects they may have upon the local environment and community. Thus, the key thing is to support awareness of one's own behavior that does not simply position it as 'right' or 'wrong', but that rather respects evolved practices, even if the overall goal is to overcome unsustainable mobility practices in the long run. Thus, design needs to reflect on the tensions between enforcing values and respecting the freedom of users (Dorrestijn and Verbeek 2013) and find more effective ways of balancing the two.

We also found that mobility planning ICTs might offer a vehicle for supporting individual mobility in more sustainable ways. In the interviews, we often found a preference to own and use a car. There are clearly situations where a car is the fastest option for getting from one place to another. Using public transport or bikes is often also characterized as a hassle. Time, as in the number of minutes it will take to do something, is typically foregrounded in travel planning tools (Brynjarsdottir et al. 2012). However, when optimizing primarily for time, other preferences that can play an important role in sustainable mobility are often neglected. Hence, the interviewees mentioned other, subtler, criteria, e.g.: getting physical exercise and being outdoors in the fresh air and sunlight; being with the family without having to focus on driving; sitting face-to-face and talking while travelling; taking a scenic route that can only be tackled by bike; getting to know the city better; getting some work done on the train; or travelling in a less stressful fashion.

These are all opportunities for ICT and travel services. As Hasselqvist et al. (2016, p. 9) put it: "Currently, travel planning tools do not suggest that replacing a 20-minutes car trip with a 40-minutes bike ride will amount to "winning" 40 minutes of exercise, sunlight or increased knowledge of the city, rather than just "losing" 20 minutes in the car." As convenience has been identified as an important factor for transportation choices (Sochor, Strömberg, and Karlsson 2014), these kinds of benefits should be highlighted in the design of travel planners. There are examples of dedicated travel planners for electric bikes that, for example, take weather conditions into account. There might also be possibilities to enhance positive experiences of sustainable transport by linking travel planning tools to other services, such as fitness tools or time reporting systems at workplaces when people are working on the train. Ridesharing among colleagues can also augment opportunities for 'chats in the hall and whilst making coffee' that are important for informal exchange. We believe that designers need to become more aware of this tension between the traditional understandings of optimization and sustainability that reside in many tools and the ways people reason about the conduct of their lives and the travel choices they are making.

### 9.5.3 Collective responsibilities vs. individual pressure

Finally, the data showed that sustainable mobility was often deemed to be something that should be a collective achievement of the members of a local community who share a local interest in living in an environmentally healthy city. Thus, many participants felt, that it was not their duty alone to care about sustainable mobility. To address this issue workplaces, schools and sports teams could work as creators and facilitators of such norm-challenging (digital) communities. These are places that naturally create communities that go "beyond the individual" and that might endorse knowledge exchange, combined with an offer of alternative mobility services. This could include joint bike maintenance, the provision of light electric vehicle leasing contracts by workplaces, ridesharing stations and support, or carsharing opportunities. This, in turn, could lead to more discussion about transport and might support an increasing acceptance of alternative modes of transport (Bartle, Avineri, and Chatterjee 2013).

A further possibility is to enhance eco-feedback tools by having visualizations that show environmental wellbeing or pollution as a collective achievement or that promote challenges that will increase awareness about what is achievable in a local community. Greater awareness of local conditions on the part of municipal city services might also be further developed and local

municipal services could be addressed as relevant stakeholders. By extension, eco-feedback tools could foster mutual exchange between a wide variety of stakeholder groups and encourage mutual learning and participative innovation processes.

A further matter worth reflection is the presence of evidence that suggests that the strong drive towards individualism in a number of countries in recent decades, with a concomitant erosion of a sense of community, has led to a certain fatigue with the sense of individual responsibility this instils. This may be leading to a growing social need for ways to escape this pressure, reflected in there being a higher demand for communalization in cities (Urry 2012; Avram et al. 2017). This, too, may represent an opportunity for developing ICT that articulates community focus around matters such as sustainability, enabling people to not only 'share' but to demonstrate that they 'care' and that they hold each other accountable for caring (Avram et al. 2017). This would bring together the above propositions, perhaps at a platform level, and provide a way of reconciling a number of different and pressing issues at the same time.

## 9.6 Conclusion

In this paper, we have presented an interview-based study where 14 participants used an eco-feedback probe to reflect upon their daily mobility habits and sustainable mobility. We applied a citizen's perspective to study the limitations and potential of eco-feedback for the support of sustainable mobility in cities. We believe that the perspective of citizens is important to move beyond gross normative appeals (e.g. 'be sustainable!') towards something that is embedded in people's real experiences of having to move around in the world. The points we have identified can be collected under more general themes that may inspire designers concerned with sustainable mobility. First of all, and to re-iterate what others have also said, there is a need to design with a focus that goes beyond measurement and towards supporting an understanding of the effects of sustainable or unsustainable mobility. Secondly, we see opportunities in designing for alternatives to resource optimization and monitoring, by examining other values that are important for sustainable practices that bring a different understanding to a specific situation. Thirdly, we see potential in dispensing with promoting just individual responsibility for sustainable mobility and providing, instead, a way in which different stakeholder groups might participate in and collaborate around processes of mutual learning and innovation. Lastly, this study itself has sought to provide a positive example of how a citizen's perspective might be

applied to sustainable HCI in ways that might inform and inspire the design of digital services that could support a more grounded transition towards sustainable mobility practices.

A limitation of this study is clearly that the selection of the participants was by no means representative. This applies also to the chosen city and the specific economic, political and legal environment within which the study was pursued. Every city has its own characteristics regarding its infrastructure, topographic landscape and history of supporting sustainable mobility practices (or not). It is important to continue this kind of work across a range of different communities around the world. There is also a need for studies of how sustainable mobility is negotiated and organized in the micro-economies of households and other lifeworld contexts, such as in partnership relationships, parent-child relationships and in companies.

# Part III: Results

In this final third part, I will summarize and discuss the main contributions to answer the research question how a practice-based design approach can support sustainable everyday-mobilities with a particular focus on TIS, SMS and EFT. This part is sectioned into two chapters: in the first chapter (Chapter 10) I will outline the main findings. This includes the theoretical conception of everyday mobilities as practices, the methodical foundation to study everyday mobilities and the SID that were developed. In the last chapter (Chapter 11) I will give a short summary and discuss limitations as well as the relevance of the work.

# 10 Summary of Findings

In my thesis, I adopted a practice-theoretical lens to understand and design for everyday mobilities. Over the years, my practical research has shaped my position on how to make a practice-theoretical lens fruitful to understand and design for sustainable everyday mobilities. In the following, I reflect up on this position with regard to three main topics: first, how the research subject is constituted in theory; second, how it could be studied empirically and third; how it can be framed by design methodologies.

## 10.1 Theoretic Conception

In part one of the thesis, I introduced Dourish's (1996) conception of 're-placing space' as the most influential practice-orientated conception in HCI research to investigate practice-orientated mobile movements. However, I also already outlined some critical points on their conception, mentioned by Brown and Laurier (2005), and Brown and Perry (2002). They stated the methodological problem of how exactly the concept can be applied empirically. In particular, they highlighted the missing methodological lens of how to study mobility practices then with the differentiation between 'place' and 'space'.

In my work and in particular in Chapter 5 I tackled this issue in detail, how everyday mobilities can be conceptualized. In particular, I outlined a methodological framing that addressed this blind spot how Dourish's conception of 're-placing space' can be applied empirically to study practices of everyday mobilities. In order find alternative conceptions, how both 'place' and 'space' are aligned in people's practices I came around the term of 'way-finding'. Way-finding focus on the practices of moving around in space (Casey 2013). More precisely Arthur and Passini (1992) describe way-finding as 'more' than:

> *"navigational questions such as whether to continue along the present route or to backtrack, what turn to take at an intersection of paths, or whether to stop and acquire information from the environment to confirm the present route",*

but also to identify the need to address the question of how people *orient* in and towards a certain environment (ibid., p. 32). Such a focus on 'orientation' as the very personal attachment to and towards places have been argued in similar ways by early pioneers in philosophical and

sociological fields, too, such as Simmel (1903), Massey (1995) or Lynch (1960) in his text 'The Image of the City'.

In this text, Lynch (1960) stressed that emotions like loneliness, or being lost, are part of the way we orient in and towards our environments. Using a so-called, 'cognitive mapping' approach he asked subjects in Jersey City, Boston and Los Angeles to draw their city to get a sense of what he called 'the image of the city', thus deriving insights into their inner worlds of feelings and emotions. Hence, his approach has enjoyed quite some popularity, particularly in urban planning and geographical information systems design, because it demonstrates how environmental access is a matter of personal perception and can be experienced differently (Vertesi 2008). Therewith, mobility practices cannot be understood as the movement through time and space (as transport used to be understood), nor as purely socially driven by personal needs or norms (as mobility used to be understood). Moreover, understanding mobilities as practices is related to the way how people *orientate* towards places in a given space. This perspective on orientation ties together the supposedly opportunistic perspectives towards 'space' and 'place' and can build the ground for the further practice-based analysis.

Another helpful conception to study 'mobility practices', that I borrowed from Media Studies was built up on the works of Tuan (1977) and Cresswell (2008). Accordingly, to Cresswell (2008), Tuan delivers in his book 'Space and Place: The Perspective of Experience' an experimental perspective on the formation of place in everyday living that he called a 'sense of place'. Cuba and Hummon (1993) define Tuan's concept of a *sense of place* in the following way:

> *"[A] sense of place is inevitably dual in nature, involving both an interpretive perspective on the environment and an emotional reaction to the environment.... A sense of place involves a personal orientation towards place, in which one's understanding of place and one's feelings about place become fused in the context of environmental meaning."*

My thesis emphasizes Tuan's notation that place is more than a '"location', while that 'more' is related to the personal experiences of places" (Tuan, 1977). Hence, in accordance with Harrison and Dourish (1996) and Dourish (2006), the attachment towards a place is based on experiences of former, broadly biographical, actions that influence the very personal orientation towards a location and way-finding practices in more general (this is also a basic thesis of Henri Lefebvre's (1991) book 'The Production of Space'). However, in contrast to Dourish, the concept of a 'sense of place' highlights the interplay between a place and one's spatial orientation

towards it, that is constituted in and through the act of moving around. Learning from Tuan (2004), my developed methodological lens to study everyday mobilities as practices suggests that the experienced place is a result from the movement to, from and around a spatial location. As a consequence of this view, way-finding practices are not only shaped by the goal of the people to reach a particular destination and the given infrastructures, but is also shaped by people's interactions, intentions and former experiences of movement in space that need to be studied.

Thus, instead to emphasize the construct of places as cultural and meaningful spaces (Harrison and Dourish, 1996; Dourish 2006), I stress that it is more promising to study how the sense of place is experienced by people in former practices or in their anticipated expectations to visit a certain space. This can be also called as the way how people *orientate* in space along their personal experiences and/or expectations of reaching a place. Studying everyday mobilities as practices means then the detailed examination of people's orientations in space. In Chapter 5 I outlined in very detail how this methodological conception was used to study in particular the way-finding practices of elderly people. Furthermore, this lens was successfully applied to study and understand SID better and to reveal new insights into the needs and requirements of daily mobility habits.

## 10.2 Methods and Research tools

The methodological lens that I outlined in Section 10.1 had major consequences on the methods and tools to research and study everyday mobilities as practices. In this section, I will shortly summarize methodical challenges and how I addressed them. In particular, I will outline the relevance of the probing technique and the WoZ method to study everyday mobility practices. Further, I will outline how the different studies are connected to the framework of design case studies.

### 10.2.1 Mobility probes

Studying how people orientate in space along their personal experiences and expectations towards certain places, needs a detailed understanding about subjective reasoning. However, as I already lined out in Chapter 3 everyday mobilities are deeply grounded in grown structures of personal lifestyles that have been developed mostly over a long period of time. These mobility

patterns are often unconsciously realized as seemingly simple everyday performances. Thus, even if travel mode choices appear as voluntary, deliberate decisions have usually a great impact to shape these patterns that can include complex, multiple factors, such as the personal living situation, the social network or just personal preferences. These patterns are often taken for granted and become visible on the analytical level only. Hence, to study everyday mobilities as practices requires then tools and methods that allow the users and participants to make their mobility choices visible and accountable again to reflect about their reasoning.

In my thesis I developed mobility probes to investigate mobility practices as they were methodically introduced by Boehner et al. (2007) or Wherton et al. (2012) to help participants with their articulation work and to make their overall unconsciously conducted travel from one place to another, recognizable again. In Chapter 5 (*Designing for way-finding as practices – A study of elderly people's mobility* ) I outlined in detail the use of one mobility probe for TIS. In that study the participants' GPS data was tracked from their personal smartphones to prompt detailed descriptions about their daily movements in space. More specifically, images of their tracked daily paths were used to support participants' reporting on occasioned events. Those maps with the tracked paths worked as accounts that allowed the participants to report on their personal experiences of concrete mobility situations. To prepare these probes, the participants were provided with a Google account to assign the GPS data produced by their personal movement tracking. Their behavior was then, with permission of each participant, tracked and recorded automatically on date, time and location by the Google service Location History (https://maps.google.com/locationhistory). During the four-week trial, the participants continued their daily lives while the GPS mobile sensors constantly tracked their outdoor movements. After that period, each participant was re-visited at their home with prepared print outs of the collected data. These print outs illustrated maps that outlined one day of their movements. These hand-outs accomplished a computer-based version that allowed the participants to zoom in and zoom out of the maps, during the interviews. Zooming in and out helped the participants to better orientate on the map. The probes were specifically designed to facilitate the recollection of the sequential order of paths followed, with detailed time information of every measured GPS location available (see Jones et al. (2011) for a similar methodological outline). The web-service additionally allowed choosing between two visualization forms, consisting of a street view or a satellite view (cf. Figure 4, page 104).

Another mobility probe was introduced in Chapter 9 in the study about *Opportunities for Sustainable Mobility: Re-thinking Eco-feedback from a Citizen's Perspective*. This probe builds up on the previous probe and is technically more advanced. It automatically recorded the participants' journeys and visualized the outline with associated modes of transport. The probe was used in a qualitative study that began with a kick-off meeting where it was installed on the participants' own smartphones. From then on, the probe passively recorded their daily mobility for a period of about four weeks. During this period, participants were able to inspect the visualizations of their mobility behavior (cf. Figure 10, page 190), as well as adjust wrongly classified modes of transport, to ensure the stored information was accurate. . It also allowed to show the ecological footprints of the own behavior and in comparison, with the community. After the trail, concluding individual interviews were conducted at the participants' homes.

Both mobility probes (see Chapter 5 and Chapter 9) were used in final interviews to support the reflection about concrete mobility situations and its environmental effects. Thus, using a probe in both studies helped the participants to give rich descriptions about their own mobility behavior and to reflect their personal environmental reasoning. In Chapter 5, the mobility probe supported the participants to follow their past trails and thus, made is easier for them to report about their situated orientation in space. This means, that the participants were able to reflect on concrete experiences or expectations within a certain space. That allowed the reconstruction of the elderly people's way-finding practices and to gain new insights into their daily needs, struggles and requirements to deal with them. The probe in Chapter 9 was technically more advanced than the paper-based version outlined in Chapter 5. However, the visualization within the app on the participants' personal smartphones had no major consequence on the quality of their reflections. From the researcher's perspective the paper-based version was even a little bit handier than the smaller outlines on the smartphone. But the app version was able to provide additional features: it showed e.g. different visualizations of mobility consumption like the CO2 footprint at a certain time and with a certain mobility mode. The use of the probe allowed to study the mobility practices of the participants, too. Therefore, the probe allowed the articulation of new ideas and for further visualizations to enhance the use of EFT. I will further report on this in Section 10.3.

### 10.2.2 Wizard of Oz

Beside mobility probes, I used the WoZ as a method in my thesis to function as a proxy to further investigate on everyday-life mobility practices. The method addressed the methodical challenge to study not yet existing or evolving practices in or as close to real-live environments as possible. Therefore, applied the WoZ approach in Chapter 7 to simulate the user experience of a robo-taxi service and to enable users to anticipate future mobility practices with not yet invented technologies. WoZ, in general, is a technique for prototyping and experimenting dynamically with the functions of a system. In this way, a technical system's performance is simulated and controlled by a human operator – a so-called wizard (Steinfeld, Jenkins, and Scassellati 2009; Wang et al. 2017). I applied the method in Chapter 7 to study passengers' interaction with SAVs and related services in real life settings to explore how passengers experience a robo-taxi service that is simulated by a WoZ approach in their real-life environment? And how can the findings help us inform the interaction design of possible robo-taxi services? As robo-taxis are currently not available, apart from in very restricted test runs, there is little opportunity for any orthodox observational work. For this reason, the WoZ approach was used to simulate robo-taxis in everyday scenarios that are not yet existing.

To minimizing 'study' effects, the participant should experience the WoZ as much as possible as a 'real' robo-taxi service. To address this issue, the 10 participants had relative freedom of choice when, where and how to use the robo-taxi service during one week. The trial was further accompanied by pre- and post-interviews. The participants could hail and use the robo-taxi service for their own purposes over a week. As passengers, the participants were completely relieved of the driving task. Further, we concluded the trial with pre- and post- interviews that were conducted with each participant. Hence, the WoZ set-up included different components that were supported, including: the taxi-hailing; timetable coordination; the robo-taxi; and robo-taxi-passenger communication. The further details are outlined in Chapter 7.

Hence, the WoZ study about the everyday usage of a robo-taxi revealed a fuller picture of passengers' experiences with the service at the different stages of hailing, pick-up, traveling and drop-off. In particular, the study gave insights into four design themes that are not typically addressed in literature so far. The first theme addressed short-term domestication, the second theme relates to the active passenger, the third refers to the passenger experience of the journey, and the fourth theme deals with breakdowns. These insights would not have been possible

without the proper simulation of the service in real-life contexts, in that the participants had relatively freedom to appropriate the robo-taxi service according their personal needs.

### 10.2.3 Appropriation Studies

Studying appropriation of the different solutions for SID turned out as a central key to develop the practice-based approach. Both, the probing technique and the WoZ method supported the analysis of users' appropriation practices. The developed practice perspective to study everyday mobilities (Section 10.1) offered a thorough and adequate basis for studying different kinds of interventions (Wulf et al. 2011, 2015; Rohde et al. 2017). As I lined out in Chapter 3, design case studies are the basic elements to understand the relationship between social practices and the design space for SID to support sustainable practices. In particular, the design case study helps to understand the interaction between the IT design and the appropriation activities over a longer period of time and when these artifacts are rolled out "in the wild" (Wulf et al. 2011, 2015; Rohde et al. 2017; Stevens et a. 2018). Therefore, design case studies typically involve three activities that, in part, build on each other, as I have already outlined above in Chapter 3. These include the context study, the design study and the appropriation study (Wulf et al. 2011, 2015). Hence, these parts can be overlapping, interleaving, and recursive, as Stevens et al. (2018) wrote:

> *Although there is a natural order of starting points with regard to the activities' temporal structure, the overall approach is reflective and, therefore, iterative. The activities are not strictly consecutive but are continuing: once an analysis of existing practices has started, it does not make sense to stop reflecting upon the trajectory of existing practice; rather, it continues throughout the design and the study of the artifact's appropriation. Once the design has started, it may be continued in several iterations, although the technology has already been introduced to potential future users.*

Hence, this allows a wide range of variations, how a design case study is actually conducted to serve the needs of the addressed practices. This can be also found in the conducted studies that are part of the findings section (Chapter 4 to Chapter 9). All studies are related to one or two of the three steps of empirical pre-study, prototyping and appropriation study. The documentation in the different studies did not always explicitly outline the connection to the design case

study framework, in particular, when the study covered only single stages of the process. Moreover, the outlined studies often evolved in conjunction with unanticipated opportunities that organically emerged when researching practices. These were partly due to the wider collaboration between researchers and users or participants and the further unpredictable context of research and development projects that normally include different stakeholder groups with their own interests and different project goals. Also, the research and development of SID always needed to deal with the contingencies of practice and innovation processes (Meurer et al. 2018). However, the analysis in all six studies was intended to gain a better understanding of the different appropriation practices of the users/participants to design for a practice-based SID. The documentation in the different studies focused less on the design case study process in general, but emphasized rather the outline of concept building, methodical research for transferability and the development design themes.

Both, mobility probes and the WoZ method needed to address two critical points to study users' and participants' appropriation practices in everyday mobility contexts: addressing these issues, in particular, mobility probes and WoZ turned out as supportive tools and methods for enabling the participants to make detailed descriptions about their complex and often habituated mobility routines. This allowed to explore and to (further) develop new technologies in real-world settings. Both tools/methods complemented therefore the approach of grounded design with its focus on appropriation. Further, the combination with the Living Lab approach was quite helpful, because it allowed to try out the methods and tools in a trustful stakeholder relationship and to observe technology appropriation over several years (e.g. Chapter 5). The Living Lab also helped to speak openly and in detail over concrete mobility situations, as it fostered long-term engagement and mutual learning processes. This allowed to gain a rich picture about the individual mobility contexts of the participants, as I outlined in much greater detail in Chapter 5. However, it is further mentionable that the set-up of a living lab infrastructure cause a considerable effort. That includes e.g. in particular three topics that are further outlined in Meurer et al. (2018): a) domestification - giving a technology a place in the participants' life – as a key activity to support in view of sustainability; b) building the capacity for continuing and evolving use (appropriation) as a condition for more complex levels of sustainability; and c) the scalability and transferability of design outcomes to other groups of users or sites.

## 10.3 SID for Everyday-Life Mobilities

In the field of mobility research, traditional design methodologies are strongly influenced by models on rational behavior. In this respect, an important contribution of the outlined praxis-based approach is to make underlying assumptions of such design methodologies visible and re-frame the design space from a different angle. In the following I will outline some of the design potential for TIS, SMS and EFT that became visible due to the practice-based approach.

Regarding ***TIS*** the practice-based approach helped to re-frame the design space to take sustainability into account. Respectively environmentally friendly mobilities, Chapter 9 showed that decisions to take public transportation are not primarily based upon factors suggested by rational choices theories (such as cost, transport time, and comfort), but can be experienced differently by various user groups. This is also consistent with the works of other authors (De witte et al. 2013; Mokhatarian et al. 2015). I also outlined in Chapter 9 that to support more environmentally friendly mobilities, alternative mobility modes need to fit the respective lifestyle better than using the own car. Doing so, there might be possibilities to e.g. enhance positive experiences of sustainable transport by linking travel planning tools to other services, such as fitness tools or time reporting systems at workplaces when people are working on the train.

Moreover, the applied practice-based approach offered great potential to support socially sustainable mobilities with TIS. The focus to explore on the experiences and expectations when moving around allowed to picture the special needs and requirements of certain user groups like (the young) elderly people. In that regard the studies with young elderly people that were reported in Chapter 4 and Chapter 5 showed that already minor health issues can have a high impact on the selection of way-finding choices. The studies have shown that the absence of information on reachability and environmental access could lead easily to in-securities in daily mobilities and might even prevent journeys when destinations are less well known for one reason or another. Further, both studies showed the great potential of TIS for the respected user group in developing new confidence and trust in planning trips to as yet unknown places, whether far away or not. Also, my research on elderly people's mobility practices uncovered more subtle elements: It made dynamic aspects of aging visible, by recognizing changed preferences around be-loved places. The findings indicated that young elderly people have their own preferences for meeting points and age specific activities. Those preferences reflect what appears to be some typical lifestyle factors. This can help to understand TIS beyond mode-

choices, but regarding choices to identify the appropriate places, events or activities for special user groups.

Regarding ***SMS***, I demonstrated in the Chapter 6 how the practice-based perspective can be applied to investigate on social factors of a sustainable living. My findings shed light on elderly people's experiences with ridesharing that go beyond functional issues such as payment systems (Allen 2009) or matching algorithms (Steger-Vonmetz 2005; Teodorović and Dell'Orco 2008). Instead, my analysis on ridesharing practices of elderly people identified 'mobile independence' and 'decisional autonomy' as central values. Regarding the value of "mobile independence", I have identified the principle of reciprocity. That means that the reciprocity of the shared practice must be constantly negotiated in the driver-passenger relationship in delicate ways. This made the relationship between both parties, the driver and the passenger, an important factor in formal and informal ridesharing practices that needed to be balanced to keep mobile independence and individual autonomy. Further, "decisional autonomy" presents the capability of flexible movement. It means having the capacity to make decisions about where, when and how to travel on one's own. This makes the own car, where possible, a preferred option that allows the older driver spontaneity, and a sense of control that cannot be replicated by other transport modes. While ridesharing creates some difficulties in relation to decisional autonomy where, when and how to travel, the findings showed also the importance of shared activities. Two kinds of shared activities seem to outweigh this lack in decisional autonomy when it comes to ridesharing: firstly, in spontaneous ride offers towards a shared event, and secondly in long-term ridesharing arrangements based on a regular and organized schedule. Further, the findings in Chapter 9 suggested that SID for ridesharing should be integrated into local community places like workplaces, schools and sports teams, too, to encourage ride-sharing cooperations. Also, tools like location-based chats could be helpful to explore the local demand and supply, as well as to endorse knowledge exchange and discussions about environmentally friendly mobility solutions. Hence, the findings of this thesis stress that the values of "independence" and "decisional autonomy" should be reflected in a sensitive ridesharing design for elderly people, but might also supportive for other user groups. Lastly, the WoZ study about the everyday usage of a robo-taxi revealed a fuller picture of passengers' experiences with the service at the different stages of hailing, pick-up, traveling and drop-off. In particular, the study gave insights into four design themes that are not typically addressed in literature so far. The first theme addressed short-term domestication, the second theme relates to the active passenger, the third

refers to the passenger experience of the journey, and the fourth theme deals with breakdowns. Further, findings showed some indicators that services like robo-taxis could foster social relationship bonding supported by the free time and release of the driving task.

Regarding ***EFT***, Chapter 8 and Chapter 9 shed light on the problem of the (often unreflected) top-down perspective in SID to change towards more environmentally friendly consumption patterns. EFT are often criticized for reinforcing sustainable norms, presuming rationality and taking a paternalistic perspective (Brynjarsdottir et al. 2012; Carrel et al. 2012; Jariyasunant et al. 2015; Zhang et al. 2015). In contrast, the practice-based perspective helped to address some of these shortcomings by understanding people's experiences and expectations within everyday-life mobility consumption. In particular, the study in Chapter 9 demonstrated that EFT can serve as a tools to reflect upon daily mobility habits, rather than to indicate behavior change from a top-down perspective. It shows that participants were highly interested in understanding and learning about environmentally friendly mobility. An important point to mention is that my study turned out that knowledge and information about how to interpret mobility data should not directly be used for persuasion. Rather it should be used to support users in developing a better awareness of the consequences of their personal mobility actions and of environmental pollution in more general. The findings indicated that eco-feedback should provide citizen-consumers the opportunity for (self-) reflection. That means to learn about the own mobility habits and its effects upon the local environment and community, without being judged. One possibility among others is to enhance EFT by having visualizations that show environmental wellbeing or pollution as a collective achievement or by visualizations that increase awareness about what is achievable in a local community.

Also, by extension, Chapter 8 and Chapter 9 outlined that ETF could foster mutual exchange between a wide variety of stakeholder groups including the local municipal city services to encourage mutual learning and participative innovation processes to advance EFT. On the side of the local municipal city services EFT could play a significant role as a strategic management tool in urban transport development. For instance, it could provide data for traffic assignment models on traffic volumes on road segments and overviews about the balance on the demand and the supply of public transportation or the need for new bike-lines.

# 11 Critical Reflection and Future Works

In this final Chapter, I firstly provide a short summary of this thesis. Secondly, I discuss limitations and thirdly, I outline possible future works that can build up on the outlined contributions.

## 11.1 Short Summary

This thesis contributes to the development, the application and better understanding of a practice-based approach in SID for everyday mobilities. Therefore, the thesis was sectioned into three parts:

In the **first part** I outlined the foundations of the thesis: In Chapter 1 I started with the motivation to study environmentally and socially sustainable everyday mobilities and outlined related works in Chapter 2. Therefore, I introduced three major of the current research fields that include TIS, SMS and EFT. I showed that conventional design approaches in all three research fields were often criticized for being too normative and too paternalistic to change effectively grown habits of everyday mobilities. To overcome the behavioristic stance, I suggested a practice-based approach in Chapter 3 and lined out its potential for the three research fields of TIS, SMS and EFT. That puts the (sustainable) every day mobilities as practices in the center and motivates the research question of how to actually apply a practice-based design approach to support sustainable mobilities in everyday-live settings?. I further outlined a need to address this question on three different levels: regarding to theoretical concepts, methods and design. In Chapter 4 I then introduced the research design of the following studies, including the methodological and methodical framing and setting.

The **second part** is the main part of this thesis and entails the 6 published papers that form the core of this cumulative dissertation. This part is sub-divided into six Chapters (Chapter 4 to Chapter 9), while each chapter presents one paper. Chapter 4 (*Becoming a smartphone user*) and Chapter 5 (*Designing for way-finding practices*) contributed mainly to the research field of TIS. In both studies I explored the usage of TIS by elderly people within its potential of social sustainability. Therefore, I conducted in Chapter 4 an extensive long-term study on elderly people's appropriation practices of smartphone usage over three years, and a shorter study in Chapter 5 to study the very detailed and situated way-finding practices of elderly people with the help

of a mobility probing technique. Both Chapters 4 and 5 show how TIS can support the particular user group in their everyday mobility practices to overcome experienced mobility barriers and insecurities, re-establish trust and confidence in the own capabilities.

Chapter 6 (*Social dependency and mobile autonomy*) and Chapter 7 (*A Wizard of Oz Study on Passengers' Experiences of a Robo-Taxi Service in Real-Life Settings*) are basically related to SMS. In Chapter 6 I studied the informal ridesharing practices of elderly people and compared them to other forms of their everyday travelling in an interview study. The focus on the elderly participants' existing mobility practices (including informal ridesharing) and why they prefer certain modes in certain life situations allowed concrete insights in their mobility needs and expectations when it comes to ICT supported ridesharing. In Chapter 7 I explored passenger experiences within a robo-taxi service. As a real robo-taxi service was not legally available to explore its appropriation in users' real world environments, I chose a WoZ method to deal with that situation and imitate such a service. The findings gave a rich picture about the requirements that a robo-taxi service needs to fit to serve the different stages of hailing, pick-up, travel, and drop-off in real-life situations.

Chapter 8 (*Bridging location-based Data with mobile phones*) and Chapter 9 (*Opportunities for sustainability design*) contributed mainly to the research field of EFT. Chapter 8 outlines a conception to select personal mobile phone data to detect individual mobility patterns. This paper presents basically a technical solution to combine context data and manual annotation with automatically selected tracking data within an EUD approach. The results showed that the interpretation of tracked mobility data is highly context sensitive and therefore should be open for adjustments by its users. Chapter 9 studied the potential of mobile phone data to support sustainable mobility practices from a citizen perspective. Therefore an interview study complemented with a mobility probe was conducted. The mobility probe was a tracking application that build up on the findings gathered in Chapter 8. The study has sought of how a citizen's perspective can be applied to sustainable HCI to inform and inspire the design of SID to support a more grounded transition towards sustainable mobility practices.

In the **third part** I returned to the research question of how sustainable everyday mobilities can be supported by a practice-based design approach and answered it in a nutshell within three different levels: theory, methods and design.

*First*, regarding theory I outlined the need for a new conceptual framing to study everyday mobilities as evolving practices (Section 10.1). Therefore, I applied Harrison and Dourish (1996) and Dourish (2006), distinction of 'space' and 'place' as a starting point and extended their conception with Tuan's (2004) concept of 'sense of place'. The concept of a 'sense of place' highlights the interplay between a place and one's spatial orientation towards it, that is constituted in and through the act of moving. Thus, instead to emphasize the construct of places as cultural and meaningful spaces (Harrison and Dourish, 1996; Dourish 2006), my lens suggests that the experienced place is a result from the movement to, from and around a spatial location (Similar, to Tuan (2004)). This allows to articulate the orientation towards a certain place on the basis of people's interactions, intentions and experiences of former, broadly biographical, actions that influence the very personal orientation towards a location. Hence, the theoretic framing of a practice-based approach to study every day mobilities served as methodological conception for the outlined studies. In particular, in Chapter 5 I showed how mobilities as practices can be studied in detail and its value for design in HCI and SID.

*Second*, I stressed methodical consequences of the theoretical lens and its methodological approach that is sensitive towards evolving practices over the time. In particular in Section 10.2 I outlined how the understanding of everyday mobility practices as people's orientation towards a place, had a major impact on the methods of investigation. In particular, the methodical conception had to deal with two challenges: (a) to make users' orientation as former experiences and expectations towards a certain place accountable. And (b) to enable users to anticipate future mobility practices with not yet invented technologies. To address (a) I suggested and made use of mobility probes. In particular in Chapter 5 and Chapter 9 I showed how the probing technique supported the participants to make their overall unconsciously conducted travel from one place to another, recognizable again and to help them with the articulation work. Dealing with (b) I applied a WoZ approach in Chapter 7 to simulate the user experience of a robo-taxi service. That allowed to make detailed observations on how users' adopted the service in their everyday-life and to gain insights into their personal user experiences through follow-up interviews. Further, I argued how the two methods of mobility probes and WoZ fit seamlessly into the grounded design approach and support appropriation studies within the Living Lab context. In my studies that was particularly stressed in Chapter 4 and 6.

*Third*, it turned out that the practice-based approach offered a new perspective on SID to identify design innovations that differ from the more traditional behavioristic and normative approaches (Section 10.3). This thesis has shown, that design, that follows a practice-orientated conception of daily mobilities as practices and a fitting methodical framing that allows to study daily mobilities as evolving practices, brings up new insights to the design. In particular, it shows that TIS and SMS are more than tools for an optimized routing (mostly regarding time and cost of travelling), but have a strong potential to provide orientation, safety, confidence and trust for particular user groups who feel limited or restricted within the use of public transportation, mobility needs to be understood as an internal part of the social life (Chapter 4-7). Also, the new perspective and methods helped to explore the new design potential for EFT. It showed that if mobility is not only addressed as a derived demand to e.g. switch mode towards more sustainable transportation options, ETF can be applied to create new forms of awareness and consumption literacy and how such tools can be integrated seamlessly into people's lifestyles. Further, I found that ETF can foster new relationships with other citizens in the same city, the city itself, and with the local municipal city services (Chapter 8-9). Finally, Chapter 11 ends with an overall summary, critical reflection and the outline of possible future works.

## 11.2 Limitation

Studying how SID for everyday mobilities can be better supported with a practice-based approach was also limited by several factors that I will summarize in this section. In particular, three main critical factors need to be mentioned:

First, in this thesis only a limited range of user groups and settings were reflected. In particular, social sustainability was mainly studied within the user group of (the young) elderly people. Also, all participants of this very special user group of the young elderly people lived in the same region: a university city in Western Germany. That city is part of a specific economic, political and legal environment within which the study was pursued. Like every other city, this has its own characteristics regarding its infrastructure, topographic landscape and history of supporting environmentally sustainable mobility practices (or not). Also, the specific kind of the user group can have a high impact in what way social and economic aspects such as the accessibility of the work place or the convenience of the travel experience can be in opposition to the environmental considerations. Thus, the selection of the selected participants was by no

means representative for a wide range of user groups. However, I showed in this thesis on the example of the particular group that mobility situations and needs are highly individually for different parts of the population and in different locations. I showed how mobility is deeply entrenched in elderly people's everyday needs, their practices and lifestyles that influence their local travel decisions. Consequently, the application of a practice-based approach will support different SID that vary considerably across user groups and locations. Therefore, it is important to continue this kind of work across a range of different communities and user groups around the world. E.g. there is a great need for studies of how sustainable mobility is negotiated and organized in the micro-economies of households and their lifeworld contexts, such as in partnership relationships, parent-child relationships or in companies.

Second, it is important to mention that only a limited range, namely TIS, SMS and EFT of SID were studied in this thesis, even though these are major topics to deal with sustainable mobility. At the same time the three research fields of TIS, SMS and EFT are quite comprehensive with many different facets that could not all be addressed in this thesis. Dealing with this challenge, the focus was explicitly not only on the tree research fields, but rather how a practice-based design approach can be applied to support more sustainable mobility practice in more general. In that regard the three research fields of TIS, SMS and EFT served as examples to explore the adaption of the practice-based approach. This provided many new insights on current research gabs in the tree fields. For instance, being aware about the importance of social sustainability was something, that is still widely neglected in SID. Some findings also indicated that social sustainability can foster environmentally sustainability. As an example, Chapter 9 showed the importance to go 'beyond the individual' to explore on collective mobility practices of a local community. Also, Chapter 6 indicated that supporting social values like 'decisional independence' and 'mobile autonomy' support a shared value system that should be reflected in SID for SMS.

Third, evaluating the impact of SID for social and environmental sustainability is extremely difficult and hard to judge. This is not only difficult in terms of scaling. Also, the complex grown nature of mobility patterns can make difficult to predict the effects of insulated solutions. They can often turn out as either ineffective or produce problematic unintended effects, such as rebound-effects. Examples are the introduction of free Park and Ride options to reduce congestion in inner urban centers, which tend to attract more car travel (Parkhurst et al., 2012: 324ff); or free bus rides which induce low value travel and lead to reduction of cycling rather

than of car use (van Goeverden et al., 2006). Because of the qualitative approach in this thesis there is no measured evidence, if and on what scale the innovations for SID regarding TIS, SMS and EFT have a quantifiable and statistically relevant effect on social or environmental sustainability. Hence, in the conducted studies rather selected an explorative approach to co-operate in Living Labs with smaller groups of users (between 8 and 19 participants) in an intense cooperation and over a long period of time. That allowed to get a detailed understanding about the local mobility practices and to rely the research along the evolving mobility practices. That required also an iterative design process that needed a constant adjustment along the findings. However, that has nevertheless the consequence that reliable numbers about the effectiveness of the different SIDs are missing, but could inspire future works to address these points.

## 11.3 Relevance and Future Work

In summary, this thesis contributes to a rising and urgent demand to support sustainable everyday mobilities. In times of an increasing digitalization of transport infrastructures, SID gets more and more into the spotlight, to make a difference on individual mobility decisions (A. Aguiléra, Guillot, and Rallet 2012; Aguilera and Boutueil 2018). However, conventional designs to support sustainable mobilities were often criticized as being too rationalistic and normative that ignore the complex grown nature of the lived mobility patterns. Such solutions often turned out as either ineffective or to produce problematic unintended intentions, such as rebound-effects (Shove 2010; Banister and Button 2015). To address the complex grown nature of every-day mobility patterns, I focused in this thesis on a practice-based design approach to put the habituated practices into the spotlight. That had influences on different levels:

First, a major relevance of this thesis was the formulation of a theoretical perspective on everyday mobilities as practices and its methodological outline. As an alternative stance to the behavioral and normative approaches, I supposed to study participants' orientation along their very personal 'sense of place' that includes their past experiences and upcoming expectations towards their journey to go to a certain place. Such a methodological stance was often claimed in HCI studies and can be easily adapted on future studies about everyday mobilities. The outlined methodological research stance in Section 10.1 can support other micro studies that pay attention to complex mobility situations, infrastructural resources, grown mobility habits and

travel expectations such as joy and excitement as well as fears and uncertainties. A further benefit of this methodological stance to focus on people's 'sense of place' is that it allows to "see" everyday mobilities with their eyes and to get aware of daily habits, struggles and necessities, as it allows to focus on specific user groups.

Second, the value of this thesis laid in its methodical innovations. To apply a practice-based approach in SID two main challenges needed to be addressed: a) to study practices that are mostly overall unconsciously conducted and highly interwoven in everyday lifestyle choices. And b) to study not yet existing or evolving practices as close to real-live environments as possible. This thesis allowed deep methodical insights how to support appropriation studies with mobility probes and the WoZ method (outlined in Section 10.2). The mobility probes and the WoZ method turned out as supportive tools to enable the participants and users to make detailed descriptions about complex and often habituated mobility routines. Further, the tools allowed to explore new technologies in their real-live environments. Both tools complement the approach of grounded design with its the focus on appropriation. They allow to study the evolution of new practices that evolved over time. In follow-up research studies, it would be interesting to include the local municipal city services more intense in the Living Lab set-up and in the actual design processes. Studying participatory design processes between both groups, the municipal city services and the local citizens, could bring new insights how citizen engagement can foster social and environmental sustainability. Further, there is an urgent need to improve the accuracy of digital mobility probes, as it is still difficult to differentiate correctly between different kinds of 'in vehicle' transportation modes. In particular the separation between taxi, bus, carsharing, and ridesharing is still a problem. Also, information about the number of passengers is not automatically available. The prototype that was used in Chapter 8 and 9 included therefore the option to add manual information and to allow corrections, if necessary. Other technical issues are due to pertain spatial accuracy and energy limitations of the battery. Further, such tools can profit form advanced smart data visualizations.

Third, but not least, the practice-based approach emphasized new innovations for SID. All findings that were presented in the Chapters 4 to 9 showed that accounting for mobility practices helped to get a rich picture how daily mobility is experienced in daily life. This helped to complement individualistic, normative top-down approaches and to identify new, innovative design requirements. E.g. it helped to design for specific user groups (like in particular for the elderly people) and social sustainability. Regarding environmentally friendly sustainability the

findings allowed a better understanding to design for the literacy of environmentally friendly mobility behavior with supportive visualizations. A better overview of the different SID can be found in Section 10.3. In future works, it would be highly interesting to further explore the mobility needs of different user groups like families, restricted mobility people, or people that are new in a city and may have a different cultural background. Also, the participative research in Living Labs with the municipal city services could shed new light on actual needs to support for social and environmental sustainability in cities and villages that can inspire new SID.

Summarizing, this thesis complements individualistic approaches that are based on abstract rational choice models to support sustainability with a practice-based perspective and showed its potentials as well as ways to implement the approach into research. Moreover, my thesis emphasis the importance to understand and appreciate daily mobility as it is: a set of performative practices that evolve over the time to often stable mobility patterns that are part of individual life-styles. Therefore, I developed a practice-based approach that takes the complexity of everyday-life mobility needs into account to inspire innovative SID that are compatible with real-world situations. Further, to make sure that social and environmentally sustainable solutions are actually usable in practice, this thesis showed the importance of the interplay between theoretical conception, methods and the actual design outcomes for SID in socio-informatics.

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