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BY
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DENMARK

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ENGLISH SUMMARY

Mobility is central to our everyday lives, for commuting, for combatting a sedentary lifestyle, for leisure, etc. Digital technologies are designed and targeted to support people mobility, from travel planners and real-time traffic information to enabling shared modes and on-demand mobility, but we need empirical knowledge about in what ways these digital technologies support mobility. In particular, little HCI research is concerned with how digital technologies and new modes of mobility impact mobility for rural and urban contexts.

This thesis investigates mobility in rural and urban contexts by studying the use and interaction with digital technologies for mobility. 1) to characterize rural and urban mobility. 2) to illustrate and discuss how digital technologies support people mobility. 3) to focus on how studies of mobility and digital technology use for rural and urban areas can be planned and carried out.

The contribution of this thesis is based on four papers that present four user studies in the field. Whereof two paper contributions portray two matters of rural mobility: how on-demand mobility services attempt to accommodate the last mile problem and integration of digital technologies for mobility. Two papers depict urban mobility on two topics: digital technologies for moving volunteers with first aid competencies purposefully and promptly to nearby cardiac arrests in public places and how shared micromobility adapts to hybrid urban mobility.

The empirical findings of this PhD project demonstrate that rural mobility is often characterized by car-based mobility. A low population density impacts the potential demand and thus a high frequency of public transportation is not profitable. Mobility service gaps between rural dwellers and transportation hubs referred to as the first and last mile are challenging to accommodate. Urban mobility is characterized by having an abundance of mobility options, private, public, and shared mobility modes are perceived as highly flexible, although adversely the many mobility options often result in congestion. New modes of hybrid micromobility have yet to establish their purpose and place in the urban mobility landscape. I propose that digital technologies can support rural and urban mobility through integration across public and private modes of mobility, creating flexible ad-hoc routes, enabling shared modes of mobility and mobilizing people. Crucial to success is that mobility information is transparently, dynamically, and timely communicated and that reliability of mobility is high. Studying digital mobility using in-situ methods can be carried out if mobility can be planned or is highly visible, but is not suitable for all mobility contexts.

The PhD stipend that made this thesis effort possible is financed partly by the DiCyPS research centre, funded by Innovation Fund Denmark. Also partly financed by the Danish north region transport authority: Nordjyllands Trafikselskab (NT).

DANSK RESUME

Mobilitet er centralt i vores hverdag, når vi pendler, modarbejder en stillesiddende livsstil, i fritiden, m.m. Digitale teknologier er designet og målrettet til at støtte person mobilitet, fra rejseplaner og realtids trafikinformation, og til at muliggøre delemobilitetsformer og on-demand mobilitet, men vi har behov for empirisk baseret viden omkring hvilke måder disse teknologier understøtter mobilitet. Særligt omhandler kun lidt HCI forskning hvordan digitale teknologier og nye former for mobilitet påvirker mobilitet på landet og i urbane områder.

Denne afhandling undersøger mobilitet på landet og i urbane områder ved at studere brugen af og interaktionen med digitale teknologier for mobilitet. 1) at karakterisere landlig og urban mobilitet. 2) ved at illustrere og diskutere hvordan digitale teknologier understøtter mobilitet. 3) ved at fokusere på hvordan studier af mobilitet og brug af digitale teknologier på landet og i urbane områder kan planlægges og udføres. Bidraget for denne afhandling er baseret på fire artikler, som præsenterer fire studier i felten. Hvoraf to artikelbidrag portrætterer to sager, som omhandler mobilitet på landet: hvordan on-demand mobilitet forsøger at imødekomme last mile problemet og integration af digitale teknologier for mobilitet. To artikelbidrag udfolder urban mobilitet over to emner: digitale teknologier til at bevæge frivillige med førstehjælpskompetencer målrettet og prompte til et hjertestop i nærområdet i offentligt rum samt hvordan delt mikromobilitet tilpasser sig hybrid urban mobilitet.

De empiriske resultater fra dette PhD projekt demonstrerer, at mobilitet på landet ofte er karakteriseret ved biltransport. En lav befolkningstæthed påvirker potentialet for forespørgsler og dermed er en høj frekvens af offentlig transport ikke profitabel. Huller i mobilitetsdækningen mellem landboere og transport knudepunkter, refereret til som first og last mile er udfordrende. Urban mobilitet er karakteriseret ved et væld af mobilitets valgmuligheder, privat, offentlig og delemobilitetsformer og bliver anset som meget fleksibel, på trods af, at de mange mobilitetsvalg ofte resulterer i trafikprop. Ny hybrid mikromobilitet har stadig til gode at etablere dets formål og brug i det urbane mobilitetslandskab. Jeg foreslår at digitale teknologier kan understøtte land og urban mobilitet gennem integration mellem offentlige og private mobilitetsformer, skabe fleksible ad-hoc ruter, muliggøre delemobilitetsformer og mobilisere personer. For success er det vigtigt, at mobilitetsinformation er transparant, dynamisk og rettidigt kommunikeret og, at pålideligheden af mobilitet er høj. At studere digital mobilitet ved brug af in-situ metoder kan udføres, hvis mobiliteten kan planlægges eller er meget synlig, men dette er ikke passende for alle mobilitetskontekster.

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THESIS DETAILS

Thesis Title: Rural and Urban Mobility: Studying Digital Technology Use and Interaction

PhD Student: Maria Kjærup, Aalborg University

PhD Supervisor: Professor Mikael B. Skov, Aalborg University

The following four papers are the foundation for the contribution of this thesis:

1. **Maria Kjærup**, Mikael B. Skov, and Niels Agerholm. 2020. Digital-Enabled Last Mile: A Study of Passenger Trips in Rural, Low-density Populated Areas. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3313831.3376509

2. **Maria Kjærup**, Mikael B. Skov. 2021. Transportation and Technology in Rural Denmark: Communities of Mobility. Submitted to: The Australian Conference on Human-Computer Interaction (OZCHI’21) – currently under review.

3. **Maria Kjærup**, Mette Elsborg, Mikael B. Skov, and Anders Bruun. 2021. Available Anytime Anywhere: Investigating Mobile Volunteer Responders for Out of Hospital Cardiac Arrest. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (CHI '21). Association for Computing Machinery, New York, NY, USA, Article 647, 1–13. DOI:https://doi.org/10.1145/3411764.3445208

4. **Maria Kjærup**, Mikael B. Skov, Niels Van Berkel. 2021. E-Scooter Sustainability – A Clash of Needs, Perspectives, and Experiences. In *Proceedings of the IFIP Conference on Human-Computer Interaction* (INTERACT’21). Springer LNCS. DOI:https://doi.org/10.1007/978-3-030-85613-7_26

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CHAPTER 1. INTRODUCTION

In this thesis I investigate mobility and in particular people mobility with a focus on digital support for rural and urban areas. According to Creswell, while highly unspecified, mobility in the western world has a lot of meaning attached to it including progress, freedom, opportunity, and modernity [22]. Creswell further argues that the simplest definition of mobility is getting from point A to point B and thus it involves a displacement, moving between locations, either towns or cities or even just a few centimeters apart [22]. In this thesis I adopt Creswell's definition and understanding that mobility is both the movement from A to B, but also a cumulative effect of meaningful movements that happen when unpacking the line between these points. He gives the following illustrative examples: moving your hand, walking, dancing, exercising, driving to work, moving home, going on holiday, marching, running away, immigrating, traveling, exploring, attending conferences. I will use traveling or making a trip as instances of people mobility facilitated by digital technologies e.g. as often seen in research on travel planning or trip chaining [9,122].

Sheller and Urry reason that mobility has a constitutive role in the functioning of most social institutions and social practices [112]. Therefore, mobility research must examine a range of complex combinations of mobility, of which they give the following examples: corporeal travel of people, physical movement of objects, virtual travel often in real-time transcending distance, communicative travel through person-to-person messages and imaginative travel [112]. In this thesis I focus on people mobility, meaning people's everyday patterns of movement. I take inspiration from Dourish and Brewer, who argue that everyday movements impact our sense of spatial organization and in extension, technologies impact our mobility and vice versa [12].

Today, mobility is often associated with access to and the use of cars, mainly due to their flexibility of mobility. According to Canzler and Knie, a modern lifestyle is closely linked with the ability to move spatially freely and individually; hence the private car has long been a symbol of high status [16]. However, in the face of urban congestion and climate change, the privately owned car is slowly losing its status and promise of unhindered mobility during rush hour periods when it is most crucial [16]. Canzler and Knie argue that as the close link between modernity and private car use begins to dissolve, it makes way for new attitudes towards urban mobility and in particular for digital options that allow for mobility without a direct need for individual vehicle ownership, but this vision currently lacks market support [16]. In line with this, Banister concludes that if mobility is viewed solely as a derived demand, there is no room for considering people mobility that is carried out as a valued activity in itself and this may result in the failure of new mobility initiatives that represent more flexible interpretations of why people travel [4].

In this introduction I will outline rural and urban mobility, respectively, in order to lay a foundation for understanding mobility in contexts that have different defining characteristics. Following this, I will show how digital technologies have opened possibilities for how people carry out mobility, in particular during the last decade and point to some of the current debates on what roles digital technologies should play in future systems of rural and urban mobility. Finally, I will present considerations for studying mobility in rural and urban areas within the framing of Human-Computer Interaction (HCI).

1.1. RURAL AND URBAN MOBILITY

Increasing urbanization has resulted in, for the first time in history, the global urban population outnumbering the global rural population [127]. Projections predict the global urban population to increase to a share of 68% by 2050. According to the UN, this rapid urbanization demands successful management to accommodate the need for e.g. housing, transportation, energy systems and other basic service infrastructures like education and health care. Simultaneously, rural populations are also increasing slightly, emphasizing the need to consider improvement of both urban and rural lives, and strengthening of urban-rural links, to achieve sustainable development [127].

Urban mobility is often characterized by 1) Multiple mobility options [16,33,47,86,123], 2) short distances [86,123], and 3) high density [16,47,48]. First, Oostendorp et al. argue that people in urban areas have good conditions for mobility, exemplified by a dense public transport network and opportunities for walking and cycling [86]. They distinguish between two concepts to describe utilizing multiple modes of mobility: multimodal and intermodal. Multimodal is defined as the use of different mobility options for different purposes over the course of a week, whereas intermodal is described as chaining different mobility options during one trip [86]. An increasing number of shared mobility options exist in urban areas, known as demand-responsive transportation, e.g. rental bikes and e-scooters, ride- or car sharing [33]. Second, the distances between available options of mobility are relatively short in urban areas, which increases the accessibility of a number of destinations [86]. Tellioğlu et al. also state that accessibility is central for the success of mobility services, but complex to implement as it requires balancing people's often contradicting mobility needs and the introduction of innovative technological developments in mobility [123]. Third, urban areas are growing ever denser, both in terms of population and in terms of the number of vehicles on the road, resulting in more numerous and diverse mobility options, but adversely also high occurrences of congestion and pollution from emissions [47,48]. Building wider roads is expensive and time-consuming and has previously not shown to lessen congestion, according to Goodall et al. [48]. With this in mind, Canzler and Knie argue that ridesourcing and liftsharing promises seamless travel without having to build new infrastructure and in addition, the accompanying digitalization is fundamentally changing the roles of producers and consumers of mobility [16]. However, there are also indications that these shared mobility options, in particular car-based, may be exacerbating challenges with congestion and pollution [48,128]. Policy efforts have been put in place by the European Commision to mitigate urban mobility issues like traffic congestion, air pollution, road safety and noise, so-called Urban Vehicle Access Regulations (UVAR) that encompass different regulations, restrictions and bans [36]. Banister points to a contradiction in wanting to speed up travel times, but also slow down urban traffic for environmental and safety reasons [4]. He further argues that banning cars altogether would be difficult to achieve and would be perceived as going against notions of freedom and choice; instead he argues that urban areas should be designed at a suitable scale to encourage public transportation, cycling and walking [4]. Adding to this, Tuncer and Brown argue that a straightforward solution in dense urban areas is the re-allocation of space currently reserved for cars to lighter forms of mobility [125].

Rural mobility is often characterized by substantially different opportunities and limitations compared to urban mobility: 1) few mobility options [37,50,52,129], 2) long distances [37,50,129] and 3) low density [23,129]. In fact, one can argue that most research points to innovative opportunities in urban mobility (as is illustrated above), while rural mobility is mostly described in terms of limitations and problems. The lack of mobility options is exemplified by the findings of the SMARTA project, funded by the European Commission with the vision of establishing and evaluating innovative initiatives for rural mobility, as they state that the reality for many rural areas is few buses, even fewer train stations and an almost total dependence on cars [37]. This reality is echoed by Gray et al., who in particular point to a dominance of the role of the privately owned car for mobility in rural areas. Coupled with low accessibility of public transportation, Gray et al. warns that rural residents without access to a car will often experience a high degree of geographic isolation and potentially amplified effects of poverty [50]. Hardy et al. additionally emphasize that rural areas, in high-income countries, have a range of unique infrastructural problems. However, they also point to high-income and developed countries as possibly rich spaces for HCI researchers and designers, to characterize these issues in order to build a solid foundation of knowledge [52]. Carroll and Rosson describe the iconic depiction of village lifestyle as Neolithic: a group of around 150 individuals pursuing a mostly agrarian economy with a modest amount of role specialization (e.g., millers and smiths). But, further underlines that this depiction is far from how contemporary villages are organized [18]. In a feudal society, ideas about mobility as freedom would have made little sense, as people were bound to their land. However, as people began moving into the cities, the ideas of mobility changed [22]. Velaga et al. conclude that rural areas are characterized by having dwellings distributed over large geographical areas. In addition, Velaga et al. also argue that rural dwellings are characterized by low-density populations, which discourages widespread public transportation as a financially justifiable option, since consequently demand is uncertain and often low [129]. Daduna investigated the evolution of public transport in rural areas and points to two developments that foreground the future of rural mobility: the availability of autonomous vehicles and the almost complete digitization of transport information [23]. He argues that timetable-based mobility services form a basic network, e.g. (regional) rail transport, regional bus and school bus, but also new forms such as innovative taxi services, car- and ridesharing and on-demand (autonomous) transportation are necessary to provide connected mobility services. However, Daduna emphasizes that a mandatory prerequisite for the successful integration of new mobility services in public transportation is interconnection with existing services, not their substitution [23].

While rural and urban mobility seem at first look to have opposing characteristics, both are attempting, at different speeds and with differing levels of success, to move away from the unsustainable private car-dependence and towards providing more innovative mobility options that can compete with the car. Both also feature a shared vision of digitalization as the future of mobility. However, rural mobility, in opposition to urban mobility, faces a distinct challenge that relates to a low population density and consequently low or uncertain demand for collective mobility options, impacting the financial justification for introducing new and maintaining multiple mobility options. Nonetheless, the argumentation from e.g. the SMARTA project motivates rural mobility as a value-adding component for agricultural, industrial and leisure (tourist) business ([37]). Both rural and urban mobility will benefit from empirical research efforts to characterize limitations and opportunities in order to better grasp and accommodate these.

To summarize, the above considerations led to the first research question in my thesis:

What characterizes mobility in rural and urban areas?

1.2. DIGITAL TECHNOLOGIES FOR MOBILITY

During the last decade, digital technologies have dramatically transformed and altered how people transport themselves. As an example, the app Uber has created opportunities for bringing together mobility demand (people that need to go somewhere) and mobility supply (people with access to cars). Uber works by matching up a driver and passenger(s) on a per ride basis, on-demand, based on options entered into an app such as vehicle size, drop off time, price, etc. and comparing these with the exact location and status of individual drivers. When matched, the passenger has the transparency option of following their ride on a digital map in real-time to keep track of the pick-up time and potential delays. What is interesting is that this information is sensed and stored, but only disclosed upon the acceptance of the driver and the passenger [126]. According to Sheller and Urry, mobility is increasingly associated with the subject of big data as they argue that mobility is to a large extent tracked, controlled, governed and under surveillance [112]. In this section I will illustrate how digital technologies are used during mobility and how digital technologies facilitate planning and carrying out mobility. When using the term ‘digital technology’ for mobility in this thesis, I adopt a broad understanding including apps for mobility, e.g. mobility behaviour tools like UbiGreen [44], travel planner apps like Whim [45], Uber [126] and other apps for ridesharing and ride sourcing (e.g. [122]), physical digital devices, e.g. desktop computers, laptops, smartphones and wearables, but also Internet-connected devices and ubiquitious technologies, e.g. vehicles like the connected car [121].

Today, we can observe that mobility is supported by digital technologies in a variety of ways, both for individual and collective mobility. We use interactive maps on smartphones that utilize GPS data on foot ([70]) or on bike ([92]) and increasingly also to identify potential mobility options, such as e.g. ridesourcing [122] or (e-)bikes and e-scooters [14,125]. We can use these mobility technologies to achieve door-to-door mobility [16,86]. In contrast to traditional often paper-based static route maps, technologies with digital maps use real-time information dynamically, often using a combination of technologies. Illustrative examples of these can be GPS navigation that dynamically updates possible routes in relation to your position and takes into account your mode of mobility, such Google Maps [49]. Apps like Waze offers live traffic information that can advise on selecting an optimal route to avoid getting stuck in dense traffic, or traffic jams caused by road accidents or road construction [130]. They often use a combination of road sensors and sensor information from mobile technologies in motion and in vehicles. There are also examples of crowd-sourcing detection of speed traps and alerting drivers: one example is Saphe, a small unit that is placed in the car and comes with an accompanying app [107]. The commercial market is booming with digital technologies to support mobility, HCI research can play a role in studying how these digital technologies are being used, interacted with, experienced and possibly combined in order to support people’s mobility needs.

Digital technologies are generally considered to be a prerequisite for the future vision of integrated, seamless mobility. Such mobility will be integrated because it will ideally offer door-to-door mobility services across private and public providers including pay-as-you-go solutions, resulting in a perception of seamless mobility, instead of the current more fragmented mobility services [33,48]. Goodall et al. argue that journey planning apps already support people to identify and compare different mobility mode options, with local and global offerings available, but the next step is to bring them all together in one solution. This solution is often referred to as mobility as a service (MaaS) [48]. The MaaS vision at its core is a digital platform that integrates trip planning, booking, electronic ticketing and payment services across public and private modes of mobility [48,128]. According to Goodall et al. this will be quite a change from where we are now and how mobility has been delivered until now [48]. Although MaaS is far from realized, initiatives are slowly moving in that direction. One such example is the Whim app, introduced in Helsinki in 2016 by Sampo Hietanen, recognized as the one to popularize the concept of MaaS [45]. The integration of multiple modes of mobility is key for MaaS and research has aimed to identify the level of integration, from single services like car-rental stations to the integration of service offers, such as the bundling of or subscription to mobility [116].

One major challenge is that these levels of integration will need strong cooperation across a diverse range of private and public mobility providers, local authorities for city planning and technical support for platforms and payment processors, as well as, a thoughtful integration of physical infrastructure that enables transit [34,48,128]. App-based mobility is increasing and both public and private mobility providers are actively engaged with the concept of MaaS, but until recently (e.g. [47,123]) it has not received much attention within HCI research.

Digital technologies have enabled shared modes of mobility, for example bike sharing, car sharing and demand responsive transportation [33]. These shared mobility modes differ from traditional collective mobility by having no fixed time schedule, but rather responding to demand e.g. individually tailored ride sourcing or ride hailing using real-time information, one of the most well-known examples of which is Uber (as described above [126]). I will also give a few concrete examples here of collective, so-called micro transit services that pool passengers together and extend service coverage ad-hoc: the urban ViaVan in Amsterdam, Citymapper Smart Ride in London, or the (now discontinued) Finnish Kutsuplus [33,61]. For rural variants, examples from Scotland are presented by Velaga et al., to name a few: dial-a-bus (Aberdeenshire and Highland), MyBus or West Lothian Taxibus, etc. [129]. While the urban mobility services rely heavily on smartphone technologies to source, track and follow rides in real-time, the rural variants often need to know demand in advance to plan for ride pooling to maximize feasibility (as exemplified in [129]).

While several studies point to issues of integrated, seamless mobility, e.g. [13,28,50,122,125,129], we need additional empirical studies on rural and urban mobility to better understand how the various technologies are used – in order to make them both reliable and flexible enough to meet diverse mobility needs.

To summarize, these considerations led to the second research question in my thesis:

How can digital technologies support mobility in rural and urban areas?

1.3. STUDYING DIGITAL TECHNOLOGIES FOR MOBILITY

Studying the use of and interaction with digital technologies is important within HCI research, as it is first and foremost human-centered (e.g. [24,62,77,94]). Mobile technologies have had a significant impact on how people communicate with each other and carry out everyday activities and several books and book chapters have been dedicated to the subject of studying and designing for use and interaction with mobile devices (e.g. [24,62,77,94]). Already within the first decade of this century, the use of mobile technologies was widespread and rapidly increasing, at least in the western world [63]. Today, mobile devices are central to modern living and it is not uncommon to own several devices, such as laptops, mobile (smart)phones, portable game consoles and wearables like smartwatches or medical sensing devices, etc. These mobile technologies often move with us. In this section I will outline conditions for scoping studies of digital technologies, briefly introduce primarily field data collection methods and present considerations and challenges when studying digital technologies for mobility in rural and urban areas.

Studying digital technologies entails aiming at understanding the context of interaction, the context can be more complex if technologies are also mobile as the contextual circumstances then change dynamically [24]. People mobility provide a context that is temporally, spatially and socially dynamic and is therefore an interesting challenge to study. Jones and Marsden emphasize that the study of interaction with mobile technologies is not rooted in scrutinizing 'smart' phones with innovative features, but is more about studying people who are smart, creative, busy or plain bored [62]. According to Creswell, mobility is always an embodied experience and in this respect it makes sense to take the movement of people as a starting point [22]. In addition, Love argues that to fully understand the utility and effectiveness of mobile systems, there should be a push towards understanding the context in which these are used [77]. Jones and Marsden illustrate how an example of a mobile navigation system can have different considerations for feedback (textual, graphical, auditory or haptic) dependent on the mode of the user; pedestrian, in-car use for driver-only situation or collaborations between drivers and passengers [62]. In addition, the granularity of information needs will be different when planning a route and when en route. Some researchers and studies argue that studying actual use of digital mobile technologies is best done in naturalistic settings, also referred to as in the field or in the wild [24,62,68,77,94,101]. As an example, Rogers et al. present a concrete study where in-situ data collection led to suprising results and substantial re-design of a mobile learning device [101]. Kjeldskov et al., recognize that studies in natural settings are resource demanding, they point to a need for HCI research to keep discussing when and how studies can be taken into the field – and into the wild [68].

Studying digital technologies' use and interaction and studying people on-the-move in naturalistic settings can be quite challenging in comparison to laboratory-based settings. In a laboratory, people and technologies can be equipped with recording equipment to monitor interaction in details (e.g. usability labs [94]). However, in naturalistic settings, Benyon points out that simply observing what people actually do on the screen is quite difficult, due to the screen size. He argues that naturalistic observations are not well suited for studying usability [24]. Adding to this, mobile technology use also sometimes happens in a domestic and private setting where observation in-person or with recording devices would be too intrusive: imagine an instance of observing mobile phone use in bed or on the toilet. However, observations and in-situ interviews can give an initial understanding, that can be unfolded using more in-depth methods such as interviews and focus groups [62]. Furthermore, for contexts that are not easily accessed, self-reporting methods such as diary studies and technology- or cultural probes can be advantageously employed [62]. Benyon and Preece et al. also point to the inherent data collection capabilities of mobile devices that are equipped with sensors that utilize e.g. gyroscopes, Bluetooth or RFID signals, etc. [24,94]. Methods can be adapted to the pace of the mobile service product industry's pressured product development cycles. An example is data mining to analyze usage logs [62]. However it should be noted that the recent General Data Protection Regulation (GDPR) has introduced more restricted access to user data, of course with the aim of protecting individuals' right to privacy of information [38].

Digital technologies and their applications are changing at a rapid pace and research methods for studying them must change with them. Preece et al. emphasize that research efforts need to creatively adapt to a wide variety of mobile, ambient, wearable and other kinds of systems, and to meet the challenges of studying people on the move and in unusual environments [94]. For mobility, much research is implicitly concerned with urban mobility (for example [3,13,40,44,66,135]). Although urban mobility has received much attention in research, challenges are still emerging, in particular with the introduction of new modes of mobilities. Recent research initiatives in HCI have called for suitable methods for studying the wave of innovations that blend and integrate mobility, electric motors, apps and mobile devices in new and sustainable ways [2,47]. One of the challenges of studying on-demand transportation is that it is not necessarily tied to one particular transportation hub such as a train station, but can happen spontaneously supported by primarily digital infrastructures that may only be visible to the individual passenger, whereas timetable-based public transportation can be identified and accessed more easily by researchers, for example buses or the metro [11,97]. This makes it challenging both to scope the field site of new modes of mobilities and to recognize people as passengers. For rural mobility, Hardy et al. have recently pointed out that research efforts within HCI research have centered primarily on developing countries with limited or no infrastructure and communities that have not normatively been associated with digital technologies [52]. They argue that it is problematic that rural developed and high-income areas are understudied because they could represent rich and productive spaces for HCI research. They encourage HCI researchers to aim to solidify their understandings of rural areas, in developed countries to make future work and comparisons possible [52]. That being said, researchers have pointed to a large degree of car-dependence in rural mobility and public timetable-based transportation may not be available or may be underutilized [23,50,55,129].

To summarize, the above considerations led to the third research question in my thesis:

How can studies of mobility and digital technology use be planned and carried out in rural and urban areas?

1.4. RESEARCH QUESTIONS

The work that constitutes this thesis questions how mobility is planned and carried out in rural and urban areas and the potential for digital technologies to support this. Accordingly, I structure this thesis around the following three research questions:

1. *What characterizes mobility in rural and urban areas?*
2. *How can digital technologies support mobility in rural and urban areas?*
3. *How can studies of mobility and digital technology use be planned and carried out in rural and urban areas?*

To address these research questions, I will present four empirical studies that illustrate topics on mobility that takes place in rural and urban areas. In addition, the studies also each focus on use and interaction with bespoke digital technologies for mobility or other digital technologies that support planning and carrying out mobility. Reflections on the approach to studying mobility and digital technology will be presented for each study.

CHAPTER 2. RELATED WORK

In this chapter I will present state-of-the art research on three qualities of the work in this thesis, these are user studies in HCI research, mobility in HCI research and lastly, mobility research in the context of rural or urban.

2.1. USER STUDIES IN HCI RESEARCH

The definition of a user study varies, but they also overlap, common to them is the inclusion of a human user. In this thesis I adopt the definition of user studies by Preece et al.; ”A generic term that covers a range of evaluations involving users, including field studies and experiments” ([95], box 13.3). This definition includes two approaches to user studies; field studies and experiments. Experimental user studies are primarily quantitative, engaged with differences between multiple conditions or groups of users often through comparison, utilizing statistical analysis to answer research questions [79]. Whereas field studies often rely on qualitative data, are descriptive and often inductive. Observational methods are key to understanding users, according to Lazar et al., “by watching and listening carefully, we can learn from what users do and how they do it. That, after all, is the point of conducting user studies.” [71]. What further sets apart field and experimental user studies is the setting, which is closely related to the importance of control. Experimental studies take place in a dedicated professional laboratory or ad-hoc lab (for example the Google Research Van), as it is important that researchers can control all aspects of the surrounding environment [72]. Preece and Roger elaborate on field studies, that they take place in natural settings where there is little or no control of users' activities in order to determine use in the real world [95].

The objective of user studies has changed over time, in line with a shift in HCI from task driven approaches to a focus on experiences and creative inquiries, similar to Bødker's notion of third wave HCI [8]. According to Shneiderman, in the early days of user studies in HCI, the purpose was to fit computerized tasks to human cognition, as such it dealt with well-stated requirements, clear benchmark tasks, established measures of human performance, and effective predictive models, such as Fitts' Law [113]. User studies was considered a task for human factor and ergonomics researchers. Standard measures of ergonomics and cognition was applied in design and tested on the basis of standardized objectives. See for example, Rubin's Handbook of Usability Testing or Jakob Nielsens' book on Usability Engineering [85,103]. However, Preece et al. argue that, “nowadays users expect much more than just a usable system; they also look for a pleasing and engaging experience” [95]. Shneiderman add that the increasing complexity in evaluations of user interaction has been clearly seen in the demand for HCI as a discipline to reflect user-oriented technologies that are ubiquitous, pervasive, social, embedded, tangible, invisible, multimodal, immersive, augmented, or ambient [113]. This has affected the areas of research and the need to be inclusive of new opportunities of experiences with technologies, of which he gives the following examples: health/wellness, education, creative arts, community relationships, etc. [113]. That being said, there is still a strong need for usability quality, in particular for professionals who have high demands in relation to life-critical systems, industrial plants, legal offices and policies agencies, according to Shneiderman [113].

2.1.1. STUDY PURPOSE AND DATA COLLECTION

The purpose of carrying out user studies is closely related to the intended contribution of the study. Wobbrock and Kientz illustrate and discuss seven types of contributions for HCI research, meanwhile they argue that empirical research contributions are the backbone of science, as they provide new knowledge through findings: "In HCI, empirical contributions arise from a variety of sources, including experiments, user tests, field observations, interviews, surveys, focus groups, diaries, ethnographies, sensors, log files, and many others." [131]. Kjeldskov and Paay present an overview of research methods and purposes (adapted from Wynekoop and Conger), here they separate field studies and lab experiments, among others. For purposes, they list five; Understanding, engineering, re-engineering, evaluating and describing [67]. In this thesis, I primarily engage with understanding and evaluating. Baarkhuus and Rode argue that the field of HCI is as much about evaluation as it is about development of new technologies [5]. Kjeldskov and Paay conclude from their survey of method approaches to mobile HCI (from 2010), that studies are primarily empirical, involving a relatively high number of field studies that focus on understanding and evaluation, as well as engineering [67]. Further, they distinguish three notable subcategories of field studies namely, 1) field ethnographies, where the researcher is present in the field, for example full-scale ethnographic studies, smaller scale observations, contextual inquiry, etc. 2) Field experiment, meaning a natural setting where a number of independent variables are manipulated, for example usability tests and quasi experiments in real use contexts. 3) Field survey, where the researcher is not always present but uses survey techniques for data collection, for example cultural probe studies [67].

For planning user studies in the field, many recognized textbooks on HCI and Interaction Design agree that certain considerations must be taken, these are commonly but not exhaustively: What are we studying, who are we studying and how do we study them (e.g. [24,62,73,77,94,114]). First, what are the goals of the study, these can be expressed more or less formally structured like a mathematical format or hypothesis, or using a simple description e.g. "understand how technology fits into normal family life" [95]. Secondly, sample, recruit, motivate and retain participants in the study (e.g. [64]) and importantly, ensure ethical treatment of participants, for example through ensuring informed consent to data handling activities (e.g. [71,95]). Third, plan how to carry out the study in terms of data collection methods. Preece et al. distinguish between overall three data collection methods; Interviews, questionnaires and observation [96]. Similar to other recognized textbooks on HCI and Interaction Design research methods (e.g. [24,62,73]). They feature variations of the three, for example interviews can be conducted one-on-one or in groups, be more or less structured, observation can be characterized as direct observation where the researcher is present in the field or indirect, with the aid of e.g. diaries or data logs. All of these variations can result in qualitative or quantitative data, in varying degrees [96]. All methods have advantages and disadvantages. For example, questionnaires are good for answering specific questions and can reach many people with little ressources, but as the researchers can't intervene the design is crucial and it is often contingent on a high response rate. While, observations in the field are good for understanding the context of user activity, it is very time consuming and huge amounts of data are produced [96]. Broad agreement exist that data collection methods can ideally be combined, also referred to as triangulation [96]. Not one approach is better than the other, as they have different strengths and weaknesses and offer different insights, as argued (among others) by Kjeldskov and Skov [68].

2.1.2. FIELD STUDIES, IN-SITU, IN THE WILD

The distinction between studies carried out in the field or in the lab has been a longlasting discussion within the HCI research community. It has even sparked heated debate, Kjeldskov and Skov remarked with their contribution to the discussion at the Mobile HCI conference in 2004; stating that there is little added value to the field setting [69]. Even prominent advocators of field studies have pointed out that the approach is markedly labour-intensive, financially expensive and requires significant investment [101]. Ten years after, Kjeldskov and Skov conclude there is still no definite answer to the lab versus field question [68]. The discussion is ongoing, as exemplified by the influential HCI conference ACM Conference on Human Factors in Computing Systems (CHI) 2019 when they featured a panel on "Tensions and Trade-offs Between Research in the Lab and in the Wild" [75]. In the panel presentation the discussion between lab and (in the wild) field studies is presented as "The most prominent paradigm divide" in HCI research. Specifically they outline the divide as quantitative (lab) and qualitative (field) and set the stage for a discussion on the parameters of scientific rigor, real-world relevance and impact. The scientific rigor and relevance of the lab-based experiment depends on internal validity, supporting claims about cause-and-effect relationships, and external validity, generalizability beyond the experiment Whereas the field or 'the wild' setting offers a validity in context, referred to as ecological validity [75].

The field is sometimes referred to as in-situ or in the wild [68]. Rogers and Marshall present a framework of research in the wild, where one of four core bases is referred to as in-situ studies, meaning evaluations of existing device/tool/service or novel research-based prototypes [102]. Kjeldskov and Skov emphasized that there is little consensus on what constitute a field setting, in particular they point to the level of control as crucial to determine whether 'the field' is perceived to represent a tame or truly wild version of the real world. They raise the question of whether it makes sense to compare field and lab studies when we don't have a common understanding of what we're comparing [68]. Instead of answering why or if one should do lab or field studies, they argue that we should instead be asking when we should do what and how to do it well [68]. Chamberlain and Crabtree contend that the development of complex interactive technologies that are mobile, ubiquitous, etc. can't be properly studied in a lab setting, as it misses the point of understanding these technologies at an ecological level [19]. Wobbrock and Kientz note that data can be aspiringly objective or unapologetically subjective [131]. Johnson et al. suggest 'being in the thick of the wild'; that instead of researchers trying to minimize their effect on participants, they could achieve an understanding of their effects by involving themselves, even joining in [60]. A notable example of research in the wild on mobility is Alan Dix's walk around Wales [31]. Research in the wild brings up new questions; "Whereas the burning question in HCI was once 'how many participants do I need?' the hotly debated question is now 'how long should my study run for?'" [100]. Echoed by Kjeldskov et al. as a 'second element' of moving beyond non-wild field studies, they argue that longitudinal studies see beyond 'snapshots' of use and concern repeated and sustained use over longer periods of time [68].

2.2. MOBILITY IN HCI RESEARCH

In this thesis I focus on people mobility, and more specifically, I will primarily outline everyday mobility, which according to Brewer and Dourish is the patterns of connection and spatial organization that arise around us, as a consequence of movement of everyday life [12]. This thesis does not aim to contribute to HCI research that focuses on mobility off the ground, e.g., airline business travel [35], or on highly mobile, nomadic, mobility [41,91] or the transportation of goods [6].

People fulfil their mobility needs using different vehicles such as cars, bikes, buses, etc. These vehicles can be grouped into mobility modes: pedestrian, cycling, public transport and car. Some of these mobility modes take people directly from point A to point B, also referred to as door-to-door trips by e.g. Goodall et al. [48], whereas, some mobility modes take the less direct form of point-to-point via point(s) as described by Hensher [55]. Mobility can be undertaken individually or collectively. Oostendorp et al. argue that multiple options of mobility are a basic requirement for using and combining transportation modes in a flexible, individual and situational way [86]. Mobility is increasingly supported by technologies that enable a higher degree of tailoring of mobility to the individual, which is often referred to as MaaS [34,48,128]. According to Goodall et al., mobility is moving from mass transit to MaaS transit [48]. However, current forms of MaaS may not be readily implemented in diverse geographies or be appropriate for all demographics, as demonstrated by e.g. [50,65,129].

2.2.1. MOBILITY MODES

Mobility can be characterized as unimodal (one mode) or multimodal, i.e. consisting of multiple modes of mobility [86]. Based on previous research, we use the term mobility modes to define a form of mobility, a vehicle or a grouping of vehicles that supports carrying out a trip. I distinguish between four different modes of mobility namely *pedestrian*, *cycling*, *public transport* and *car*. This section is structured by the sustainable paradigm hierarchy of mobility modes, as suggested by Banister: with pedestrian and cyclist mobility at the top and cars at the bottom [4].

The first mobility mode, *pedestrian,* refers to mobility that is carried out on foot, for example walking. However, walking is not straightforward, as Laurier et al. points out: "Pedestrians do not just walk. They rush, they dawdle, they stroll, they amble, they circle, they pause, they stop, they edge past, they saunter, they plod, they advance, they retreat, they backtrack, they lead, they follow" [70]. Due to this often erratic behavior and the fact that they are not protected by the structures of a vehicle, pedestrians are considered the most vulnerable road users. Research has aimed at improving safety for pedestrians: for vehicles to communicate intent to pedestrians (e.g. [25,26]), or to facilitate road crossing [58]. Pedestrian mobility can be undertaken as a trip that requires information on navigating from A to B alone or together or walking around and exploring a particular site (e.g [54,70]), and with the intention of exercising and combatting a sedentary lifestyle, such as running, jogging, speed walking, walking meetings, etc. (e.g. [3,7,20,111]). Walking has even been utilized as a research method (e.g. [31,118]). As an illustrative example, Laurier et al. investigated inter-subjective pedestrian practices when their walking was mediated by maps on mobile devices, through observing a couple of tourists trying to find their way to a destination in an urban area, "... to study a contemporary mode of walking: together with touchscreens" [70]. In contrast, Seuter et al. investigated how interaction with wearable technologies impacted individual running movements, as this fast-paced activity notably necessitates a coordinated movement of, in particular, both legs and arms to avoid injuries. They carried out a motion-capture, experimental study comparing participants' interactions with a smartphone, a smartwatch and smart glasses while running [111].

The second mobility form, *cycling,* refers to individual, single-user transportation on lightweight vehicles, such as bicycles. Research has focused on bicycles as a mobility mode and on biking experiences (e.g. [14,15,80,92,98]). As an illustrative example, Pielot et al. did a field evaluation of their prototype Tacticycle, which used tactile feedback to promote tourist biking experiences aimed at the exploration of unfamiliar environments [92]. Research on biking as an urban mobility mode, has explored possible connections with public transit: so-called last mile solutions to cover the distance from transit stop/station to destination (e.g. [15,76]). In addition, some combinations of mobility modes have a symbiotic relationship, as Oostendorp et al. argue that while cycling provides accessibility and flexibility, public transportation can dramatically extend cycling's speed and spatial reach [86]. However, HCI research has only recently focused on the new mobilities of small electric motorized vehicles such as e-bikes, e-scooters, hoverboards, segways, e-skateboards, uniwheels etc. that are now rapidly becoming part of the urban mobility scene [47,125].

The third mode, *public transportation,* sometimes also referred to as public or mass transit, is a collective mode of mobility and has been emphasized as a sustainable alternative to individual transportation by car (e.g. [4]). Public transportation covers a broad range of physical vehicles and infrastructures, such as train, bus, metro, light rail or tram – fossil fueled, bio fueled or powered by electricity – and can also include ferry and airline transportation. It is characterized as being available for use to the general public, on a time schedule and includes a ticketing fee [110]. HCI research on public transit has focused on mobility experiences that improve passenger satisfaction and promotes sustainable transportation choices (e.g. [11,44,56]). As an example, Bowen et al. reported on a large-scale design of metro trains involving the public to contribute towards co-designing future mobility; they were particularly interested in how to utilize digital media and tools to enable region-wide public participation in the early phase specifications and managed to capture over 400 individual short conversations in combinations with a core group of 20 participants [11]. Hildén and Väänänen have contributed with tools for designing for the bus context e.g. travel mindsets and personas, based on empirical studies of frequent intra-city bus passengers' needs, experiences, values and activities. They emphasize: "Bus is an interesting service context to study, since it contains services both in the physical realm, i.e. the actual transportation system, and in the digital sphere, i.e. the digital services in the bus, bus stops and on the passengers' mobile devices" [57]. Public transportation has undergone an evolving process of digitalization that has been reflected in HCI research; see for example Pritchard et al. on replacing cash payments with digital-only means of payment on London buses ([97]) and in particular, delivering real-time traffic information on routes and trip-chaining to passengers (e.g. [21,66,135]).

Fourth and finally, the mobility mode car refers to trips carried out in an automotive vehicle such as a car. Glöss et al. argue that HCI on mobility is dominated by automotive research [47]. Automotive or car-based HCI research is an established subfield of HCI research on mobility with a dedicated conference since 2009, namely the ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications. Additionally, it has also gained substantial focus within other HCI research venues like CHI, Interact, TOCHI, etc. Key themes in automotive HCI research have been e.g. safety – specifically attention and interaction while driving with dashboard or alternative user interfaces and modalities (e.g. [51,84,109]) but also the detection and alteration of emotional states such as stress or rage that can affect driving performance (e.g. [32,88]). HCI research on (semi-) automated vehicles has opened up explorations of activities during travel time (e.g. [93,108]), communicating automation-manual handovers (e.g. [104]), signaling intent to other road users (e.g. [25,40]) and making decisions on behalf of drivers (e.g.[82,90]). Electric vehicles have recently seen a more widespread adoption, although HCI research has pointed to challenges in the perceived desirability of the driving experience in comparison to traditional fossil fueled cars e.g. in terms of driving range and lack of supporting infrastructures, see for example Jensen et al. [59]. In HCI research, some research has critiqued individual car ownership and aimed to challenge the car-norm (e.g. [53,117]). In particular, individual car ownership is critiqued from a Sustainable HCI perspective (e.g. [30]).

2.2.2. TECHNOLOGY SUPPORTED MOBILITY

Digital technologies currently play a big role in how people organize, coordinate and carry out their mobility and according to Goodall et al ([48]), such technologies may play an even bigger role in the future: "… streaming services like Netflix have fundamentally changed the way people search for, consume, and pay for media. Transportation now stands on a similar frontier" [48]. Since 2005 the SIGCHI ACM International Conference on Human-Computer Interaction with Mobile Devices and Services has contributed to, in their own words: "reflect the societal and technological transition where mobility has become pervasive and prime to our lives" [1]. That being said, other major HCI venues are also concerned with research on combinations of technology and mobility. In this section I will first present work on how digital technologies have supported mobility for specific user groups; following this I will elaborate on the concept of MaaS, how it has been adopted in research and what impact researchers imagine it will have on future mobility research and design. Finally, I will illustrate how, primarily mobile technologies have supported shared mobility for multiple mobility modes in order to, among other reasons, achieve more sustainable mobility habits.

Digital technologies have facilitated accessibility and autonomy of mobility for a diversity of road users: elderly commuters (e.g. [81,119]), children (e.g. [42]), people with cognitive disabilities (e.g. [17]) and people with lowered mobility or reduced sight or hearing (e.g. [13,74,89]), etc. But on the other hand, digital technologies for mobility have also proven to unintentionally exclude populations characterized as e.g. low socio-economic (e.g. [28,65]) and reinforce a digital divide (e.g. [99,132]).

The concept of MaaS is a mobility vision of seamless trips that are planned, paid for and carried out with the help of technologies, preferably a one-entry solution for all modes of mobilities [78,128]. MaaS has only recently been mentioned in HCI research on mobility, in the format of workshops [47,123]. As an example, Tellioğlu et al. argued that MaaS solutions are key to addressing increasingly contradicting requirements of mobility and mobility-related issues in urban transportation. They emphasize a need for HCI researchers to engage with balancing on the one hand, technological innovations that initiate new ways of transportation and on the other hand, a thorough understanding of the mobility patterns of people, their needs and economic givens in order to rethink mobility habits [123]. The integration of multiple modes of mobility is key for MaaS and Sochor et al. have proposed a topology to describe the level of integration, ranging from levels 0 to 4: 0) no integration, i.e. single, separate services like a traditional car-rental station, 1) integration of information, i.e. multimodal travel planner and price info, 2) integration of booking and payment, 3) integration of the service offer, i.e. bundling or subscription of mobility services, and 4) integration of societal goals, i.e. policies, incentives etc [116]. Visions of future ideal MaaS solutions necessitate a strong connection between private and public mobility actors in order to deliver seamless multimodal trips via trip chaining. This demands multiple sources of real-time data to be available. This will require public transport authorities and private mobility providers (e.g. Uber, Taxi, VOI, etc.) to work together on providing data [33,55,128].

Technologies, particularly mobile technologies, have supported shared modes of mobilities. As an example, a car can be viewed as an individual mode of mobility, but has also been explored as a shared mobility resource in an attempt to reach more sustainable transportation behaviors, see e.g. research on ridesharing and carsharing (such as [10,13,65,120,122]). Flexible, demand-responsive transportation have been introduced to extend public transit services or as a stand-alone mobility service [61,129]. Hensher refers to these as hybrid multimodal service models; “Uberisation/digital technology is about providing more service points in the spectrum between buses and conventional taxis" [55]. Demand responsive transportation can be considered a shared mobility mode, Durand et al. argue, and it can be either collective or individual [33]. Collective indicates door-to-door or stop-to-stop services that provide on-demand transport. They are also sometimes referred to as flexible micro transport services or micro transit and are public transport services that do not operate according to a schedule. Durand et al. give some examples: the Opstapper, Buurtbus, and Brengflex. In addition, ViaVan in Amsterdam, Lyft Line in the USA, Citymapper Smart Ride in London, and UberPOOL in multiple countries [33]. The individual mode, also referred to as ride hailing or ride sourcing, are matching supply and demand by allowing travellers to use a smartphone application to request individual car rides in real-time from potential suppliers; “Examples of ride-sourcing services include Uber, Lyft and Didi Chuxing” [33]. Shared micromobilities, e.g. bikesharing or e-scooters, can be rented through unmanned parking stations or free-floating, via payment in a mobile application (e.g. [14,15,34,48,76,115,125]). These shared mobilities hold potential to service ad-hoc routes between public transit hubs, also referred to as last mile [14,76]. Albeit, HCI research such as by Glöss et al. and Kameswaran et al. have also critically looked into working conditions for an increasingly mobile labour market, the implications of technologies and responsibilities when designing these technologies for an on-demand mobile workforce [46,65].

2.3. RURAL AND URBAN MOBILITY RESEARCH

I have divided the following sections into two areas, often presented as opposites in their definitions and characteristics (see for example [52]): rural and urban mobility. First, I will define these two areas respectively, and I will illustrate how HCI and transportation research has pointed to characteristics of and challenges for mobility in these areas. Finally, I will outline how research has suggested, designed and evaluated solutions to address these aforementioned challenges.

Research on mobility points to differences based on geography and population demographics. Scarcity of access to mobility is linked to reduced access to other societal services such as health services and contribute to amplify the effects of poverty [29,50,52]. Additionally, research has argued that accessibility of mobility is reduced as you approach low-density populated, rural areas (e.g. [50,52,129]). Urban areas are characterized by having a multitude of mobility modes available, but despite this struggle to address a growing populations' mobility needs and to provide modes of mobility that are sustainable socially, economically and environmentally [29,55,106,123,134].

2.3.1. RURAL MOBILITY

In HCI research there are multiple definitions of rural (see for example [50,52,129]). In this section I adapt the definition by Hardy et al. on rural as a relational category, used to denote social and spatial difference, in contrast to urban [52]. In continuation of Hardy et al.'s definition, I use primarily what they refer to as descriptive definitions of rural, meaning population density and access to nearest transportation hub, which according to their survey is also the most dominant definition in HCI studies. In contrast to other proposed definitions, e.g. sociocultural or symbolic [52].

Rural potentials and challenges can be characterized in order to better grasp research gaps and opportunities for design and development. HCI research has focused on characterizing rural in terms of mobility. Hardy et al. underscores the lack of research that concerns technology use and development in rural areas of developed high-income countries, where some degree of technology infrastructures are often available as a resource for design. They conclude that HCI research that focus on infrastructure and specifically concerns transportation access is important for understanding rural experiences [52]. To this end, Velaga et al. argue that access to frequent and widespread public transportation in rural areas may to a great extent enhance economic growth, improve social inclusion and accessibility to mobility [129]. However, they highlight three characteristics of rural areas that present as challenges for achieving these goals; potential passengers are distributed over large geographical areas, population density is low, which impacts the potential passenger number and finally, the level of demand for public transportation is unpredictable [129]. These challenges have resulted in a high degree of car-dependence in rural areas, which further reduces the incentives to offer widespread public transit in these areas [50,52,55]. The last mile problem of mobility refers to areas with low or no mobility coverage, creating gaps in mobility services known as the first and last mile problem [55,76]. Gray et al. argue that service gaps in mobility are particularly problematic for individuals without access to cars [50].

Solutions to address mobility service gaps in rural areas have been proposed and explored. In response to low access to public transportation, researchers have argued that public-private collaboration towards offering more flexible transportation (e.g. on-demand) or community-based initiatives could ideally be involved in a MaaS scheme of hybrid mobility delivery for rural areas [50,55,129]. Velaga et al. investigated possibilities for flexible transportation to accommodate the service gaps in public transportation in remote and rural areas (the first and last mile) and found eight research challenges to address. These concern e.g. integration of multiple modes of transport, real-time communication to and from users, and estimating transport demand in rural areas [129].

2.3.2. URBAN MOBILITY

Urban is rarely strictly defined, but much research on mobility is either explicitly or implicitly about mobility in urban areas. Urban is sometimes expressed, in adaptation of dictionary definitions, as relating to or constituting a city [124]. Some distinguish intercity and intra-city traveling [57]. Urban residing can be a requirement for study participation [53], or urban can be a study field location [125]. Some have used urban as a descriptive (nominal) variable based on population size [27]. I adopt the definition of urban, as argued by Foth et al., where in this thesis I will use urban to include: "… sub-urban (referring to separate residential communities within commuting distance to a physical city centre) or peri-urban (referring to the area immediately surrounding urban settlements) contexts" [43].

Urban areas are increasing worldwide and are expected to continue growing, which results in challenges of adequate resources and service provisions [4,105,123]. The emissions, congestion and pollution caused by people mobility in urban areas are of pressing urgency and necessitate radical transformation [2,125]. However, according to Tuncer and Brown, urban transportation in most industrialized countries has remained essentially unchanged [125]. Zheng et al. warns that the increasing urbanization is making high demands on public transportation services to change with it, but the pace at which e.g. bus routes change is slower than the pace at which citizens' mobility needs them to change. They propose data-centric approaches to tackle this, such as flexible shuttle-transit routes that are derived based on the demand for actual passenger trips from taxi trajectories [134]. Such shuttle-transit routes have been explored in recent research, with more or less success, such as with Kutsuplus [61]. The concept of urban computing or urban informatics [43,134], raises an awareness that urban areas do not just happen; they are planned, monitored and controlled based on a wide variety of data sources and massive amounts of data [134]. Sadeghian et al. further argue in a workshop proposal, that mobility is both a desire and a necessity and has been a driver of past technological achievements; therefore technologies may also prove to be key for the development of future sustainable mobility [105]. Meanwhile, the importance of a critical look at what technologies contribute in an urban mobility context has been underscored by e.g. Dillahunt and Veinot, who underline that while digital technologies offer new opportunities for addressing transportation needs, these opportunities are not equally accessible. They emphasize a scarcity of transportation access in urban areas that are characterized by low socio-economic populations [29].

Solutions designed to address the challenges of urban mobility have primarily considered the individual end-user practices of transportation and designing persuasive technologies to promote sustainable transportation habits (e.g. [44,53,117,135]) and designing new mobility experiences, infrastructures and policies (e.g. [4,55,76]). As an illustrative example of the first, Hasselqvist et al. carried out a car-free year study, in the wild, where they recruited three urban residing families to swap their car transportation for provided two or four-wheeled electric, non-car, vehicles e.g. box bike, motorcycle, scooter, bike, as well as public transportation that was already available to them. They found that in comparison to car-based mobility, car-free mobility required considerable amounts of planning, even for daily inter-city trips, as they had to take into account road conditions for different vehicles through a multitude of digital planning tools. Additionally, participants had emotional responses to having to defend in social situations their perceived odd or extreme choice of car-free mobility [53].

CHAPTER 3. PAPER CONTRIBUTIONS

In this thesis I investigate mobility and in particular people mobility with the focus on digital support for rural and urban areas. The paper contributions presented here constitute the main contribution of this thesis that aim to answer the following research questions: First, what characterizes mobility in rural and urban areas? Second, how can digital technologies support mobility in rural and urban areas? Third, how can studies of mobility and digital technology use be planned and carried out in rural and urban areas?

These four papers present four empirical studies whose findings will be the basis of the discussions and conclusions to the research questions presented above. They each explore different problems that fall under two contexts of mobility: rural or urban. Two papers explore rural mobility, the first presented here reflect on the last mile problem in relation to mobility in rural areas through a study of an on-demand public rural mobility service. The second paper illustrate ways that rural dwellers use digital technologies to plan and coordinate everyday mobility. The next two papers document urban mobility, where the third paper presented here deals with purposeful movement, in this case how digital technologies can engage volunteers with first aid competences to move promptly to the site of a cardiac arrest outside of hospital. The fourth and final paper presented here illuminate how rental e-scooters can be viewed as hybrid shared micromobility services and how these adapt to dense urban mobility. The four papers are presented and throughout this thesis referenced as follows:

Paper 1: Rural Mobility and the Last Mile Problem

Paper 2: Rural Mobility and Technology Integration

Paper 3: Urban Mobility and Purposeful Movement

Paper 4: Urban Mobility and Hybrid Shared Micromobility

All four studies are primarily qualitative field studies, but approach studying digital mobility differently. Paper 1 and paper 4 demonstrate mixed method studies that include interviews, both outside of the context and in the context of mobility activities (in-situ/in the wild), together with a workshop (paper 1) and media analysis (paper 4). Where paper 1 report from participant observation of invited trips, paper 4 employed more opportunistic recruitment and in addition features interviews with groups of people. In both cases the researcher was co-located with participants. Paper 2 and 3 report on interviews where the researcher and participant were not co-located, but mediated by digital technologies. I planned this based on pandemic restrictions (paper 2) and ethical concerns (paper 3).

3.1. RURAL MOBILITY AND THE LAST MILE PROBLEM

Maria Kjærup, Mikael B. Skov, and Niels Agerholm. 2020. ***Digital-Enabled Last Mile: A Study of Passenger Trips in Rural, Low-density Populated Areas****. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3313831.3376509*

This paper presents a study of an on-demand public mobility service that aims to support last mile people mobility in rural areas. Last mile people mobility refers to the last and sometimes first stretch of a journey from point of departure and via a transit hub to the final destination, as public transportation typically stops only every mile on average to maintain a high speed ([133]). This stretch is challenging because it is resource demanding, often referred to as the last mile problem (exemplified by [6,76,133]). Due to feasibility issues, public transportation routes are often discontinued in rural areas and consequently residents become isolated from public transit hubs. On-demand mobility services have been proposed as a solution to the last mile problem of people mobility. In this paper we study such a service called Plustur. Contrary to other modes of public transportation, on-demand mobility services are not timetabled, but creates routes ad-hoc when requested. Contrary to traditional taxis, Plustur operates at a lower price level offered by public transportation regulations. In contrast to other rural, on-demand mobility services, Plustur can only be requested via a dedicated digital platform. Thus, I refer to it as a digital-enabled last mile service.

This paper presents a qualitative study that applied a mixed methods approach consisting of interviews with 11 passengers and three drivers, along with Plustur trips with three invited passengers and two solo trips (in the wild) and lastly, an ideation workshop with stakeholders of the regional mobility authority. Interviews were carried out in-person and semi-structured following an interview guide. Interviewees were all living in or frequently traveling in rural areas of North Jutland (Denmark), characterized by being low-density populated with increasing out-migration. Their transportation habits varied from daily use of public transportation to monthly or less frequent use of public transportation. In order to capture in-situ observations of traveling in rural areas, we followed three passengers before, during and after making a Plustur trip, which provided valuable insights without having to recall events. Additionally, we also carried out solo trips to destinations in rural areas. The purpose of one solo trip was to interview the driver: this in-situ interview offered exciting perspectives that were followed up with phone interviews with two additional drivers from different subcontractor companies. Interviews were audio recorded, except for in-situ and phone interviews, which relied on notetaking. After the interviews, recordings were transcribed, then coded and analyzed thematically and iteratively.

Our findings outline four themes. The first theme relates to digital-enabled passenger trips and describes how participants relate to Plustur as the first solely digital mobility service and the coupling with mobile technologies when planning and carrying out trips. We found that our participants already extensively used mobile technologies while traveling for information, communication and recreational purposes. The second theme relates to integrations of modes of transportation in rural areas, as the Plustur concept involves changing transportation modes at least once during a trip. We investigated how our participants experienced digital technologies facilitated this mode change. Our findings emphasized the importance of transparency of travel information and a wish to relay dynamic information in case of changes and delays in travel plans. The consequences of missed mode changes in rural areas often meant being stuck in place for a considerate amount of time and this potential scenario could deter traveling in the first place. The third theme emphasizes a perceived link between a high level of autonomy of mobility and car access, which adversely also meant that people with no access or means to drive a car were perceived as particularly disadvantaged in rural areas. The final theme relates to rural passengers' desire for flexibility and spontaneity and depicts the kind of needs that Plustur fulfills according to participants. Common for all was a dissatisfaction with the level of spontaneity, e.g. Plustur must be booked two hours in advance to achieve feasible passenger pooling. as well as with the level of flexibility, in particular in connection with return trips, as it was not always easy to determine the end of a current activity, e.g. sports events going into overtime.

Our findings corroborate argumentation from rural mobility research, that private car dependence is often high and closely linked to the perception of autonomy of mobility. Consequently, rural dwellers without access to cars are disadvantaged with regards to freedom of mobility, as not a lot of other options exist to overcome the challenge of the last mile problem. Widespread and frequent public transportation is deemed unfeasible due to uncertain demands, which exacerbates first and last mile stretches for rural dwellers. The real-time data capabilities of mobile technologies have made it possible to extend rural public transportation with demand responsive mobility services. However, our findings show that the private car is still widely preferred. It meets passengers' expectations of flexibility and spontaneity, in a way that public transportation in rural areas can't when passenger pooling is a necessity to determine demand in order to keep fares at a low price. Crucially, travel information presented to passengers was static, adversely creating a risk of additional en route planning in case of unforeseen changes to the travel plans. This often resulted in a preference for private mobility modes for covering the last mile stretch that responded more flexibly to emergent needs. That being said, participants were not fully deterred from combining public and private modes of mobility for the overall trip, but primarily on their own terms.

3.2. RURAL MOBILITY AND TECHNOLOGY INTEGRATION

Maria Kjærup, Mikael B. Skov. 2021. ***Transportation and Technology in Rural Denmark: Communities of Mobility****. Submitted to: The Australian Conference on Human-Computer Interaction (OZCHI'21) – (Under review)*

This paper presents a study that exemplifies how digital technologies are integrated, or fail to integrate, to support mobility in rural areas. Mobility in rural areas are predominantly car-based, often due to low fruequency or no service of public transportation. Research has argued that there is a risk to exacerbate feelings of isolation and social exclusion for rural dwellers who do not have access to or means to drive a car such as children, elderly and handicapped ([50]). In response, research has considered possibilities for on-demand approaches of mobility such as demand-responsive public transportation, formalized lift-giving and community transport schemes (see for example [129]). While research has focused on the mobility receivers and providers of community-based rural transportation, there is little focus on the technologies that support this mobility and their potential for combining to provide integrated multimodal rural mobility that effectively respond to mobility needs. Some limitations of rural on-demand transportation in meeting enhanced mobility, connectivity and thereby social inclusion are: they are only targeted at specific populations, do not allow booking on the day of travel, and use very little or no intelligent transport systems or advanced information and communication technology support [129].

This study was carried out as a qualitative study, where we inquired about the influence of technologies on mobility in rural areas, through semi-structured interviews with 19 people who either lived in or frequently traveled to rural areas of the North Region of Denmark. Interviews were carried out in two rounds, with 11 participants in the first round and eight participants in the second round. For the first round interviews were all conducted co-located, whereof seven participants were interviewed in their home or at their workplace, reached exclusively by means of public transportation and walking. For the second round of interviews, we carried out all interviews online, in accordance with local restrictions of the pandemic lock-down and for general safety. First round of interview inquired about everyday experiences of rural mobility, mobility needs and technology use in combination with mobility. The second round extended the interview guide to include topics that emerged from the first round, such as specifically inquiring about household's use of technologies to plan, coordinate and carry out mobility, and in addition a prompt to imagine future (rural) mobility. Participants were recruited through several channels; the public regional transport authority's official website or social media, and dedicated social media groups and pages for rural residents. Interviews were transcribed and thematically and iteratively analyzed for both rounds of interviews.

Our findings are covered in three themes: rural mobility and transportation communities, technologies for rural mobility, and rural mobility futures. We found that communities of mobility existed on different levels: household, neighborhood and local area. Interestingly, participants expressed the value of community transportation without the interference of transport authorities or private mobility actors. We found that rural mobility often encompassed a combination of private and public mobility modes. While participants described their use of digital technologies for planning and carrying out mobility, we were surprised to see the examples of how they combined digital technologies for the purpose of mobility and general technologies (such as social media) for efficient mobility on their own terms. In addition, we found that household members held expectation of the other members, and in extension of the household also neighbours, to cover their mobility needs. This was often carried out with car-based mobility. For the last theme, participants imagined the future of (rural) mobility as on-demand and extreme ad-hoc, consisting of autonomous vehicles and imagined possibilities for public transportation as social spaces with some of the same services that we usually only see on commercial airplanes. They had an emphasis on sustainability, although not at the cost of flexibility. In summary, our findings illustrate two distinct contradictions of rural mobility: a contradiction of conflicting expectations of what mobility service offers should prioritize and contradictory demands for the availability and flexibility of public transportation.

Our findings from this study show that participants' expectations of future mobility, or imagined ideal mobility services, is a marked change from the rural mobility services provided today. In order to answer the revealed contradictions, I believe that the findings that concern communities of mobilities hold potential value, extending argumentation from related work on building community transport capacity and capability. I argue that in order to realize something that resembles participants demands on mobility services, there is a need for digital technologies to support and integrate the ways mobility is carried out on community levels of household, neighborhood and local area levels. However, not as a full substitution for existing mobility services. This integration depends on physical infrastructures, as well as a variety of mobility actors, but equally also on mobile data on peoples' mobility patterns and preferences.

3.3. URBAN MOBILITY AND PURPOSEFUL MOVEMENT

Maria Kjærup, Mette Elsborg, Mikael B. Skov, and Anders Bruun. 2021. ***Available Anytime Anywhere: Investigating Mobile Volunteer Responders for Out of Hospital Cardiac Arrest.*** *In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21). Association for Computing Machinery, New York, NY, USA, Article 647, 1–13. DOI:https://doi.org/10.1145/3411764.3445208*

This paper presents a study of how volunteers with first aid competences can be purposefully moved to the site of a cardiac arrest, with the aid of digital technologies. The chances of survival for a person suffering an out of hospital cardiac arrest depend on efficient and effective first aid intervention and is a highly time sensitive matter. Although emergency response services, like ambulances, can bypass even dense urban traffic, they are rarely positioned conveniently nearby where a cardiac arrest happens. In a dense urban area, people are however moving more dynamically throughout the day and heart runner schemes use this as a basic premise for sourcing nearby first aid competences for a dual response together with emergency services. It is important to get volunteers to the site of a cardiac arrest as quickly as possible and the facilitation of digital technologies to lead them there is crucial – one might even argue, a matter of life and death. The infrastructure for the real-time information required is already largely implemented in urban areas, according to Townsend [124]. This case features several people (volunteers and potential bystanders) and several tangible mobile technologies (mobile phones and wearables, defibrillators, vehicles), together with an intangible infrastructure of cellular networks, GPS signals and traffic sensors for navigation. Only when combined can the right people be purposefully moved to the right place, in time to make a difference.

This study was carried out as a qualitative interview study, with 16 volunteers (referred to as heart runners) who represented a total of five heart runner schemes. Due to the nature of the volunteer work, we decided not to utilize in-situ or participatory data collection methods, as we could not ethically defend this. As an example, we were naturally not able to collect consent from all involved. In addition, we took care to not encourage participants to disclose information on specific cases, but rather give accounts of tasks and activities. For recruitment, we allied with administrators of closed social media groups as gatekeepers to pass on study information, so as not to reveal the identitites of the individual volunteers. Interviews were carried out based on the same interview guide but in two rounds: before and after the onset of the pandemic, as it opened up new questions that necessitated re-inquiring with early participants. Interviews were transcribed and data was analyzed thematically. Interview transcripts were sent to the individual participants to confirm that their opinions were rightfully represented; in only one case did this result in redacting a few lines.

Our findings are represented in five themes that relate to temporal and spatial elements of availability. The first theme concerned motivations and expectations for signing up as a volunteer. The second theme concerned what considerations participants made before leaving their current activity, two imminent considerations included how fast they could leave and how responsibly they could depart, e.g. not leaving small children without adult supervision, not being impaired by alcohol or illness, etc. The third theme relates to spatial contemplations on area and familiarity. Participants interestingly acknowledged using primarily cars for transportation, even for shorter distances, as this was less straining. Participants emphasized the heightened dependency on navigation via technologies if called to respond in an unfamiliar area and also the lack of support for multiple modalities and current traffic situation in current navigation. The fourth theme, safety and role assignment, underlined that the greatest fear of participants was arriving as the only volunteer, as the many tasks were too demanding for one person. Furthermore, we found that local area groups assigned roles ad-hoc based on their knowledge of other volunteers' strengths; however there was no transparency of this before arriving on site. The final themes concerned technology opportunities and limitations. Some participants reported experiences of technical difficulties, such as location via GPS signals not being accurate and not updating frequently enough. Others had experiences, although with rare occurrence, of misdirections or devices displaying unactionable directions for navigating. Overall we found a misalignment in the way that the participants perceived distance and how distance was implemented in the technologies.

The interaction that happens between humans and technologies is at the center of initiating purposeful movement, as the dependencies are very strong. People (i.e. volunteers) are not an infinite resource; just as technologies have created possibilities for moving relevant people, technologies should in turn adhere to and respect human terms and preferences in this interaction. Technologies should assist, not hinder mobility. Our findings point to that in a dense urban environment, participants choose their mode of transportation based on an assessment of e.g. familiarity with peak traffic hours and other variables. Technologies should support navigation for these in-situ decisions, particularly in this very time-sensitive case. Our findings also point to social dynamics within volunteer communities that represent possibilities for technologies to integrate more dynamic and transparent communication for volunteers about competences and roles. Sourcing nearby people with relevant first aid competences in dense urban areas is often easier than sourcing in rural, low-density areas. Rural areas also often feature greater distances and geographical isolation from health services. These differences impact how spatial and temporal elements should be understood and integrated into technologies, in order to move people purposefully.

3.4. URBAN MOBILITY AND HYBRID SHARED MICROMOBILITY

Maria Kjærup, Mikael B. Skov, Niels Van Berkel. 2021. ***E-Scooter Sustainability – A Clash of Needs, Perspectives, and Experiences****. In proceedings of the IFIP Conference on Human-Computer Interaction (INTERACT'21). Springer LNCS (In press). DOI:https://doi.org/10.1007/978-3-030-85613-7_26*

This paper investigates hybrid shared micromobility services through rental e-scooters in an urban context. In urban areas people often travel shorter distances. As the population density is high, there is a high potential demand for mobility services, which makes it feasible to have multiple options. The many mobility options adversely often result in road congestion in peak traffic hours. Shared modes of mobility may positively impact urban congestion by resulting in fewer vehicles on the roads. In addition, a shift from individual car mobility to public transportation and micromobility modes e.g. bikes and single-user lightweight electric vehicles such as e-skateboards, uniwheels, e-bikes etc., would not only provide more space on the roads, but would also decrease emissions. However, this shift has proven to be difficult to make for many people, often because these shared mobility modes can't provide the flexibility to meet people's varying mobility needs of privately owned cars. Recently, new hybrid shared micromobility modes like the dockless rental e-scooters have been introduced into urban areas across the world and have received a mixed reception. While statistics and reports show that they are increasingly being used for commuting and fun mobility experiences, users are often portrayed in the news as a danger to themselves and other road users when e-scooters clutter up streets and pavements, and when riders exhibit reckless and inconsiderate behaviour. As they are introduced into more and more urban contexts, this raises the question of in what ways they meet urban mobility needs and how can the hybrid elements support urban mobility?

The study in this paper was carried out as a mixed methods approach that combined participant observations with contextual, in-situ interviews and interviews away from the mobility context itself, that had a longer duration and offered more in-depth conversations on the subject of urban mobility and experiences with riding e-scooters. All interviews followed the same semi-structured interview guide, although for the in-situ interviews the immediate surroundings and activities were conveniently in focus. In addition, social media post threads to news articles on e-scooters in a recognized Danish newspaper were analyzed for more nuanced reactions, including from people who did not ride e-scooters. Participant observations consisted of two types: first, riding an e-scooter around the city among other road users, thereby covering a lot of ground due to the dynamic movement. Second, as a pedestrian observing a relatively restricted area and watching e-scooter users pass by. The first type resulted in most of the in-situ interviews, given the ability to tag along with riders. The latter was more consistently time framed, e.g. an hour of observation by the central train station during morning commute.

Our findings illustrate three themes on participants' mobility needs, environmental motivations, perceptions and accounts of experiences with hybrid mobility bridging the digital and physical. In addition, non-user perceptions of e-scooters was a relevant theme. First, our findings point to e-scooters being used for shorter distances that would otherwise be considered walking distances, but e-scooters slightly extend the reach of walking without the strain. Participants primarily saw three purposes for e-scooter use: convenience, everyday commuting and tourist/sightseeing. Participants expressed that e-scooters were particularly well suited for flexible mobility as they can cut across bus corridors. All participants agreed that the free-floating structure meant that they were more easily available than other modes of transportation, compared to locating a transportation hub. However, it was crucial that the mass of e-scooters met users' demands. Participants environmental perceptions of e-scooter riding trended toward a positive environmental impact, strongly connected to the emissions of electric vehicles. Some participants expressed a general preference for electric vehicles as the basis of future transportation. In contrast to this, the analysis of social media comments included more mixed sentiments of the environmental impact, as they featured concerns about sourcing materials for production, the discarding of especially batteries, and sourcing electricity for charging. Our findings point to instances of rental e-scooter use where the digital and physical world merged; as an example, riding in the real world was regulated by invisible lines and zones, which only became visible through the companion apps. The close relationship between mobility and internet infrastructure became apparent for tourists, as a data connection was a prerequisite for riding and something to take into account for data plans when abroad. The physical vehicle received much attention from non-users, as a new mode of mobility they had to interact with on the roads. Our findings exemplify non-user concerns, when we observed a participant instruct us on how to hack the e-scooter hard set speed limit to double itself.

Dockless rental e-scooters offer door-to-door mobility, in contrast to the point-via-point mobility exemplified by time-scheduled public transportation. This contributes to the perceived accessibility of this mode of transportation. Nonetheless, our findings indicate that they rarely substitute car-based mobility, but rather are seen as an alternative to walking, which does not necessarily contribute to less congestion. However, e-scooters have the ability to make routes ad-hoc as they have the possibility to bypass heavy traffic by taking alternate routes or possibly connecting with other modes of mobility, which is ideal in an urban context. Rental e-scooters present a new form of mobility that is solely enabled via mobile digital technologies. Hence we call them hybrid as the combination of tangible vehicles and intangible digital infrastructures is made visible through the companion apps or haptic through e.g. regulating the speed through pedestrian streets. Our findings suggest that technologies could be used beneficially to ensure the reliability of available e-scooters, to support the perceived accessibility.

CHAPTER 4. DISCUSSION

In this thesis I investigate people mobility with the focus on digital support for rural and urban areas. For this discussion I will first reflect on four statements that illustrate rural and urban digital mobility. Following, I will focus on the integration of mobility that moves through or between rural and urban areas, specifically how digital technologies can support this mobility. Finally, I will look beyond the scope of this thesis to suggest directions for research on future mobility.

4.1. RURAL AND URBAN DIGITAL MOBILITY

I argue that on-demand last mile mobility services are difficult to implement in rural areas, as travelers find it inflexible and even risky. In particular, paper 1 demonstrate how rural last mile mobility is challenging to accommodate. Mobility services that address the last mile problem, have primarily been studied in urban areas [15,61,76,133]. Hardy et al. argue that rural areas face unique challenges that relate to e.g. mobility infrastructure [52]. Velaga et al. also point to geographic distance, low-density population and uncertain demands as challenges towards feasible rural public transportation [129]. A way to accommodate uncertain demand is passenger pooling for on-demand mobility services, in rural areas in particular, to connect with main lines of mobility [55,129]. However, findings from paper 1 accentuate that for rural area mobility, the planning aspects involved in this mobility form was experienced as a burden and at times even discouraged use. Remarkably, paper 1 suggest that return trips were perceived as more problematic than one-way trips, as for social gatherings and events it was often difficult to determine an exact time for ending and returning, as opposed to a set meeting time where you could more flexibly plan arrival. I argue, in accordance with e.g. Hensher, that here exists possibilities for using digital technologies for flexible scheduling and more transparent real-time communication between driver and passengers [55]. In the same way that urban on-demand mobility (e.g. Uber) works ([126]). In addition, I also see possibilities to tailor and reserve mobility to specific local events, to encourage more public and shared mobility that meet actual current mobility demand, in particular for rural areas.

Digital technologies hold opportunities for flexible mobility for rural households. Extending argumentation from related work [37,50,52,129]. Interestingly, paper 1 and 2 showed that rural households' vehicles and digital technologies were both important for planning and negotiating mobility. Rural household members would use digital technologies to create opportunities for flexible mobility, usually in the form of arranging lifts via social media or phone calls. To such a degree, that parents shared ground rules they had established for negotiating mobility, for example: Stating certain times of unavailability to respond to requests for mobility. Studies from paper 1 and 2 also saw how older siblings were involved in ensuring mobility for members of the household. None of the households included in the studies expressed using analogue technologies like calendars, notes, etc., for negotiating mobility, but rather made arrangements as mobility needs arose. In this way digital technologies supported flexible rural mobility. When household members were not available, some participants used their neighbours as extension of the household to cover mobility needs. For paper 2 we argued that the household and their neighbours constitute a small-scale mobility community. The findings from the contributions on rural mobility for this thesis resembles the rural household mobility scenarios presented by Gray et al., while they do not focus on technologies for negotiating mobility, but rather on the activities and modes of mobility and who provides mobility for whom [50]. Gray et al., acknowledge the benefits of a research agenda on technologies' impact on social relations on community and household levels [50]. Similarly, Velaga et al. argued for the shortcomings of flexible rural mobility that did not effectively use intelligent transport systems or advanced information and communication technology support [129]. In addition, I argue based on study findings from primarily paper 2 that rural dwellers rejected formalized approaches to ridesharing, for this purpose they also used social media groups to arrange lifts with locals. Study participants argued for this preference for social media over dedicated ridesharing platforms because of the perceived informality of arrangements, and the perception of less commitment, consequently experiencing this approach as more flexible.

Sometimes motorized vehicles are strategically used for short distance trips in urban areas. Glöss et al. argue that HCI research are favoring car-based mobility [47]. Meanwhile Canzler and Knie reason that the private car is losing its significance in the face of climate change and permanent urban congestion [16]. While paper 1 and 2 showed an expected dependency on the car to maintain high levels of autonomy of mobility in rural areas, paper 3 somewhat surprisingly showed a preference for car-based mobility in urban areas. I extend argumentation that cars have a role to play in future mobility, with an illustrative case of how car transportation is a means to potentially saving lives. While the Danish heart runner scheme is largely being advertised showing volunteers running in urban areas, our study findings show that most often heart runner volunteers have a preference for car-based mobility. At the destination, a lot of physically demanding tasks are waiting, consequently mobility by car is less straining and will additionally often get volunteers there faster. Sheller and Urry argue that when discussing mobility, we should recognize the complexity of the underlying social organization by getting beyond the idea that mobility 'consumers' simply should stop driving cars and start taking the bus [112]. With their car-free year study, Hasselqvist et al. underscored that the car is the norm and their participants experienced having to make excuses to family, friends and colleagues for making alternative mode choices that were considered odd, for example using an electric box bike [53]. E-scooters are also motorized vehicles, and findings of paper 4 point to them being perceived as an alternative to walking, as they conveniently cover distances that are comparable to walking distance but with less strain. Tuncer and Brown refer to e-scooters as a representative for a hybrid mobility, because its placement on the road/pavement/bike lane determine how riders perceive themselves and consequently act in traffic [125]. This blurs the line between the modes of mobility I presented earlier in related work. In Denmark, e-scooters are regulated like bikes and are expected to ride in the bike lane, however according to paper 4 e-scooters can also be perceived as a vehicle that bridges two modes of mobility: pedestrian and biking. In addition, paper 4 suggest that e-scooters represent a form of mobility that is often being carried out for fun, but also as a door-to-door mobility solution. Related work has also pointed to the importance of viewing mobility not only as a derived demand, but with the lens of mobility as a valued activity in itself [4]. As an example, Hasselqvist et al. discuss seeing beyond optimization of time, to consider: being outdoors, getting physical exercise, being with the family without having to focus on driving etc. [53]. I suggest that this points to a tension between the reliability of vehicle ownership and the accessibility of dockless shared micromobility, and a need to thoroughly understand the mechanism of these options.

Planning for trips consisting of both traditional time-tabled transportation and for on-demand mobility services is a challenge and an opportunity for mobile HCI research. My paper contributions illustrate that travel information is fragmented across several different platforms, often accessed via different applications and on a variety of devices. This can result in a planning and coordination burden for travellers and in addition, fragmented or static travel information can discourage intermodal trips. This is in contrast to the MaaS vision of a one entry mobility platform for travel and payment information [33,48,128]. Sochor et al. presented levels of MaaS integrations, level one-four with increasing integration, where bundling of services were almost at the top level [116]. Although such examples exist, for example the Whim travel service, they are not commonplace and my paper contributions provide no examples of complete high levels of integration. Paper 1 show that when travellers are not certain that travel information will adjust dynamically in cases of unforeseen events when trips contain one or more mode shifts, it can discourage taking the trip altogether. Svangren et al. found that most shared rides was supplemented with other modes of transportation and suggested that ridesharing services could have an element of more proactive travel recommendations, that would take into account smartphone sensing of location, activity and maybe also calendar events to suggest nearby mobility options [122]. For paper 4, proactive mobility suggestions could ideally be combined with features to ensure reliability of mobility options. My paper contributions, primarily 1 and 2, also point to people combining private and public modes of transportation e.g. arranging lifts from the busstop or trainstation and to the final destination (last mile). I suggest for HCI research to consider what constitutes ideal integrations of private and public transportation, according to and with the inclusion of travelers, and how digital technologies can support this integration. One thing that I would propose is to support sharing of real-time travel information between traveler (mobility ‘consumer’) and mobility provider (As an example, a relative planning to provide a lift for the last mile stretch), to support communication and decision making for both. That being said, paper 3 illustrate an example of mobility that is very difficult to plan for.

4.2. INTEGRATION AND KNOWLEDGE TRANSFER

In this section I will discuss two themes that relate to rural and urban digital mobility, these are integration between rural and urban mobility and knowledge transfer between rural and urban mobility. For integration I point out that rural and Urban mobility have been presented as separate throughout this thesis, however many trips will cross from rural to urban areas or the other way around, or any combination e.g. rural to rural via urban. Knowledge transfer refers to the possibility that discussions and conclusions on rural mobility may be applicable to urban mobility, and vice versa. Foth et al. address a challenge and opportunity for research to address issues “beyond the urban” [43]. They discuss that an undifferentiated attention on urban may segregate from what they refer to as non-urban areas or rural and remote locations, as residents, commuters and visitors move in and out of citites and in these ways nurture symbiotic relationships and exchanges between urban and rural areas [43].

As illustrated by the findings from my paper contributions, people may travel between rural and urban areas for commuting to school or work, for leisure activities e.g. outdoors, for visiting family and friends, etc. For these purposes they use a number of mobility modes, but not all modes are equally suited for travelling between rural and urban areas. Oostendorp et al argue that intermodal mobility is the key to more efficient and sustainable urban mobility systems [86]. My contributions on rural mobility additionally indicate that a combination of private and public modes of mobility are being used to cover the first and last mile. However, I also demonstrate a lack of integration between these modes of mobility. Hensher argue for a mobility service model that is hybrid, meaning that digital technologies can aid in creating more service points of mobility between traditional timetabled mobility and on-demand mobility services [55]. The concept of hybrid mobility is also argued by Tuncer and Brown, directed at the way e-scooters behave as a mode of mobility in an urban context [125]. I argue that the concept of hybrid mobility will aid in understanding how private and public mobility modes can be combined and achieve a higher level of integration. This is also the cornerstone of the MaaS vision of mobility [33,48,128]. While Durand et al. conclude that MaaS seemingly has potential for reaching specific population groups, particularly young and tech-savvy urban individuals [33]. I argue that based on the findings on rural dwellers’ visions for future mobility, there are possibilities for including rural areas in this vision. What is crucial for this to work is the integration, not only at the most basic levels, as Sochor et al. demonstrate ([116]), but transparent and dynamic travel information delivered timely to passengers that includes possibilities of trip-chaining with multiple modes of mobility.

A discussion of knowledge transfer from urban to rural mobility can be illustrated with an outset in the paper contribution 3, the study of the heart runner scheme. The current implementation does not discriminate between rural and urban areas, although I argue that there are different considerations with respect to understanding proximity. For this thesis, this study primarily represent a contribution towards understanding urban mobility and in particular, how to mobilize volunteers with the aid of digital technologies. However the study also suggested implications for rural heart runner schemes. By mobilizing volunteers, I mean getting them from point A to point B, here technologies currently assist in 1) locating current position (A) and 2) navigation to destination (B). For current location, two technological approaches were used: GPS (app-based) and SMS. The GPS pinpoint the location of the individual volunteer and choose a pool of volunteers based on proximity to be mobilized. The SMS approach instead aim at mobilizing a group of volunteers based on a pre-defined geographical area coverage, therefore the current position of the individual volunteer is not known. Findings from our study suggest that there are other considerations besides current location to take into account, considerations that are both spatial and temporal. Ozcan et al. illustrated temporal barriers in their model and also hinted at spatial considerations [87]. Although not explicitly stated, these related primarily to heart runner schemes in urban areas. In contrast, participants expressed a different understanding of rural proximity, as a consequence of the knowledge that often emergency response vehicle dispatch centers are further away and thus they take longer to arrive and that a low-population density means that sourcing an adequate number of volunteers would require a much wider radius than in an urban area. One thing that is similar for urban and rural heart runner schemes are the temporal aspects of being available to responsibly leave your current activity. Digital technologies are often equipped with sensors and could potentially be used to infer current activity, together with location, this may give a more accurate assessment of the availability of heart runner volunteers.

4.3. BEYOND CURRENT MOBILITY SCENARIOS

The MaaS vision is clearly worded as addressing individual's mobility needs, however it may be neglecting a view that travelling can be a social endeavour. All paper contributions that constitute this thesis demonstrate social aspects of mobility, examples range from a participant of the study in paper 2 explaining how her granddaughter loves riding the bus and it's an activity they do together, to paper 4 where the method naturally, although unforeseen, included interviewing groups of people on e-scooters together. Ridesharing was demonstrated in paper 1 and 2 to enrich mobility experiences with casual encounters, often with other locals. Banister argues that there is a need to move beyond viewing transportation as solely a derived demand if it is to truly meet the mobility needs of people [4]. I agree that mobility should be able to include these social aspects. It would require, as Sanders et al. argue, that travel planning and coordination, beyond the individual's trip, was supported by travel planners and other digital technologies [106]. Hildén and Väänänen also demonstrated social motivations for bus passengers in their personas and scenarios toolkit [57]. While this thesis does not provide concrete answers on how to do this, inspiration can be found in the paper contributions, for example a participant of the study in paper 2 imagined re-branding public transportation as a café on wheels.

Autonomous vehicles will be a big part of future rural transportation, according to Daduna [23]. He reasons that autonomous driving will expand individual mobility for defined groups of people characterized as under-aged, elderly and disabled, and in particular for rural areas where there is an undersupply of public passenger transport, especially for these groups [23]. My paper contributions also emphasize these mentioned groups of people as often lacking in autonomy of mobility. Participants' imaginations of future visions of mobility, from paper 2, featured autonomous driving. The main reasons given was decreased personnel costs and fewer human errors, however participants did not go into further details on implementation. Daduna also mention these, but additionally emphasize an expansion of service hours, emotionally influenced behaviours eliminated which could lead to fuels savings costs and reduction of traffic-related emissions [23]. He asserts that rural areas constitute an important field for first step suitability for autonomous vehicles, since traffic conditions are less critical than in urban areas. He imagines this should not be viewed as a full replacement, but a substitution of underutilized standard buses in rural areas or smaller citites and as last mile connections to higher-level traffic systems [23]. A few participants from paper 2 was concerned about the implications for the currently employed transport personnel, and for paper 1, interviews with drivers showed general dissatisfaction towards future prospects of their working conditions. HCI research has also recently engaged with how the developments of mobility impact mobile workers in both negative and positive ways [46,65]. Daduna mention the continued necessity for service, maintenance and repair personnel [23].

CHAPTER 5. CONCLUSION

In this thesis I have three research questions, for which I will present conclusions. To summarize, these research questions are: 1) What characterizes mobility in rural and urban areas? 2) How can digital technologies support mobility in rural and urban areas? And 3) How can studies of mobility and digital technology use be planned and carried out in rural and urban areas?

I answer these research question through empirical studies of bespoke digital technologies for people mobility, demonstrated primarily in paper 1, 3 and 4 as well as looking at ways that people make digital technologies work together to enable mobility, demonstrated primarily in paper 2. The contributions demonstrate multiple, qualitative data collection methods. For all studies I carried out semi-structured interviews, while for the studies in paper 1 and 4 I incorporated data collection in-situ, as participant observation and interviews in the context of mobility activities.

5.1. FIRST RESEARCH QUESTION

The first research question in my thesis is:

What characterizes mobility in rural and urban areas?

I will characterize mobility in rural and urban areas with an outset in three mobility modes. These are mobility based on private cars, mobility based on public mobility services and pedestrian/biking mobility.

For the private car as a mobility mode, I conclude that mobility in rural areas is often characterised as involving the use of cars, and interestingly this was also the case for certain situations of urban mobility. Study findings from paper 1 and 2 showed how rural households often own one or more cars, or at least have access to a car. Access does not equal the means to drive a car, resulting in a perception of autonomy of mobility that is lower for children, teenagers and elderly people, also pointed out in related work ([50,52]). Paper 1 and 2 show examples of how household members hold each other accountable (parents and siblings) for covering mobility needs. In addition, paper 2 show how local mobility communities, such as neighbours, aid in liftgiving. Interestingly, papers 1 and 2 showed that participants' imaginations of future mobility included autonomous vehicles and public car-sharing. For urban car-based mobility, related work shows issues of congestion and restrictions on emissions, and for these reasons suggest a decline in the popularity of the private car (e.g. [16]). Nonetheless, I found that for the urban heart runner schemes (paper 4), car-based mobility was seen as a dominant preference as it moved volunteers strategically quickly and without strain.

Second, Rural mobility is often characterised by complex needs and combinations of flexibility and planning. I found that the first and last mile was a challenge to accommodate using traditional timetable-based public transportation, as low and uncertain demand made it unfeasible to cover all rural destinations. The empirical study of paper 1 showed that on-demand public mobility services to address the last mile problem lacked the flexibility and spontaneity of private car transportation. However, the study from paper 2 identified some interesting visions for future mobility that included re-imagining public transportation as more than transportation; as a social space. Related work has also suggested travel planners should implement features for traveling together ([106]) and future expectations of bus service levels ([56]), though aimed primarily at urban mobility. Future work could engage with this alternative approach to public mobility services.

Third, pedestrian and biking mobility in rural and urban areas are carried out for different purposes. Pedestrian and biking mobility in rural areas are primarily recreational or aimed at exercising; paper 1 and 2 shows rural dwellers hiking in the woods or biking along the coast. Meanwhile the study findings in paper 3 illustrate that pedestrian and biking mobility are perceived as modes for commuting, but micromobility modes like e-scooters are also used by tourists, for leisure, for business, and just-for-fun mobility experiences. In accordance with the conclusions of related work ([125]), I also found that the e-scooter was perceived as a hybrid between pedestrian and biking modes of mobility, as often distances were short but because it was a motorized vehicle these distances were covered expediently with little strain.

5.2. SECOND RESEARCH QUESTION

The second research question in my thesis is:

How can digital technologies support mobility in rural and urban areas?

I found that digital technologies can support mobility in rural and urban areas through four approaches, namely integration across public and private modes of mobility, creating flexible ad-hoc routes, enabling shared modes of mobility and mobilizing people.

First, digital technologies can support mobility by integration across public and private modes of mobility, according to related work on MaaS (e.g. [33,48,116]); the empirical studies in papers 1, 2 and 4 however indicate a lack of integration. The study in paper 1 illustrate how static travel plans are perceived as risky for intermodal trips and in some cases deter mobility due to their lack of adaptability to changes in the travel plan and consequently risk a potential planning burden. In addition, the study in paper 4 exemplifies how e.g. payment between modes is fragmented across several digital platforms, in comparison to bundling mobility offers like the Whim app-based mobility service ([45]).

Secondly, the studies presented in paper 1 and 4 show how bespoke digital technologies for mobility can support mobility by creating flexible opportunities for ad-hoc routes, but approach this by looking at mobility in different contexts. While the study in paper 1 focused on last mile mobility in a rural area, the study in paper 4 reveal findings on shared hybrid micromobility in an urban context. Both conclude that reliability of access is crucial for perceived flexibility of mobility. Future work should look into how digital technologies can implement guarantees of mobility.

Third, digital technologies support mobility by enabling options for shared modes of mobility. Paper 2 demonstrates how a variety of digital technologies play a role in enabling mobility beyond the individual, in a rural context, e.g. using social media or phone calls for sharing travel information to arrange lifts, as dedicated ridesharing platforms were often found to be too rigid for planning mobility. This confirmed the conclusions of related work that showed people collaborating through a number of mobility services to plan and negotiate ridesharing, outside the features of dedicated ridesharing platforms [122].

Fourth, digital technologies can play a key role in mobilizing people toward a common goal. This is illustrated primarily in the study of heart runner schemes (paper 3), where digital mobilities enable volunteers with first aid competencies to move quickly to the site of a cardiac arrest. The study findings also point to the importance of understanding the context of mobility to implement features that support the mobility needs of people e.g. navigation in accordance with their mobility mode preference in the moment, which could potentially be sensed by digital technologies.

5.3. THIRD RESEARCH QUESTION

The third research question in my thesis is:

How can studies of mobility and digital technology use be planned and carried out in rural and urban areas?

I conclude on my choice of approaches to plan and carry out studies of mobility based on two traits; conditions for carrying out participatory studies of digital mobility and some mobility situations that are challenging to study.

Paper 1 and 4 demonstrated that mobility and digital technologies can be studied while the researcher participates in the mobility activity if planning is possible (Paper 1) or mobility frequency and visibility is high (paper 4). Participation in the context of mobility is resource demanding, but can provide valuable insights about experiences of mobility and can establish some common ground with participants that can aid researchers' understanding of the impact of contextual factors of mobility.

Certain kinds of mobility are challenging to study as it involves extreme ad-hoc and sensitive situations, as demonstrated by paper 3. It is important that researchers reflect on how they position themselves in order to respect participants' rights.

5.4. LIMITATIONS

This thesis does have some limitations that I will unfold here. These limitations relate to defining rural and urban, and study context and generalizability. Nonetheless, the scope of this PhD thesis was never to exhaust all definitions of areas of mobility or embrace all possible contexts for mobility.

I have throughout this thesis applied the concepts of rural and urban as oppositions, in accordance with definitions from related work. However, definitions vary and can encompass a lot of areas in between and beyond these definitions. An example of urban as a unified concept can be seen in Foth et al. that unpacks urban to constitute both metropolitan, suburban and peri-urban with respective differentiation in definitions [43]. In the same manner, rural have been defined in many ways and some have distinguished between rural and remote areas [43,50,52,129]. Recently, also bridging conceptualizations have emerged, for example the word 'rurban' meaning rapidly expanding rural areas into ancillerary communities to nearby cities [83]. Authors Murray et al. assert that 'rurban' areas hold unique characteristics that are different to both rural and urban areas [83]. For the paper contributions in this thesis participants have primarily self-defined their belonging to rural or urban by answering calls directed at e.g. "rural dwellers". Although, recruiment calls have also been directed through targeted distribution channels. Argumentation from participants have primarily been descriptive with examples of: population density, acces and frequency of public transportation, proximity to transportation hubs or other services, etc.

Furthermore, the study context in which I have identified rural and urban areas have been located in Denmark and study findings and conclusions can't be readily generalizable to rural and urban areas of the world. This is both a matter of scale in descriptive categories of rural and urban (see for example [27,39,52,129]) and cultural and historical views on mobility, for example Copenhagen (the capitol of Denmark) is often exemplified as a biking friendly urban environment. Canzler and Knie illustrate this with a comparison of the respective frameworks for mobility which are, "…given in Copenhagen and very much less so in Los Angeles" [16]. Acces to and options of mobility is also contingent on socio-economic factors, as Hardy et al. recently reported a lack of studies of rural mobilities for developed and high-income countries [52]. Daduna exemplify that rural mobility in developing countries are often insufficient due to network structure and range, and parallel to these exist paratransit, flexible and (partly) on-demand vehicles often with individual vehicle design; usually converted midi or mini buses operated by micro-entepreneurs, examples are: Camiones (Cuba), Camioneta (Guatemala), Dolmuş (Turkey) Marschrutka (in countries from the former Sowjet Union), Tanka tanka (Gambia), etc [23].

LIST OF REFERENCES

[1] ACM. MobileHCI 2021 frontpage. Retrieved from https://mobilehci.acm.org/2021/

[2] Dirk Ahlers. 2020. Challenges of Sustainable Urban Mobility Integration. In *22nd International Conference on Human-Computer Interaction with Mobile Devices and Services*, ACM, New York, NY, USA, 1–3. DOI:https://doi.org/10.1145/3406324.3426767

[3] Aino Ahtinen, Eeva Andrejeff, Maiju Vuolle, and Kaisa Väänänen. 2016. Walk as You Work: User Study and Design Implications for Mobile Walking Meetings. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, ACM, New York, NY, USA, 1–10. DOI:https://doi.org/10.1145/2971485.2971510

[4] David Banister. 2008. The sustainable mobility paradigm. *Transp. Policy* 15, 2 (March 2008), 73–80. DOI:https://doi.org/10.1016/j.tranpol.2007.10.005

[5] Louise Barkhuus and Jennifer A. Rode. 2007. From Mice to Men - 24 Years of Evaluation in CHI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA. DOI:https://doi.org/10.1145/1240624.2180963

[6] Oliver Bates, Adrian Friday, Julian Allen, Tom Cherrett, Fraser McLeod, Tolga Bektas, Thuba Nguyen, Maja Piecyk, Marzena Piotrowska, Sarah Wise, and Nigel Davies. 2018. Transforming Last-mile Logistics: Opportunities for more Sustainable Deliveries. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–14. DOI:https://doi.org/10.1145/3173574.3174100

[7] Jakim Berndsen, Barry Smyth, and Aonghus Lawlor. 2019. Pace my race: recommendations for marathon running. In *Proceedings of the 13th ACM Conference on Recommender Systems*, ACM, New York, NY, USA, 246–250. DOI:https://doi.org/10.1145/3298689.3346991

[8] Susanne Bødker. 2006. When second wave HCI meets third wave challenges. In *Proceedings of the 4th Nordic conference on Human-computer interaction changing roles - NordiCHI '06*, ACM Press, New York, New York, USA, 1–8. DOI:https://doi.org/10.1145/1182475.1182476

[9] Joel Booth, Prasad Sistla, Ouri Wolfson, and Isabel F. Cruz. 2009. A data model for trip planning in multimodal transportation systems. In *Proceedings of the 12th International Conference on Extending Database Technology*

Advances in Database Technology - EDBT '09, ACM Press, New York, New York, USA, 994. DOI:https://doi.org/10.1145/1516360.1516474

[10] Paul Bossauer, Thomas Neifer, Gunnar Stevens, and Christina Pakusch. 2020. Trust versus Privacy: Using Connected Car Data in Peer-to-Peer Carsharing. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376555

[11] Simon Bowen, Peter Wright, Alexander Wilson, Andy Dow, Tom Bartindale, and Robert Anderson. 2020. Metro Futures: Experience-Centred Co-Design at Scale. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376885

[12] Johanna Brewer and Paul Dourish. 2008. Storied spaces: Cultural accounts of mobility, technology, and environmental knowing. *Int. J. Hum. Comput. Stud.* 66, 12 (December 2008), 963–976. DOI:https://doi.org/10.1016/j.ijhcs.2008.03.003

[13] Robin N. Brewer and Vaishnav Kameswaran. 2019. Understanding Trust, Transportation, and Accessibility through Ridesharing. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–11. DOI:https://doi.org/10.1145/3290605.3300425

[14] Craig Bullock, Finbarr Brereton, and Sive Bailey. 2017. The economic contribution of public bike-share to the sustainability and efficient functioning of cities. *Sustain. Cities Soc.* 28, (January 2017), 76–87. DOI:https://doi.org/10.1016/j.scs.2016.08.024

[15] Kayleigh B. Campbell and Candace Brakewood. 2017. Sharing riders: How bikesharing impacts bus ridership in New York City. *Transp. Res. Part A Policy Pract.* 100, (June 2017), 264–282. DOI:https://doi.org/10.1016/j.tra.2017.04.017

[16] Weert Canzler and Andreas Knie. 2016. Mobility in the age of digital modernity: why the private car is losing its significance, intermodal transport is winning and why digitalisation is the key. *Appl. Mobilities* 1, 1 (January 2016), 56–67. DOI:https://doi.org/10.1080/23800127.2016.1147781

[17] Stefan Carmien, Melissa Dawe, Gerhard Fischer, Andrew Gorman, Anja Kintsch, and James F. Sullivan. 2005. Socio-technical environments supporting people with cognitive disabilities using public transportation. *ACM Trans. Comput. Interact.* 12, 2 (June 2005), 233–262.

DOI:https://doi.org/10.1145/1067860.1067865

[18] John M. Carroll and Mary Beth Rosson. 2013. Wild at Home: The Neighborhood as a Living Laboratory for HCI. *ACM Trans. Comput. Interact.* 20, 3 (July 2013), 1–28. DOI:https://doi.org/10.1145/2491500.2491504

[19] Alan Chamberlain and Andy Crabtree. 2020. *Into the Wild: Beyond the Design Research Lab*. Springer International Publishing, Cham. DOI:https://doi.org/10.1007/978-3-030-18020-1

[20] Sixian Chen, John Bowers, and Abigail Durrant. 2015. "Ambient walk": a mobile application for mindful walking with sonification of biophysical data. In *Proceedings of the 2015 British HCI Conference*, ACM, New York, NY, USA, 315–315. DOI:https://doi.org/10.1145/2783446.2783630

[21] Carl Collins, Amy Grude, Matthew Scholl, and Robert Thompson. 2007. txt bus: wait time information on demand. In *CHI '07 Extended Abstracts on Human Factors in Computing Systems*, ACM, New York, NY, USA, 2049–2054. DOI:https://doi.org/10.1145/1240866.1240948

[22] Tim Creswell. 2006. *On the Move: Mobility in the Modern Western World*. Routledge.

[23] Joachim R. Daduna. 2020. Evolution of Public Transport in Rural Areas - New Technologies and Digitization. . 82–99. DOI:https://doi.org/10.1007/978-3-030-49757-6_6

[24] Benyon; David. 2014. *Designing interactive systems : a comprehensive guide to HCI, UX and interaction design* (Third ed.). Pearson.

[25] Debargha Dey, Azra Habibovic, Bastian Pfleging, Marieke Martens, and Jacques Terken. 2020. Color and Animation Preferences for a Light Band eHMI in Interactions Between Automated Vehicles and Pedestrians. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376325

[26] Debargha Dey and Jacques Terken. 2017. Pedestrian Interaction with Vehicles: : Roles of Explicit and Implicit Communication. In *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ACM, New York, NY, USA, 109–113. DOI:https://doi.org/10.1145/3122986.3123009

[27] Marco Diana. 2012. Measuring the satisfaction of multimodal travelers for

local transit services in different urban contexts. *Transp. Res. Part A Policy Pract.* 46, 1 (January 2012), 1–11. DOI:https://doi.org/10.1016/j.tra.2011.09.018

[28] Tawanna R. Dillahunt, Vaishnav Kameswaran, Linfeng Li, and Tanya Rosenblat. 2017. Uncovering the Values and Constraints of Real-time Ridesharing for Low-resource Populations. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 2757–2769. DOI:https://doi.org/10.1145/3025453.3025470

[29] Tawanna R. Dillahunt and Tiffany C. Veinot. 2018. Getting There: Barriers and Facilitators to Transportation Access in Underserved Communities. *ACM Trans. Comput. Interact.* 25, 5 (2018), 1–39. DOI:https://doi.org/10.1145/3233985

[30] Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. Mapping the landscape of sustainable HCI. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, ACM Press, New York, New York, USA, 1975. DOI:https://doi.org/10.1145/1753326.1753625

[31] Alan Dix. 2020. Step by Step Research. In *Into the Wild: Beyond the Design Research Lab*, Alan Chamberlain and Andy Crabtree (eds.). Springer, 7–29. DOI:https://doi.org/10.1007/978-3-030-18020-1_2

[32] Dmitrijs Dmitrenko, Emanuela Maggioni, Giada Brianza, Brittany E. Holthausen, Bruce N. Walker, and Marianna Obrist. 2020. CARoma Therapy: Pleasant Scents Promote Safer Driving, Better Mood, and Improved Well-Being in Angry Drivers. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376176

[33] Anne Durand, Lucas Harms, Sascha Hoogendorn-Lanser, and Toon Zijlstra. 2018. Mobility-as-a-Service and changes in travel preferences and travel behaviour : a systematic literature review. *Bijdr. aan het Colloq. Vervoer. Speurw.* (2018), 1–15.

[34] Ministerie van Infrastructuur en Waterstaat. 2018. Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review (English)-Document-Netherlands Institute for Transport Policy Analysis. (2018).

[35] Enrique Encinas, Dimitrios Raptis, Jesper Kjeldskov, and Mikael B. Skov. 2020. Readiness, Seamlessness and Connectedness Understanding Business

Travellers’ Door to Door Journeys. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*, ACM, New York, NY, USA, 1–11. DOI:https://doi.org/10.1145/3419249.3420123

[36] European Commission. 2021. What are Urban Vehicle Access Regulations (UVARs)? Retrieved from https://urbanaccessregulations.eu/userhome/what-are-access-regulations-uvars-or-urban-vehicle-access-regulations

[37] European network for rural development. 2021. *Rural mobility matters - insights from SMARTA*.

[38] European Union. 2016. General Data Protection Regulation (GDPR). *GDPR.EU*. Retrieved from https://gdpr.eu/tag/gdpr/

[39] Eurostat. Urban-rural typology. Retrieved from https://ec.europa.eu/eurostat/web/rural-development/methodology

[40] Stefanie M. Faas, Andrea C. Kao, and Martin Baumann. 2020. A Longitudinal Video Study on Communicating Status and Intent for Self-Driving Vehicle & Pedestrian Interaction. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–14. DOI:https://doi.org/10.1145/3313831.3376484

[41] Pedro Ferreira, Karey Helms, Barry Brown, and Airi Lampinen. 2019. From Nomadic Work to Nomadic Leisure Practice. *Proc. ACM Human-Computer Interact.* 3, CSCW (November 2019), 1–20. DOI:https://doi.org/10.1145/3359213

[42] Michela Ferron, Chiara Leonardi, Paolo Massa, Gianluca Schiavo, Amy L. Murphy, and Elisabetta Farella. 2019. A Walk on the Child Side: Investigating Parents’ and Children’s Experience and Perspective on Mobile Technology for Outdoor Child Independent Mobility. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3290605.3300827

[43] Marcus Foth, Jaz Hee-jeong Choi, and Christine Satchell. 2011. Urban informatics. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work - CSCW ’11*, ACM Press, New York, New York, USA, 1. DOI:https://doi.org/10.1145/1958824.1958826

[44] Jon Froehlich, Tawanna Dillahunt, Predrag Klasnja, Jennifer Mankoff, Sunny Consolvo, Beverly Harrison, and James A. Landay. 2009. UbiGreen: investigating a mobile tool for tracking and supporting green transportation

habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1043–1052. DOI:https://doi.org/10.1145/1518701.1518861

[45] MaaS Global. Whim app. Retrieved from https://whimapp.com/

[46] Mareike Glöss, Moira McGregor, and Barry Brown. 2016. Designing for Labour: Uber and the On-Demand Mobile Workforce. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1632–1643. DOI:https://doi.org/10.1145/2858036.2858476

[47] Mareike Glöss, Sylvaine Tuncer, Barry Brown, Eric Laurier, Sarah Pink, Vaike Fors, Erik Vinkhuyzen, and Helena Strömberg. 2020. New Mobilities: A Workshop on Mobility Beyond the Car. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–8. DOI:https://doi.org/10.1145/3334480.3375169

[48] Warwick Goodall, Tiffany Dovey Fishman, Justine Bornstein, and Brett Bonthron. 2017. The rise of mobility as a service Reshaping how urbanites get around. *Delotitte Rev.* 20 (2017), 111–130. Retrieved from https://www2.deloitte.com/content/dam/insights/us/articles/3502_Mobility-as-a-service/DR20_The rise of mobility_reprint.pdf

[49] Google. Google Maps. Retrieved from https://www.google.dk/maps/

[50] David Gray, Jon Shaw, and John Farrington. 2006. Community transport, social capital and social exclusion in rural areas. *Area* 38, 1 (March 2006), 89–98. DOI:https://doi.org/10.1111/j.1475-4762.2006.00662.x

[51] Renate Haeuslschmid, Bastian Pfleging, and Florian Alt. 2016. A Design Space to Support the Development of Windshield Applications for the Car. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 5076–5091. DOI:https://doi.org/10.1145/2858036.2858336

[52] Jean Hardy, Susan Wyche, and Tiffany Veinot. 2019. Rural HCI Researc: Definitions, Distinctions, Methods, and Opportunities. *Proc. ACM Human-Computer Interact.* 3, CSCW (November 2019), 1–33. DOI:https://doi.org/10.1145/3359298

[53] Hanna Hasselqvist, Mia Hesselgren, and Cristian Bogdan. 2016. Challenging the Car Norm: Opportunities for ICT to Support Sustainable Transportation Practices. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1300–1311.

DOI:https://doi.org/10.1145/2858036.2858468

[54] Adrian Hazzard, Steve Benford, and Gary Burnett. 2014. Walk this way: musically guided walking experiences. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 605–614. DOI:https://doi.org/10.1145/2556288.2557250

[55] David A. Hensher. 2017. Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change? *Transp. Res. Part A Policy Pract.* 98, (April 2017), 86–96. DOI:https://doi.org/10.1016/j.tra.2017.02.006

[56] Elina Hildén, Jarno Ojala, and Kaisa Väänänen. 2016. User Needs and Expectations for Future Traveling Services in Buses. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, ACM, New York, NY, USA, 1–6. DOI:https://doi.org/10.1145/2971485.2996733

[57] Elina Hildén and Kaisa Väänänen. 2019. Communicating User Insights with Travel Mindsets and Experience Personas in Intra-city Bus Context. In *Human-Computer Interaction -- INTERACT 2019*, David Lamas, Fernando Loizides, Lennart Nacke, Helen Petrie, Marco Winckler and Panayiotis Zaphiris (eds.). Springer International Publishing, Cham, 34–52. DOI:https://doi.org/10.1007/978-3-030-29390-1_3

[58] Kai Holländer, Andy Krüger, and Andreas Butz. 2020. Save the Smombies: App-Assisted Street Crossing. In *22nd International Conference on Human-Computer Interaction with Mobile Devices and Services*, ACM, New York, NY, USA, 1–11. DOI:https://doi.org/10.1145/3379503.3403547

[59] Rikke Hagensby Jensen, Michael Kvist Svangren, Mikael B. Skov, and Jesper Kjeldskov. 2019. Investigating EV Driving as Meaningful Practice. In *Proceedings of the 31st Australian Conference on Human-Computer-Interaction*, ACM, New York, NY, USA, 42–52. DOI:https://doi.org/10.1145/3369457.3369461

[60] Rose Johnson, Yvonne Rogers, Janet van der Linden, and Nadia Bianchi-Berthouze. 2012. Being in the thick of in-the-wild studies: the challenges and insights of researcher participation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1135–1144. DOI:https://doi.org/10.1145/2207676.2208561

[61] Jani-Pekka Jokinen, Teemu Sihvola, and Milos N. Mladenovic. 2019. Policy lessons from the flexible transport service pilot Kutsuplus in the Helsinki Capital Region. *Transp. Policy* 76, May (April 2019), 123–133.

DOI:https://doi.org/10.1016/j.tranpol.2017.12.004

[62] Matt Jones and Gary Marsden. 2006. *Mobile Interaction Design*. Wiley.

[63] Matt Jones and Gary Marsden. 2006. Possibilities. In *Mobile Interaction Design*. John Wiley and Sons Ltd., 3–36.

[64] Matt Jones and Gary Marsden. 2006. Watching, asking, probing. In *Mobile Interaction Design* (First). John Wiley and Sons Ltd., 121–168.

[65] Vaishnav Kameswaran, Lindsey Cameron, and Tawanna R. Dillahunt. 2018. Support for Social and Cultural Capital Development in Real-time Ridesharing Services. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3173574.3173916

[66] Matthew Kay, Tara Kola, Jessica R. Hullman, and Sean A. Munson. 2016. When (ish) is My Bus?: User-centered Visualizations of Uncertainty in Everyday, Mobile Predictive Systems. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 5092–5103. DOI:https://doi.org/10.1145/2858036.2858558

[67] Jesper Kjeldskov and Jeni Paay. 2012. A longitudinal review of Mobile HCI research methods. In *Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services - MobileHCI '12*, ACM Press, New York, New York, USA, 69. DOI:https://doi.org/10.1145/2371574.2371586

[68] Jesper Kjeldskov and Mikael B Skov. 2014. Was it Worth the Hassle ? Ten Years of Mobile HCI Research Discussions on Lab and Field Evaluations. *Proc. 16th Int. Conf. Human-computer Interact. with Mob. devices Serv. (MobileHCI '14)* (2014). DOI:https://doi.org/10.1145/2628363.2628398

[69] Jesper Kjeldskov, Mikael B. Skov, Benedikte S. Als, and Rune T. Høegh. 2004. Is It Worth the Hassle? Exploring the Added Value of Evaluating the Usability of Context-Aware Mobile Systems in the Field. In *International Conference on Mobile Human-Computer Interaction*¨. Springer, 61–73. DOI:https://doi.org/10.1007/978-3-540-28637-0_6

[70] Eric Laurier, Barry Brown, and Moira McGregor. 2016. Mediated Pedestrian Mobility: Walking and the Map App. *Mobilities* 11, 1 (January 2016), 117–134. DOI:https://doi.org/10.1080/17450101.2015.1099900

[71] Jonathan Lazar, Jinjuan Feng, and Harry Hochheiser. 2017. Working With

Human Subjects. In *Research Methods in Human-Computer Interaction* (Second). Morgan Kaufmann, 560.

[72] Jonathan Lazar, Jinjuan Feng, and Harry Hochheiser. 2017. Usability Testing. In *Research Methods in Human-Computer Interaction* (Second). Morgan Kaufmann, 560.

[73] Jonathan Lazar, Jinjuan Feng, and Harry Hochheiser. 2017. *Research Methods in Human-Computer Interaction* (2nd ed.). Morgan Kaufmann.

[74] Sangwook Lee, Yunho Kang, and YuKyoung Lee. 2016. LaneMate: Car Sensing System for the Deaf. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, ACM, New York, NY, USA, 32–37. DOI:https://doi.org/10.1145/2851581.2890634

[75] Can Liu, Hamed S. Alavi, Enrico Costanza, Shumin Zhai, Wendy Mackay, and Wendy Moncur. 2019. Rigor, Relevance and Impact: The Tensions and Trade-Offs Between Research in the Lab and in the Wild. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–6. DOI:https://doi.org/10.1145/3290607.3311744

[76] Zhili Liu, Xudong Jia, and Wen Cheng. 2012. Solving the Last Mile Problem: Ensure the Success of Public Bicycle System in Beijing. *Procedia - Soc. Behav. Sci.* 43, (2012), 73–78. DOI:https://doi.org/10.1016/j.sbspro.2012.04.079

[77] Steve Love. 2005. *Understanding Mobile Human-Computer Interaction* (1st ed.). Elsevier Ltd.

[78] Maas-alliance. MaaS-alliance.eu/what is MaaS. Retrieved from http://maas-alliance.eu/homepage/what-is-maas/

[79] I. Scott MacKenzie. 2013. Scientific Foundations. In *Human-Computer Interaction: An Empirical Research Perspective*. Morgan Kaufmann, 121–155.

[80] Thomas Maskell, Clara Crivellaro, Robert Anderson, Tom Nappey, Vera Araújo-Soares, and Kyle Montague. 2018. Spokespeople: Exploring Routes to Action through Citizen-Generated Data. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3173574.3173979

[81] Johanna Meurer, Dennis Lawo, Lukas Janßen, and Volker Wulf. 2016.

Designing Mobility Eco-Feedback for Elderly Users. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, ACM, New York, NY, USA, 921–926. DOI:https://doi.org/10.1145/2851581.2851599

[82] Alexander G. Mirnig and Alexander Meschtscherjakov. 2019. Trolled by the Trolley Problem: On What Matters for Ethical Decision Making in Automated Vehicles. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–10. DOI:https://doi.org/10.1145/3290605.3300739

[83] Maria Murray, Nadia Pantidi, and Trevor Hogan. 2019. Conflict and Belonging: Socially engaged art practice as a resource for resilience-building in rurban communities. In *Proceedings of the 9th International Conference on Communities & Technologies - Transforming Communities*, ACM, New York, NY, USA, 60–64. DOI:https://doi.org/10.1145/3328320.3328388

[84] Alexander Ng, Stephen A. Brewster, Frank Beruscha, and Wolfgang Krautter. 2017. An Evaluation of Input Controls for In-Car Interactions. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 2845–2852. DOI:https://doi.org/10.1145/3025453.3025736

[85] Jakob Nielsen. 1993. *Usability Engineering*. Morgan Kaufmann.

[86] Rebekka Oostendorp, Daniel Krajzewicz, Laura Gebhardt, and Dirk Heinrichs. 2019. Intermodal mobility in cities and its contribution to accessibility. *Appl. Mobilities* 4, 2 (May 2019), 183–199. DOI:https://doi.org/10.1080/23800127.2018.1554293

[87] Kerem Ozcan, Dawn Jorgenson, Christian Richard, and Gary Hsieh. 2017. Designing for Targeted Responder Models: Exploring Barriers to Respond. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*, ACM, New York, NY, USA, 916–924. DOI:https://doi.org/10.1145/2998181.2998334

[88] Pablo E. Paredes, Francisco Ordonez, Wendy Ju, and James A. Landay. 2018. Fast & Furious: Detecting Stress with a Car Steering Wheel. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3173574.3174239

[89] Jagannadh Pariti, Vinita Tibdewal, and Tae Oh. 2020. Intelligent Mobility Cane - Lessons Learned from Evaluation of Obstacle Notification System using a Haptic Approach. In *Extended Abstracts of the 2020 CHI Conference*

on Human Factors in Computing Systems, ACM, New York, NY, USA, 1–8. DOI:https://doi.org/10.1145/3334480.3375217

[90] So Yeon Park, Dylan James Moore, and David Sirkin. 2020. What a Driver Wants: User Preferences in Semi-Autonomous Vehicle Decision-Making. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376644

[91] Marianne Graves Petersen, Aviaja Borup Lynggaard, Peter Gall Krogh, and Ida Wentzel Winther. 2010. Tactics for homing in mobile life: a fieldwalk study of extremely mobile people. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services - MobileHCI '10*, ACM Press, New York, New York, USA, 265. DOI:https://doi.org/10.1145/1851600.1851646

[92] Martin Pielot, Benjamin Poppinga, Wilko Heuten, and Susanne Boll. 2012. Tacticycle: supporting exploratory bicycle trips. In *Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services - MobileHCI '12*, ACM Press, New York, New York, USA, 369. DOI:https://doi.org/10.1145/2371574.2371631

[93] Kathrin Pollmann, Oilver Stefani, Amelie Bengsch, Matthias Peissner, and Mathias Vukelić. 2019. How to Work in the Car of the Future?: A Neuroergonomical Study Assessing Concentration, Performance and Workload Based on Subjective, Behavioral and Neurophysiological Insights. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–14. DOI:https://doi.org/10.1145/3290605.3300284

[94] Jenny Preece, Helen Sharp, and Yvonne Rogers. 2015. *Interaction Design: Beyond Human-Computer Interaction* (Fourth ed.). John Wiley and Sons Ltd.

[95] Jenny Preece, Helen Sharp, and Yvonne Rogers. 2015. Introducing Evaluation. In *Interaction Design: Beyond Human-Computer Interaction* (Fourth). John Wiley and Sons Ltd., 584.

[96] Jenny Preece, Helen Sharp, and Yvonne Rogers. 2015. Data Gathering. In *Interaction Design: Beyond Human-Computer Interaction* (Fourth). John Wiley and Sons Ltd.

[97] Gary Pritchard, John Vines, and Patrick Olivier. 2015. Your Money's No Good Here: The Elimination of Cash Payment on London Buses. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in*

Computing Systems, ACM, New York, NY, USA, 907–916. DOI:https://doi.org/10.1145/2702123.2702137

[98] Sasank Reddy, Katie Shilton, Gleb Denisov, Christian Cenizal, Deborah Estrin, and Mani Srivastava. 2010. Biketastic: sensing and mapping for better biking. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, ACM Press, New York, New York, USA, 1817. DOI:https://doi.org/10.1145/1753326.1753598

[99] Elissa M. Redmiles, Sean Kross, and Michelle L. Mazurek. 2017. Where is the Digital Divide?: A Survey of Security, Privacy, and Socioeconomics. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 931–936. DOI:https://doi.org/10.1145/3025453.3025673

[100] Yvonne Rogers. 2011. Interaction design gone wild. *interactions 18*, 58. DOI:https://doi.org/10.1145/1978822.1978834

[101] Yvonne Rogers, Kay Connelly, Lenore Tedesco, William Hazlewood, Andrew Kurtz, Robert E. Hall, Josh Hursey, and Tammy Toscos. 2007. Why It's Worth the Hassle: The Value of In-Situ Studies When Designing Ubicomp. In *UbiComp 2007: Ubiquitous Computing.*, 336–353. DOI:https://doi.org/10.1007/978-3-540-74853-3_20

[102] Yvonne Rogers and Marshall Paul. 2017. *Research In the Wild*. Morgan & Claypool, London.

[103] Jeffrey Rubin. 1994. *Handbook of Usability Testing*. John Wiley and Sons.

[104] Shadan Sadeghian Borojeni, Susanne C.J. Boll, Wilko Heuten, Heinrich H. Bülthoff, and Lewis Chuang. 2018. Feel the Movement: Real Motion Influences Responses to Take-over Requests in Highly Automated Vehicles. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3173574.3173820

[105] Shadan Sadeghian Borojeni, Maximilian Schrapel, Philipp Wintersberger, Christian Koetsier, Andrew L. Kun, Matthias Laschke, Andreas Riener, Michael Rohs, and Johannes Schering. 2020. Workshop on Designing Technologies for Future Forms of Sustainable Mobility. In *22nd International Conference on Human-Computer Interaction with Mobile Devices and Services*, ACM, New York, NY, USA, 1–4. DOI:https://doi.org/10.1145/3406324.3424586

[106] Kevin Sanders and David Geerts. 2019. You Can't Go Your Own Way: Social Influences on Travelling Behavior. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–6. DOI:https://doi.org/10.1145/3290607.3313079

[107] Saphe. Saphe. Retrieved from https://saphe.com/uk/

[108] Clemens Schartmüller, Sayan Sarcar, Andreas Riener, Andrew L. Kun, Orit Shaer, Linda Ng Boyle, and Shamsi Iqbal. 2020. Automated Cars as Living Rooms and Offices: Challenges and Opportunities. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–4. DOI:https://doi.org/10.1145/3334480.3381054

[109] Eike Schneiders, Mikkel Bjerregaard Kristensen, Michael Kvist Svangren, and Mikael B. Skov. 2020. Temporal Impact on Cognitive Distraction Detection for Car Drivers using EEG. In *32nd Australian Conference on Human-Computer Interaction*, ACM, New York, NY, USA, 594–601. DOI:https://doi.org/10.1145/3441000.3441013

[110] Joseph L. Schofer. 2017. Mass Transit, city transportation, mass transportation, public transit, public transportation. *Britannica*. Retrieved from https://www.britannica.com/topic/mass-transit

[111] Matthias Seuter, Max Pfeiffer, Gernot Bauer, Karen Zentgraf, and Christian Kray. 2017. Running with Technology: Evaluating the Impact of Interacting with Wearable Devices on Running Movement. *Proc. ACM Interactive, Mobile, Wearable Ubiquitous Technol.* 1, 3 (September 2017), 1–17. DOI:https://doi.org/10.1145/3130966

[112] Mimi Sheller and John Urry. 2006. The new mobilities paradigm. *Environ. Plan.* 38, 2 (2006), 207–226. DOI:https://doi.org/10.1068/a37268

[113] Ben Shneiderman. 2011. Claiming success, charting the future. *interactions* (2011). DOI:https://doi.org/10.1145/2008176.2008180

[114] Ben Shneiderman and Catherine Plaisant. 2010. *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. DOI:https://doi.org/10.1016/0166-3615(93)90066-A

[115] Scott Smith and Joseph Schwieterman. 2018. *E-scooter Scenarios: Evaluating the Potential Mobility Benefits of Shared Dockless Scooters in Chicago*.

[116] Jana Sochor, Hans Arby, I.C. MariAnne Karlsson, and Steven Sarasini. 2018.

A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. *Res. Transp. Bus. Manag.* 27, (June 2018), 3–14. DOI:https://doi.org/10.1016/j.rtbm.2018.12.003

[117] Caleb Southern, Yunnuo Cheng, Cheng Zhang, and Gregory D. Abowd. 2017. Understanding the Cost of Driving Trips. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 430–434. DOI:https://doi.org/10.1145/3025453.3025686

[118] Shenando Stals, Michael Smyth, and Wijnand Ijsselsteijn. 2014. Walking & talking: probing the urban lived experience. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, ACM, New York, NY, USA, 737–746. DOI:https://doi.org/10.1145/2639189.2641215

[119] Martin Stein, Johanna Meurer, Alexander Boden, and Volker Wulf. 2017. Mobility in later life - Appropriation of an integrated transportation platform. *Conf. Hum. Factors Comput. Syst. - Proc.* 2017-May, (2017), 5716–5729. DOI:https://doi.org/10.1145/3025453.3025672

[120] Michael K. Svangren, Margot Brereton, Mikael B. Skov, and Jesper Kjeldskov. 2019. Investigating the Use of an Online Peer-to-Peer Car Sharing Service. . 740–759. DOI:https://doi.org/10.1007/978-3-030-29387-1_43

[121] Michael K. Svangren, Mikael B. Skov, and Jesper Kjeldskov. 2017. The connected car: an empirical study of electric cars as mobile digital devices. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services*, ACM, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3098279.3098535

[122] Michael K. Svangren, Mikael B. Skov, and Jesper Kjeldskov. 2018. Passenger Trip Planning using Ride-Sharing Services. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3173574.3174054

[123] Hilda Tellioğlu, Martin Berger, Christoph Kirchberger, and Flora Strohmeier. 2019. Mobility Transformation: What does mobility mean in the future? In *Proceedings of the 9th International Conference on Communities & Technologies - Transforming Communities*, ACM, New York, NY, USA, 349–353. DOI:https://doi.org/10.1145/3328320.3328411

[124] Anthony Townsend. 2009. Foreword. In *Handbook of Research On Urban Informatics - the Practice and Promise of the Real-time City*, Marcus Foth

(ed.). DOI:https://doi.org/http://dx.doi.org/10.4018/978-1-60566-152-0

[125] Sylvaine Tuncer and Barry Brown. 2020. E-scooters on the Ground: Lessons for Redesigning Urban Micro-Mobility. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1–14. DOI:https://doi.org/10.1145/3313831.3376499

[126] Uber. A Guide for How to Use Uber. Retrieved from https://www.uber.com/dk/en/ride/how-it-works/

[127] United Nations. 2018. 68% of the world population projected to live in urban areas by 2050.

[128] Roni Utriainen and Markus Pöllänen. 2018. Review on mobility as a service in scientific publications. *Res. Transp. Bus. Manag.* 27, July (June 2018), 15–23. DOI:https://doi.org/10.1016/j.rtbm.2018.10.005

[129] Nagendra Velaga, John Nelson, Steve Wright, and John Farrington. 2012. The Potential Role of Flexible Transport Services in Enhancing Rural Public Transport Provision. *J. Public Transp.* 15, 1 (March 2012), 111–131. DOI:https://doi.org/10.5038/2375-0901.15.1.7

[130] Waze. Waze. Retrieved from https://www.waze.com/waze

[131] Jacob O. Wobbrock and Julie A. Kientz. 2016. Research contributions in human-computer interaction. *Interactions* 23, 3 (April 2016), 38–44. DOI:https://doi.org/10.1145/2907069

[132] Johanna Ylipulli and Aale Luusua. 2019. Without libraries what have we?: Public libraries as nodes for technological empowerment in the era of smart cities, AI and big data. In *Proceedings of the 9th International Conference on Communities & Technologies - Transforming Communities*, ACM, New York, NY, USA, 92–101. DOI:https://doi.org/10.1145/3328320.3328387

[133] Desheng Zhang, Juanjuan Zhao, Fan Zhang, Ruobing Jiang, Tian He, and Nikos Papanikolopoulos. 2017. Last-Mile Transit Service with Urban Infrastructure Data. *ACM Trans. Cyber-Physical Syst.* 1, 2 (February 2017), 1–26. DOI:https://doi.org/10.1145/2823326

[134] Yu Zheng, Licia Capra, Ouri Wolfson, and Hai Yang. 2014. Urban Computing: Concepts, Methodologies, and Applications. *ACM Trans. Intell. Syst. Technol.* 5, 3 (October 2014), 1–55. DOI:https://doi.org/10.1145/2629592

[135] John Zimmerman, Anthony Tomasic, Charles Garrod, Daisy Yoo, Chaya Hiruncharoenvate, Rafae Aziz, Nikhil Ravi Thiruvengadam, Yun Huang, and Aaron Steinfeld. 2011. Field trial of Tiramisu: crowd-sourcing bus arrival times to spur co-design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, 1677–1686. DOI:https://doi.org/10.1145/1978942.1979187

PAPER CONTRIBUTIONS

The following four papers are presented in this chapter as they are originally accepted:

1. Maria Kjærup, Mikael B. Skov, and Niels Agerholm. 2020. Digital-Enabled Last Mile: A Study of Passenger Trips in Rural, Low-density Populated Areas. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3313831.3376509

2. Maria Kjærup, Mikael B. Skov. 2021. Transportation and Technology in Rural Denmark: Communities of Mobility. Submitted to: The Australian Conference on Human-Computer Interaction (OZCHI'21) – currently under review.

3. Maria Kjærup, Mette Elsborg, Mikael B. Skov, and Anders Bruun. 2021. Available Anytime Anywhere: Investigating Mobile Volunteer Responders for Out of Hospital Cardiac Arrest. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21). Association for Computing Machinery, New York, NY, USA, Article 647, 1–13. DOI:https://doi.org/10.1145/3411764.3445208

4. Maria Kjærup, Mikael B. Skov, Niels Van Berkel. 2021. E-Scooter Sustainability – A Clash of Needs, Perspectives, and Experiences. In proceedings of the IFIP Conference on Human-Computer Interaction (INTERACT'21). Springer LNCS. DOI:https://doi.org/10.1007/978-3-030-85613-7_26 (In press).

Papers will be prefaced by a page introducing paper no. in thesis, paper details and abstract. Paper 1 and 3 are attached as appendix. Feel free to reach out to Maria Kjærup for author versions of abovementioned work.

PAPER 1: DIGITAL-ENABLED LAST MILE: A STUDY OF PASSENGER TRIPS IN RURAL, LOW-DENSITY POPULATED AREAS

Authors:

Maria Kjærup, Mikael B. Skov, Niels Agerholm

Abstract:

Public transportation in rural areas is difficult due to low numbers of passengers and diverse needs, also reflected in the last mile problem that points to the distance to access transportation hubs in order to connect with core networks of transportation. In this paper, we study public transportation in rural areas using a digital-enabled, demand-responsive service called Plustur. This service was recently introduced as an effort to increase mobility in underserved rural areas by creating routes ad-hoc to answer to the last mile(s). We study how passengers and drivers understand Plustur, as well as experience the role of passenger. Our findings show that Plustur is viewed as a benefit for autonomy of mobility in rural areas, however is lacking in addressing integration of modes of mobilities, flexibility and spontaneous trips. We contribute with design implications for digital multimodal mobility services.

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Digital-Enabled Last Mile: A Study of Passenger Trips in Rural, Low-density Populated Areas of Denmark

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ABSTRACT
Public transportation in rural areas is difficult due to low numbers of passengers and diverse needs, also reflected in the last mile problem that points to the distance to access transportation hubs in order to connect with core networks of transportation. In this paper, we study public transportation in rural areas using a digital-enabled, demand-responsive service called Plustur. This service was recently introduced as an effort to increase mobility in underserved rural areas by creating routes ad-hoc to answer to the last mile(s). We study how passengers and drivers understand Plustur, as well as experience the role of passenger. Our findings show that Plustur is viewed as a benefit for autonomy of mobility in rural areas, however is lacking in addressing integration of modes of mobilities, flexibility and spontaneous trips. We contribute with design implications for digital multimodal mobility services.

Author Keywords
Mobility as a service, demand-responsive transit, mobility on demand, digital-enabled passenger trips.

CSS Concepts
•Human-centered computing~Human computer interaction (HCI)~HCI design and evaluation methods~User studies

INTRODUCTION
Several countries have challenges with providing necessary and effective public transportation in rural, low-density population areas due to demand, cost etc. [12]. Over the last decades, route-based and time-tabled public transportation services like trains or buses have been cut down gradually in rural areas, and people living there are heavily relying on car access. This implies that people without such car access like children or people without means of driving experience very restricted mobility [8,28]. At the same time, traffic congestion, due to higher private car ownership rate is increasing [6] and under-utilization of public transportation services result in buses 'moving fresh air' but no or few passengers [15]. Recent small-scale tests support that mobility as a service (MaaS) might change this. Future-proof public transportation has to meet the demand of consumer-centered mobility and promote the choice of public transportation over private car traffic, also in rural, low-density populated areas and for people with no car access [15,27,28].

Some MaaS initiatives are found to be flexible, relatively low-priced and demand-responsive, supplementing existing public transportation. We have digital platforms offering trip planning and shared-rides (UberPool, GoMore, BlaBlaCar etc. [25]). Additionally, transit-services attempts to accommodate what is often referred to as the last mile problem of providing transportation offers to and from major hubs including public bicycle systems and flexible micro transport (for example [16,17]). Common for such initiatives is the use of connected mobile technologies for planning, booking, and payment. But while such services are successful for urban transportation or between major cities or hubs, we have limited knowledge on their applicability for transportation in rural, low-density populated areas, and how such services can supplement or replace car access. Hardy et al. [13] argue that little attention has been paid to evaluating rural perspectives for high-income countries.

We investigate digital-enabled passenger trips in rural, low-density populated areas, in this case we study a digital last mile transportation service called Plustur, which was introduced in 2018 in the northern region of Denmark (North Jutland). Plustur enables people in rural areas to plan, book, and carry out trips using digital services. Through interviews, participating field trips, and a workshop we collected empirical data on how people use the service and how they perceive mobility in rural areas. We present our findings on how digital-enabled trips changes trips, and the importance of successfully integrating different transportation modes.

RELATED WORK
Human-computer interaction research has investigated and studied transportation and mobility for many years. In this section, we present HCI research on mobility in terms of current themes and modes of transportation. We illustrate research within MaaS and flexible transport, and how services

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have mostly centered on challenges for urban areas and smart cities. We further outline rural mobility challenges and how advanced mobile MaaS solutions, digital-enabled passenger trips and flexible demand-responsive transport services have tried to extend and supplement transport mode shifts to accommodate challenges like the last mile problem.

HCI and Mobility

Recent HCI research on mobility features several themes and modes of transportation [3,7,10,14,20,22–25]. As an example, research aims to promote sustainable modes of transportation over private car ownership (e.g.[14,23]). For example, Hasselqvist et al. [14] carried out a study of three families giving up their car in favor of light electric vehicles during one year, in order to explore opportunities to design for supporting car-free living. Southern et al. also aimed to challenge the car-norm by disclosing the total cost of owning and maintaining a car. A number of studies explore circumstances where people don't have a choice in being car-less, e.g. elderly who are not capable of driving themselves [24], people with disabilities that hinder accessibility both for private and public transportation [20] and low-resource populations, where scarcity of appropriate mobility offers is often an issue [7]. Sanders et al. additionally emphasize that new mobility offers must be able to accommodate instances where travel is a social action, beyond the individual, where detours and mode preferences will have to be accounted for in travel planning assistance [22]. HCI research on mobility also addresses other perspectives than passengers, namely the work environment for drivers as an on-demand mobile workforce, whether for passengers [10] or parcels [3]. As well as, the communication and negotiation inherent in ridesharing planning supported by technologies [25].

Mobility as a Service and Flexible Mobility on Demand

The MaaS-alliance describes mobility as a service as the "*integration of various forms of transport into a single mobility service accessible on demand.*" Furthermore, mobility services should feature a diverse menu of transport options public transport, ridesharing, car sharing or bike sharing, taxi or car rental or a combination of these. Also, it is usually accessed through a single payment channel, in opposition to multiple ticketing options [18].

Atasoy et al. argue that conventional public transportation with time-tabled transportation can't compete with flexible mobility on demand (FMOD) with concerns to passenger satisfaction and operator benefits, based on a proof-of-concept simulation [1]. What has made MaaS initiatives possible is the accessibility through the app-capabilities of smartphones providing a more efficient way to service mobility needs. To a point where one can imagine a mobility service 'Mytrain' modeled after the likes of music streaming service e.g. Spotify [15]. Advanced MaaS solutions that offer a subscription plan do exist e.g. the Whim app [9] among others (e.g. see [27]).

Hensher distinguishes modes of transport as direct point-to-point (taxi service) or point via point-to-point, combining modes [15]. Point via point-to-point like services are providing an alternative in between high-flexibility and high-cost taxi service and low price, lower quality and medium-flexibility bus-based public transportation [16].

Digital-Enabled Passenger Trips and Last Mile Transit

A widely agreed problem with rural transportation is the lack of access to various transportation services, in contrast to urban travelers [13]. People with no or restricted car access in rural areas experience particular disadvantage, especially if they don't have any means of mobility to participate in the social networks of the community [12]. Velaga et al. characterize barriers for improving and developing public transportation in rural areas; 1) rural dwellings are distributed over large areas, 2) Low population density, very low modal-share for public transportation and therefore low potential passenger numbers, 3) level of demand is unpredictable [28]. Here we will present two examples that operate with a model that consider last mile transportation via transportation hubs: A public bicycle scheme in Beijing and Finnish pilot project Kutsuplus.

The public bicycle scheme in Beijing is imagined to solve the last mile problem, thus bike racks are usually found near train/bus stations or other major hubs, to extend the journey in order to reach the destination in a low-carbon, inexpensive manner. A transport survey in Beijing showed that 71.6% of all bicycle trips covered less than 5 kilometers, thus concluding that bicycling is most suitable in core and dense areas of town, where returning a rented bike is possible within 3-400 meters of your destination. Otherwise the scheme would suffer from unnecessary detours to return the bikes in a designated rack. A re-imagined public bicycle scheme is looking towards improving sustainable transport mode shifts in "public bicycle + public transit + public bicycle" form in order to connect users to public transit networks and meet challenges of the last mile problem [17].

The now shut down Kutsuplus has been defined as located in the continuum between taxi and bus service and digitally enabled through an online platform [16]. Kutsuplus operated as a demand-responsive mini-bus shared ride service that coordinated pick up and drop off through (primarily) regular busstops/busstations. Kutsuplus was a pilot that ran in the Helsinki metropolitan area, operational from October 2012 to December 2015 (due to the program being shut down for a number of reasons accounted for in e.g. [16,27]). It was worldwide premiered with a full reliance on automated vehicle location, trip optimization and route algorithms. Drivers received real-time in-car driving instructions for booked routes. Thus, the technology was an essential prerequisite. Kutsuplus was an initiative led by Helsinki Regional Transport (HSL) in order to increase the number of car users switching to public, shared and more sustainable modes of transport, and at length establish public transportation as the primary mode of choice [16].

PLUSTUR: FIRST AND LAST MILE

Plustur is a web and app service offered to increase and improve mobility in rural, low density population areas of

Denmark by covering otherwise underserved or non-service first and last mile. In particular, areas where public transportation is not accessible and other means of transportation is compulsory. In this way Plustur has replaced minor bus routes that are too expensive due to the low or varying demand. According to Hardy et al. rural areas are often characterized by what they lack, but by changing this narrative we might also view them as rich and productive spaces for HCI research. In particular, high-income countries is often characterized by having better-resourced areas with higher technology access [13].

The public transportation Authority of North Jutland (NT) was awarded the Union Internationale des Transports Publics (UITP) award for 'Small Cities and Low Density Areas' for their project titled 'Around Your World', which incorporates three initiatives, one of these is Plustur which is a "*demand-responsive transportation service that links the rural areas to the core network at the same tariff as buses and trains"* [26]. Plustur was piloted and first implemented in North Jutland by NT, but has since been adopted by other regional traffic companies. All municipalities along the west coast of Jutland, the main intended coverage for Plustur service, comprises a population density of 8-14 people per square km and decreasing (according to recent statistics [5]).

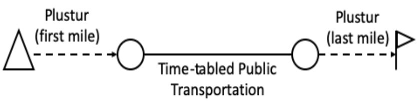

Figure 1 Illustrates a journey where Plustur is included. The triangle and flag respectively represent pick-up and drop-off for Plustur, the dots represent connections with the core network through transportation hubs, along the core network mode shifts (e.g. bus-to-train) might occur.

Plustur is a service that links rural destinations with the core networks of public transportation by offering passengers a ride to the nearest hub (local bus stop or train station), and thereby making connections ad hoc where public transportation routes are not already established. Whereas buses and trains are always available independent of demand, the only way to ride a Plustur is when booked through the online travel planner called MinRejseplan – therefore we call it a digital-enabled passenger trip. Plustur is an extension to already existing public flexible transport options, but sets itself apart by being dependent on making connections with routes on the core network. Additionally, Plustur is offered at fixed rate of approximately €3, as opposed to the usual per zone, minutes or kilometer rates. The connecting modes of transportation has to be paid as traditional public transportation trips on fixed routes.

Plustur is further implemented as a ridesharing service which means that more passengers will be sharing a ride, if they are going for relatively nearby destinations. Therefore, the ride (origo to hub) could be extended via one or more pick-up point(s). In spite of this, service providers guarantee that you will reach your public transportation connection in time, by operating with a measure of flexibility in pick-up and drop-off times. The extent of ridesharing for North Jutland is mirrored in the quarterly reports for 2018 and 2019 (Q1+Q2) for Plustur where in 2018 1.669 passengers are divided on a total of 1.232 trips. While the number of passengers using the service slowly increases in North Jutland, recent initiatives (e.g. advertisement campaigns, reduced fares) has increased passenger numbers from approximately 500 to 1400 every month. Current data from the region shows that overall more females (60%) than males use the service and the largest user segments is represented by the age group 40-49 (27,5%) closely followed by 20-29 (26%).

Figure 2 (partial) Screenshot from Plustur travel planning app (MinRejseplan), where different components of a trip can be seen at the buttom of the figure, e.g. X Bus 970X (regular service bus) and the Plustur ride.

The Plustur vehicles and drivers are operated by private taxi companies, whereas the connecting modes of transport can be private transport companies or public regional or national transport companies. The Plustur service is offered by NT and interlinked with MinRejseplan (figure 2) combined with an online booking and payment platform hosted by an independent company founded by NT. Plustur can only be booked online and paid in advance using a valid credit card. Also, passengers have to book their trip at least two hours in advance. This differs in regional implementations from one-two hours. Connecting travels are paid with 'Rejsekortet' (eng: The Travelcard), which resembles other travel cards like the London-based Oystercard [19]. This payment option has been available in Denmark since 2011 and for all modes of public transport in the entire country since 2016. Depending on the region and mode of transportation, other payment have also been available.

METHODS

Our investigation focused on consequences of introducing solely digital-enabled public transportation in low-density, rural populated areas of North Jutland. Our investigation was part of a larger study of introducing mobile digital technologies in public transportation. We conducted the study late 2018 and into 2019. We applied a mixed methods approach based on interviews, in-the-wild experiences, and an ideation workshop.

Interviews with Passengers and Drivers

We interviewed eleven passengers of public transportation including the Plustur service and three Plustur taxi drivers (employed for the service). The eleven passengers (9 females) were on average 31.9 years old (SD=13.1) and they used public transportation for various purposes (see table 1 for details). The interviews with passengers aimed to uncover their experiences and perspectives on public transportation in rural areas and Plustur trips. Further, we were interested in transportation needs and habits, and how they viewed and experienced mobility in their respective areas. We aimed for some diversity by including regular commuters but also casual public transportation passengers.

	Gender (Age)	Rides	Transportation Purpose
P1	F (21)	>25	Commuting and causal
P2	M (52)	>25	Commuting
P3	F (29)	<10	Causal
P4	F (45)	<10	Excursion
P5	F (27)	<10	Visiting family and friends, appointments
P6	M (23)	10-25	Commuting, visiting family and friends
P7	F (23)	10-25	Commuting, visiting family and friends
P8	M (19)	>25	Commuting, visiting family and friends
P9	M (20)	>25	Commuting, casual visiting
P10	F (48)	<10	Special occasions
P11	F (24)	>25	Visiting family and friends

Table 1: Overview of passenger interview participants P1-P11 demographics, an estimated average of monthly rides with public transportation accompanied by primary purpose of these rides.

We recruited the passengers using several techniques. First, we advertised our research study on the official NT website and also on their social media pages. Secondly, we showed recruitment ads on digital screens inside local buses in the region. Thirdly, recruitment messages were displayed on social media groups for local area communities, e.g. municipalities and local town Facebook pages in selected groups after seeking permission from administrators. Fourthly, a recruitment call was made on a social media page dedicated for recruitment of students. Finally, we utilized our social and professional networks and interviewees were asked to recommend other potential candidates. Targeted efforts such as inquiring into own networks, local social media pages and asking interviewees to recommend other potential candidates was the most successful recruitment strategies.

Interviews were carried out using a semi-structured design with an elaborate interview guide. The interview guide was formed on the basis of an exploratory and informal effort to gather first impressions from commentaries on posts on the official NT Facebook page as well as commentaries on news articles announcing the Plustur service. This allowed an insight into immediate responses and questions arising. The interview guide contained questions like "In which cases do you prefer public transportation?", specifically for Plustur service and how it differentiates from trips with traditional public transportation "Do you feel confident in planning and carrying out a Plustur?" and "What information do you think is necessary to receive in order to plan and carry out a Plustur?" Additionally, several internal and public reports from NT was made available to us e.g. a mobility index survey, and their mobility plans for the region as well as on an international level from a ministerial taskforce, a report on how the Plustur service was planned in terms of functionality, implementation, and integration to existing services. Participants received a cinema gift card as compensation for their participation. Seven passengers were interviewed in their private homes, while four passengers were interviewed on university campus. All interviews were audio-recorded and lasted between 20 to 60 minutes and were later transcribed for analysis.

We further conducted interviews with three taxi drivers employed in the Plustur service. Here we aimed to uncover how the service had affected their work practice, and generally how they perceived this mobility services. One driver was recruited while we as researchers carried out one of the solo trips (interview done in-person), while the two other drivers were recruited and interviewed over phone. The drivers worked in three different taxi companies and all had more than 10 years of experience driving taxi, and they all had worked for the service less than a year. We refer to the drivers as D1-3 in the findings.

In the Wild: Participating Field Trips

As encouraged by Rogers and Marshall [21], we further conducted field or in the wild studies due to the importance of studying and understanding people and technologies in their natural contexts. We spent several hours riding on buses and trains in the designated rural areas (inspired by Pritchard et al. [19]) to learn about local public transportation and the Plustur service. We further carried out two trips as solo-trips where we acted as passengers ourselves, and one author of the paper booked a Plustur and subsequently went on the trip, for example one solo-trip involved being picked up at small town bus stop in a rural area and transported to a major hub. The solo-trips lasted each approximately two hours, and we collected data by noting down experiences and observations.

We carried out Plustur trips with three invited passengers to supplement our understanding and observations based on the interviews and solo-trips. All three trips involved first-time passengers of the Plustur service and included planning, booking, and carrying out the trip. Unlike the study in Pritchard et al. [19] who observed and interacted with passengers travelling on London buses with the Oister Card, we were unable to directly observe Plustur passengers in a similar manner due to the characteristics of Plustur (not achievable without knowing them in advance). Instead we invited three passengers to book and carry out a Plustur with us observing and interviewing them while booking and on the trip (labelled F1-3 in table 2).

	Gender (Age)	Rides	Transportation Purpose
F1	F (29)	<10	Visiting family and friends
F2	M (28)	>25	Commuting, visiting family and friends
F3	F (55)	<10	Commuting, appointments

Table 2: Overview of field trip passengers F1-F3 demographics, an estimated average of monthly rides with public transportation accompanied by primary purpose of these rides.

We interviewed the three field passengers while on the trip and we further noted down experiences and observations.

Workshop with Local Public Transport Authority

As final way of collecting empirical data about the service and public transport in rural areas, we participated in a workshop hosted by NT. The purpose of the workshop was to uncover and discuss opportunities and limitations of the current version of the Plustur service and further outline future directions for the service. It was organized as a half day workshop in March 2019. Public transportation in many rural areas is a quite well-known challenge and concern in many countries [12,28], and this is also the case for NT and other Danish transport companies and authorities. Therefore, we found that such a workshop could potentially provide us with complementary viewpoints on public transportation.

22 people participated in the workshop including various people from NT, e.g. project managers, customer services, marketing, platform supporters, top management, as well as the authors of this paper. The workshop spanned three hours and consisted of a mix of oral presentations, group work and plenary discussions, e.g. we gave a presentation on current findings as a basis for ensuing plenum discussions. Additionally, reading materials summarizing lessons from the first year of service was sent prior to the workshop. For data collection, we made notes on statements and decisions.

Data Collection and Analysis

Data collection consisted of audio recording when possible, primarily from interviews, at other times notes were taken in-situ and following expanded while fresh in memory to ensure recalling of information e.g. for phone interviews, trips and workshop. All audio recordings were transcribed verbatim for our analysis.

We employed thematic data analysis inspired by Clarke and Braun [4] adapting four steps. First, we familiarized ourselves with the collected data by reading through the interviews and notes. Secondly, we generated codes to quotes and observation notes (e.g. the code "Experience (with Plustur)" to the quote "The third trip everything went exactly as it was supposed to.") Thirdly, we made physical cut-outs of quotes and notes and we used affinity diagramming to iteratively uncover and identify themes. This was done over several iterations manually grouping and clustering the quotes. In this manner, our second step of analysis served to organize data into broad codes, and our third step elicited more detailed themes within the scope of these codes. This resulted in six themes, which we reviewed for their relevance to the issues presented in this paper. The final themes are represented in our findings section.

FINDINGS

Plustur is a new first/last mile mobility service for passengers of North Jutland, we will here highlight themes that emerged from our analysis of data from passenger and driver interview and trips. Our study design enabled us to get insights into what happens before, during and after a Plustur trip. We want to show the understanding and experiences of Plustur as a mobile digital-enabled mobility services in rural areas in regard to themes that span changes for passenger trips, integrating modes of transportation, autonomy of mobility, and flexibility and spontaneity for trip planning.

Participating interview passengers will be referred to as P1-11, invited Plustur passengers as F1-3 (in total 14 passengers) and Plustur drivers will be referred to as D1-3.

Changes for Digital-Enabled Passenger Trips

Changes in features of (mobile) technologies have made it possible to consider MaaS options to be available on a large scale and deliver a high degree of freedom of mobility. Plustur is reliant on these advances in technologies for delivering first/last mile transportation that meets the needs of passengers. For this study, we asked participants to consider what possible opportunities and challenges were introduced by Plustur as a digital-enabled service. We found that the digital elements of Plustur introduced opportunities for payment that previously had been experienced as more cumbersome, but added extra work for participants to understand the terms of the Plustur service. Also, drivers were hesitant towards what Plustur might mean for the taxi industries and their individual role in this context.

We saw that Plustur changed the planning, booking, and paying for trips, largely because Plustur is solely digital-enabled. Participants expressed that most parts of this new digital process were considered useful, such as the single-entry platform was considered positive by most of the participants. As an example, **P3** and **P9** expressed that they saw the potential of gathering mobility offers on one platform, as this made planning, ticketing and payment a lot easier. Furthermore, another participant also stressed that moving away from physical cash exchanging hands was in line with societal trends in general (**P5**). S/he remembered several times where s/he had to use different forms of payment when crossing regional borders and how this was further complicated by the fact that s/he had to go to specific major transport hubs in order to purchase vouchers for traveling by either bus or trains.

All participants (14/14) expressed satisfaction regarding pricing implemented for the Plustur service. E.g. **P6** was positively surprised to find out that the Plustur service operated with a fixed rate that was comparable to bus tariffs, as they compared previous experiences with taxi pricing "*Okay, Plustur in itself, but then you add Plus-service and plus-pricing, am I right?*" (**P6**). S/he was puzzled how the prizing was going to cover the drivers pay, the fuel expenses, the coordination etc. All drivers shared the view that services like these and concepts like sharing economy was draining the traditional taxi business, in particular for the rural areas. **D3** was particularly worried about how further scaling would affect their individual paycheck. D2 expressed a wish to focus on the core competences of each individual provider and not mash it up into one solution under governance of one company. Drivers interviewed expressed some distrust in the concept of pooling together mobility offers as a joint effort: "*They want it all and the service just gets poorer and poorer*" (D3). In opposition to this, passengers interviewed saw it to their benefit that they had to book and pay on the same platform, from a starting point that they all in advance knew and used on a regular basis for planning transportation (MinRejseplan app). Although it was pointed out by **F1-F3,** that multiple steps where involved in the booking procedure itself, in particular as a first-time user: "*It is not as easy as picking up the phone.*" (**F3**). For the workshop we discussed the challenges of the first-time user, as we in advance were asked to plan and book a Plustur. We experienced the multiple steps of first-time booking and some encountered technical errors with creating a user profile, but overall managed the task.

The navigation of a system on the constraint of mobile screen size can sometimes present as unmanageable, if not scaled properly. This was experienced by **F1** who we observed during planning, booking and payment s/he first tried to do so on a smartphone, but after some frustration switched to a laptop. This was possible when booking from home, but could present as challenging or unhandy when you are outside. In spite of this s/he seemed to navigate the booking and payment quite naturally. Cases of technical issues and system errors were experienced while observing participants book Plustur rides, however one type of errors was not found to consistently appear.

We saw that Plustur changed the way you relate to the driver, as they are comparably very close to you as a passenger. **P8** and **P3** experienced talking to the driver as a pleasant experience, as well we observed that **F3** engaged in conversations with the driver about the destination and various small-talk, but also felt comfortable to share personal information like residential town, workplace and marriage status. All drivers agree that it can be pleasant to talk to passengers in most cases, unless they e.g. have particularly bad hygiene. **D2** stresses that in some situations when driving to and from hospital appointments they are aware to be very sensitive in how they relate to passengers as they might be in pain or distress. All drivers agreed that with experience you get a feeling for which passengers would like to have a conversation and if they would just prefer a quiet ride.

Integration of Different Modes of Transportation

Plustur was introduced as a first/last mile mobility service to accommodate gaps in public transportation service, where bus routes had been cut over time. These gaps in service had resulted in public transportation being hard to access, introducing the first/last mile problem of covering the distance to the nearest bus stop or train station. This gradual change in accessibility of public transportation was pointed out by our participants. We asked participants to assess how well Plustur covered these gaps and if it encouraged more use of public transportation overall. We found that integration of modes of transport was essential for the success of Plustur.

When living in rural areas, our participants articulated that integration of different means of transportation is important. For example, most of them (12/14) would be on a journey where several transportation modes (e.g. personalized taxi ride to the general bus ride) were integrated when going from one place in a rural area to a city or another place in a rural area. Our participants pointed out that when traveling with public transportation, it is not unusual to have to change modes of transportation e.g. bus-to-bus or train-to-bus, supplementing with walking or arranging for someone to drive you by car (first/last mile), e.g. **P7** mentioned that when visiting his/her parents living in a rural area, s/he had a 30-minute walking distance from the nearest bus stop.

Changing transportation modes often entailed idle times between connections, in particular when trips were not well integrated or synchronized. Several participants frequently experienced long waiting times (usually more than 30 minutes). They would make plans with a family member or a friend to come and pick them up to avoid the waiting time.

"*When it [waiting time] begins to close in on 40-50 minutes to an hour, I would want my parents to come and pick me up.*" (**P11**)

Unsurprisingly, we found that travel schedule changes, e.g. a bus being late or early, was extremely important for how well transport integration worked and was perceived by our participants. A delay on one leg of the journey could cause passengers to miss a connecting leg. In a rural context this could in some cases imply waiting more than one hour. In most rural areas missing your connecting transportation might result in stranding with no other option than to look for other means of (private) transportation. Some of these areas are not even serviced by public transportation, as articulated by one participant "*I had the impression that it was practically impossible to get out of the cities, to reach all the smaller areas. Either you would have someone drive you, or else it was just not possible*" (**P6**)

Delays were so problematic in some rural areas, that people living there would create own mechanisms to handle them. For example, **P10** told how their daughters' friends from another town formed a text-based chain to alert each other when the school bus in the morning was delayed. S/he stressed that this would be a technological opportunity:

"*We are so digital today, we expect to receive notice if the train for some reason or another is not coming, then it will be on the screens and on MinRejseplan [app]. It will appear pretty fast, but it won't for buses.*" (**P10**)

Plustur offers integration of transportation modes by connecting rural areas to the main corridors of public transportation. As an example, one participant experienced that the Plustur service successfully eliminated their need to bike two kilometers to the nearest bus stop in the morning: "*I could sleep in. I didn't have to worry about my bike having a flat tire, because sometimes that happens. I had more time to get ready and eat breakfast. And I wasn't cold all the way to the bus*" (**P8**). Plustur is arranged as part of a whole journey, integrating personalized taxi ride with public transportation. A travel plan of your whole journey will be available to view on your travel profile on the route. In this set-up the personalized transport service was perceived as being more flexible and therefore holds a promise of a guaranteed connection. When this lines up it is well received by passengers: "*Well, it feels like a luxury being picked up like this. I can remember when stepping out of the bus and directly into the taxi… I could get used to this.*" (**P3**)

Delays were sometimes (rarely) an issue for Plustur journeys, for example participants highlighted experiences where the Plustur ride arrived late for a pick up (**P3**) or involved longer detours to pick up or drop off other passengers (**P8**). This was also articulated by the three drivers, who expressed a need for better integration or coordination of trips in order to be more flexible in respect to unforeseen events such as heavy traffic. Hand-over of assignments to other drivers in cases of delay was not as neatly coordinated as desired, and **D3** would for instance express that sometimes they would experience being booked last-minute, if another taxi is heavily delayed or is unable to carry out the planned trip. At the point when they are told, they are already late for the pick-up time and this reflects badly on the driver and their associated company when it happens often, although it is out of their control. They refer to this as "*garbage-collection rides*." According to **D3** this introduces an unnecessary stress factor for the driver when they are confronted with dissatisfied passengers.

During our study, we experienced that interruptions of or changes to time-tabled transportation (e.g. bus route) were not well integrated into journeys that involved a Plustur. For example, for participant **F2**, the Plustur was the last leg of the journey. However due to road construction work, the first leg of the journey (bus) took an alternate route and did not service the regular bus stop. It resulted in a need to cancel the entire journey. That being said, a call center is established and passengers are urged to contact if problems/delays occur.

We identified an interesting challenge of integrating various transportation modes namely the use of hubs or non-hubs when changing modes of transportation for the individual passenger. Public transportation forms normally service fixed located stops like a bus stop or a bus station in a time-tabled manner, whereas the Plustur service has no fixed hubs. But a bus stop doesn't have a specific address and therefore can be challenging to locate and specify in the Plustur service. Our three drivers all expressed that the way they receive notice about an upcoming trip made it difficult to tell the exact pick-up location. **D3** would like to see some solution where bus stops might have identifiers so they can distinguish it from a pick up at a private home address, as is the case for some of the other transportation services they deliver. Furthermore, our passenger participants expressed that they were unsure what the Plustur vehicle looked like, as **F3** exemplified s/he was in doubt how to recognize the Plustur ride for the connection and sat for approximately five minutes while the vehicle was waiting and we intervened and pointed it out. On one of the solo trips we had to cross the road and walk 150 meters because the Plustur connection was parked at another bus stop in the opposite direction of where the bus dropped us off.

Autonomy of Mobility and Car Access

As one would expect, autonomy of mobility was considered important by all participants (14/14). But due to rural and low-populated areas being characterized by geographical gaps in public transportation service also referred to as first/last mile, autonomy came with car access or ownership. In fact, the autonomy provided by cars was argued as a necessity by participants to cover the first/last mile, stating that commuting to work was otherwise not possible or was drastically reduced in time spent by having a car compared to traditional public transport, and commuting by own car lends a flexibility to insert or change plans in the daily routine. "*You are always told that you can't live in a place like that without a car and I believe that is true*" (**P6**). We found that first/last mile problems in rural areas were in particular affecting young people's mobility.

Several participants (8/14) has access to a car within the household. **P4** has access to two cars in the household and could not imagine only having one car to meet the family's needs. **P10** has two daughters living at home and has bought the eldest a car on the condition that she will help with driving her little sister. All of the passengers stressed that they expected to own at least one car at some point: " *I think we are getting so locked in now that there is so little public transportation available*" (**P10**)

P5 and **P9** emphasized the absolute necessity of owning a car in rural areas, as they found public transportation not geared for everyday transportation e.g. (grocery) shopping and attending after-school sports or hobby programs. A specific example of this is transport for schools and education. Until a certain age, school transport is provided in the catchment areas. But participants argue that when you reach a certain educational level, you will have to move away from the most rural areas, as you will have limited options for commuting to your education as these tend to cluster in the larger cities. Despite this, some argued that oppositely if public transportation would have the same frequent operation as in larger cities, a lot of the time they would drive around almost empty: "Most *teenagers get a driver's license as soon as* *possible to have that freedom, where kids in the cities might not hurry as much in comparison because they have the freedom of the public transportation*" (**P11**)

In many cases the main roads going through rural areas are heavily trafficked, also with heavy vehicles like trucks and the speed limit is raised outside of city limits. This can hinder bicycling and walking along the roads. **P5** argued that as a child they were forbidden by their parents to go near the main road on their own without supervision. **P10** supported that argument, as s/he doesn't want their teenage daughters to bike to and from home when it is dark outside. Instead s/he would prefer to drive them to and from activities or the train station. Although s/he would like an alternative to driving at all times of the day. "*My children have gotten the offer (for a taxi), I'll be happy to pay to get out of getting up in the middle of the night to go and pick them up. But not everyone can afford that. Then there are those who have longer distances, they can't even have a night out if no one will come and pick them up.*" (**P10**)

In particular, our study showed that young people often suffered from poor mobility in rural areas, as they don't have many alternatives to get around by themselves and meeting up for social events like parties across the rural destinations and small towns. Attending sports activities or visiting friends required either meticulous planning or arranging lifts by parents. **P7** recalled attending sports activities in the next town on a weekly basis, as it was always challenging getting to and from the activity. Further, having easy access to public transportation for daily commuting was argued by one participant as a determining factor for where to live and work: "*If it is not a good fit with the bus routes, then it is not the job I want.*" (**P2**)

The Plustur service could potentially increase autonomy of mobility for people living in rural areas. Additionally, Several participants that moved out to live on their own or attend higher education (5/14) would use the service to visit family, e.g. parents living in rural areas, as they have expressed a realization that their parents might not always be well enough or over time retain the same autonomy in mobility for driving them for that last mile stretch. One participant (**P4**) was planning to move further away from the main lines of public transportation and found that Plustur as a service was really useful in this context.

Interestingly, the three drivers also had opinions about the service related to autonomy and mobility. In fact, they found that some Plustur purposes were more acceptable than others, in particular if the journey increased mobility for elderly people. Two of them agreed (**D2, D3**) that they had no problems driving an elderly person to a recreational or social activity, that this elderly would otherwise have limited means of getting to. According to **D1**, this purpose was currently most frequent. However, driving large groups of young people for parties, especially if they were intoxicated, was considered a misuse of the service and public resources.

Plustur was further considered an opportunity for people with disabilities to more freely move around independently, in particular when buses are not available or not easily accessible. **P5** who owns a car, but from time to time experience a loss of their sense of orientation and proper function of their legs, that hinders transportation in their own car for e.g. weekly hobbies or even to get to a doctor or pick up medicine. "*At times where I can't drive I will take the bus instead. I don't want to put others in danger and it is a good thing that you have the opportunity*" (**P5**). Somewhat surprisingly, Plustur drivers were not expected or required to help passengers enter or exit the vehicle, it is a 'curb-to-curb' solution. Drivers mentioned that it can delay them when people do not understand this condition and they must assist to a large degree, but all three were happy to assist special-needs passengers, and the drivers requested more flexibility in planning to do so.

Flexibility and Spontaneity

The transport authority (NT) has been very explicitly using the term last mile in their internal reports and marketing communication. Participants however argue that making use of on-demand transport services (e.g. Plustur) would not be a standard go-to, but would be preferred when going out for drinks or other instances where you are not able to drive the car yourself. However, it requires your planning to be more flexible than private modes of transportation. **P4** sometimes use these services when going out, although s/he enjoy the freedom of this possibility very much, it is not often that the drop off and reservations exactly match up. S/he experienced one time having to make the decision to be either 10 minutes late or 45 minutes early.

Expectedly, participants argued that commuting with public transportation offered less flexibility than going by car. As a rule of thumb, **P6** would factor in double the time for the same distance for public transportation compared to by car "*Busy people shouldn't use public transportation*" (**P6**). On the other hand, public transportation offered a space for other activities as (9/14) use the transport time for either work or relaxation. **P2** starts working when s/he get on the bus in the mornings. **P9** enjoys the time to just sit by themselves and listen to music and zone out. **P7** even expressed that s/he preferred the busride over driving, in particular when commuting for their internship: "*Really early in the morning it is nice to just get on a bus and drive and the same goes when going home, you can just lean back and relax*" (**P7**).

As Plustur incorporates ride pooling, bookings have to be made at least two hours in advance. All interviewed passengers expressed concern about the spontaneity of planning for Plustur. In particular, they had doubts about what would happen if you miss a connecting trip on the route, would want to travel at odd hours or for events that might change the expected time schedule like sports matches going into overtime, a social gathering that would extend later than planned or the possibility that you wanted to leave before a planned time. **P10** mentioned that their daughter often visit friends on the weekends where no buses are available to take her to the train station: "*There will be times when (Plustur) wouldn't work, when it is a sudden impulse she gets. It does introduce some limitations.*" The ridesharing element of Plustur introduces a high level of coordination but none of the passengers interviewed saw this element as a nuisance, except for when it caused delays they were not prepared for. **P4** views it as "*charming*" - "*I like the idea of sharing economy and that is part of it and you get to meet and greet other people*".

Plustur can be viewed as a MaaS initiative pointing to visions for future mobility, and it is still a relatively new mobility service. Reflected in the total number of trips and passengers it might take some time to get used to. This was clearly expressed in the many doubts, assumptions and expectations by the interviewed passengers and drivers of this study. Demand-responsive transport is however seen as future proof "*A lot of people in these rural areas are yelling out for more scheduled buses, but I think that belongs in the past. I think this is the future*" (**P4**). Although most saw a need for offering better suitable mobility services, in particular in regards to young people and children in rural areas. Some other future visions and extensions of flexible rural mobility services was expressed, for example **P6** imagined having so-called speed shuttles on a timed loop and supplementing with demand-responsive transportation offers. In the workshop, we discussed the potential attractiveness of bundling together events and transportation involving Plustur, to encourage and facilitate recreational and cultural activities in rural areas. Although it was argued by **P3** that it might be a challenging task to break the force of (transportation) habits, s/he sees future possibilities for on-demand, digital-enabled services like Plustur.

DISCUSSION

We have studied how people travel to and from rural, low-density populated areas in North Jutland characterized by the challenge of the first/last mile, using a new digital service (Plustur). We have illustrated how they perceive and use this service as part of mobility in such rural, low-density populated areas. Like the study by Pritchard et al. [19], we studied consequences of mobility services transformed to being solely digital and replacing traditional options. Adding to this, Hardy et al. strongly encourage HCI research to address rurality in developed and high-income countries and solidify understanding of inherent unique issues and commonalities [13].

While we see our findings on digital-enabled transportation in rural, low-density areas as a primary contribution of this paper, we will discuss opportunities and challenges for digital-enabled last mile transportation in rural areas and suggest design implications that have the possibility to accommodate and facilitate better passenger experiences.

Integrating Transparency in Trip Dynamics

As a last mile transportation service Plustur has at least one point of connecting with another mode of time-tabled transportation. During transportation, changes to the itinerary or plan might occur. Our findings showed that what caused most concern for passengers was accounting for dynamic changes in planning and this was related to their experience of rural mobility in general. Missing a bus or train can leave you stranded for up to several hours in rural, low-density populated areas, unless you are able to supplement with private transportation modes. Our findings confirmed that these points of connection is often influenced by delays or unexpected events but passengers are presented with a static travel document that does not account for changes. This static travel document offers nor or little transparency in the dynamics of possible connections or unexpected events both for drivers and passengers.

According to Hensher it is a crucial question how efficiently public transportation can be integrated with other modes of transportation and this can be answered through exploiting real time data on demand [15]. In line with the example from our findings of the school children's chain message to alert in case of delays in the bus routes, we suggest to implement this feature into the travel plan to introduce dynamic updates that can be transparent and actionable for passengers and/or drivers. This resembles how transit-centric mobility offers operate e.g. Uber, Lyft, VIA, etc. Demand-responsive MaaS solutions is proposed to address problems of first/last mile [1,15,27], often in the context of an urban setting [16,17]. However, our findings suggest that there are issues particularly for a rural context, as flexibility of demand-responsive trips holds frustrations of planning when travel times are dynamic either unknown or subjective to changes. For last mile transportation in rural areas, Velega et al. suggest that research efforts must focus on understanding demand [28].

Autonomy in Mobility without a Car: Possible?

Previous research has shown that mobility in rural areas is often equated with having access to a car [2,8]. This was also confirmed in our study where car ownership was closely linked to experienced mobility. Living without a car in rural areas introduce challenges and limitations, for example Utriainen & Pöllänen illustrate that there is a need for research to study the extent to which individuals would be willing not to own a car [27]. Additionally, recent studies have looked into how going car-less might be best facilitated and if it is even perceived as a possibility [14,23]. However, Gray et al. also warn to be mindful of the particular role that mobility and car dependence play in rural areas [12].

It was echoed in our findings that in rural areas you need a car to get around – or to get anywhere. For children and young people this meant relying on parents to drive them to and from activities, as public transportation seemed mostly geared to transport children to and from school. Our findings showed that attending after school activities like sports, where socializing is a big part of it, was considered challenging as this required meticulous planning of transport. Barker et al. point out a number of references that point to rural living children's experience of less independent spatial mobility in comparison to urban children [2]. On-demand mobility services like Plustur may be able to increase mobility for people without direct access to cars, e.g. elderly or children, to accommodate the first and/or last mile.

Fundamental Changes of Digital-Enabled Mobility

Digital-enabled mobility services changes the way we pay for the service as the need for cash is often eliminated [19,25]. While Pritchard et al. [19] found that the elimination of cash payment sometimes left people stranded because of payment issues, our participants did not experience this, but found the digital services more laborious when compared to traditional modes of transport. Perhaps most importantly, passengers were required to plan ahead as the service is only enabled when called upon two hours in advance, compared to deciding last-minute to go by time-tabled transportation. Booking rides using the service required some technology literacy, as it can only be carried out through a web booking portal, compared to e.g. taxi or other flexible services where booking can be done over telephone.

The Plustur service is one of many offerings, and more to come, governed by NT. In a MaaS context, multimodal transportation offers is dependent on adequate regulation [15]. Our findings show that the driver's perspective suggest a general negative attitude towards the development of multimodal offerings, as they feared that it might undermine their business and impact their individual paycheck. This is worth keeping in mind when negotiating policy and contracts for a MaaS scheme where different mobility modalities co-exist. It is worthy of further investigation to be more representative, however some indications from literature validate these views [1,11,27].

Plustur resembles what Hensher calls point via point-to-point, where the route may feature detour pick-up spots that will change your individual direct route [15]. Our findings show that this was rarely a nuisance to passengers; on the contrary this meant an opportunity to meet and greet new people and possibly even chat with the driver. In comparison to their habits in a normal time-tabled bus, where they would zone out, relax, or work. Usually, drivers also liked having conversations with passengers.

Studying Mobility-as-a-Service In-Situ

We encountered challenges of studying Plustur in situ. Unlike Pritchard et al. who spent hours riding the London buses and 'hanging around' particularly interesting spots [19], we cannot identify such spots, e.g. pick-up and drop-off points, as they existed only ad-hoc in response to a specific demand. We were unable to contact passengers in the same way as Plustur users are not identifiable while waiting at bus stops. This being said, we are not stating that accessing a mode of transport gives automatic access to passengers as participants in a study.

While internal reports gave us some indications on which rural areas passengers would usually use the service, it gave little indication of predicting where to focus recruitment as travel needs vary and some of the trips could be one-time occurrences. This is supported by Velaga et al. as a commonality of rural areas [28]. Some similarities can be drawn with the study by Pritchard et al. [19], in introducing change and understanding what went before, what happened during and after this change. In our case; introducing (multimodal) digital-enabled passenger trips.

Limitations

Defining rural can be challenging. Rural contexts are different for various regions/countries. This affects the generalizability of results and conclusions.

For this study we have understood rural areas in a high-income country, as a relational category on spatial difference - entailing long distances to major transportation hubs and/or low frequency of public transport time-tabled service (inspired by [28]). Our definition of rural have been primarily descriptive, an approach recently criticized [13]. In response to this, our findings supplement these initial definitions with sociocultural ways of approaching defining rural, e.g. how participants organize transportation to and from rural areas and the positive/negative ways they describe rural mobility. Views on public transportation can vary a lot and influence the adoption of transportation services in transportation-scarce areas, rural as well as urban [7].

CONCLUSION

We have investigated digital-enabled passenger trips in rural, low-density populated areas and particularly we have studied a digital service called Plustur introduced in 2018 in the northern region of Denmark. Our findings suggest that services like Plustur can address some of the problems of last mile in rural areas, as Plustur can be booked on demand. But we also found that passengers lacked higher degrees of flexibility for such demand-responsive services, and it was not immediately clear to them if it could answer to their transport needs, in particular for spontaneous trips. Additionally, we stress the need for integration of modes of transportation and transparency in travel planning. Drivers' attitude towards Plustur as a piece of a bigger MaaS puzzle was somewhat hesitant. We contribute with empirical understanding of digital-enabled passenger trips to facilitate mobility in rural areas, as previous research has indicated possibilities for how mobile technologies might aid in answering challenges experienced in this particular domain.

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REFERENCES

[1] Bilge Atasoy, Takuro Ikeda, Xiang Song, and Moshe E. Ben-Akiva. 2015. The concept and impact analysis of a flexible mobility on demand system. Transportation Research Part C: Emerging Technologies 56: 373–392. http://doi.org/10.1016/j.trc.2015.04.009

[2] John Barker, Peter Kraftl, John Horton, and Faith Tucker. 2009. The road less travelled - New directions in children's and young people's mobility. Mobilities 4, 1: 1–10. http://doi.org/10.1080/17450100802657939

[3] Oliver Bates, Adrian Friday, Julian Allen, et al. 2018. Transforming last-mile logistics: Opportunities for more sustainable deliveries. In Conference on Human Factors in Computing Systems - Proceedings. http://doi.org/10.1145/3173574.3174100

[4] Virginia Braun and Victoria Clarke. 2012. Thematic Analysis. APA Handbook of Research Methods in Psychology: Volume 2.

[5] Danmarks Statisik and Geodatastyrelsen. 2018. Kort over befolkningstæthed i kommunernes landdistrikter (Eng: Map of population density in the municipalities' rurals).

[6] Joyce Dargay, Dermot Gately, and Martin Sommer. 2007. Vehicle ownership and income growth, worldwide: 1960-2030. Energy Journal 28, 4: 143–170. http://doi.org/10.2307/41323125

[7] Tawanna R. Dillahunt, Vaishnav Kameswaran, Linfeng Li, and Tanya Rosenblat. 2017. Uncovering the values and constraints of real-time ridesharing for low-resource populations. Conference on Human Factors in Computing Systems - Proceedings 2017-May: 2757–2769. http://doi.org/10.1145/3025453.3025470

[8] Epinion and Nordjyllands Trafikselskab. 2018. (DK) Mobilitet - Nulpunktsmåling, Hovedrapport, februar 2018.

[9] MaaS Global. Whim app. Retrieved from https://whimapp.com/

[10] Mareike Glöss, Moira McGregor, and Barry Brown. 2016. Designing for Labour. 1632–1643. http://doi.org/10.1145/2858036.2858476

[11] Warwick Goodall, Tiffany Dovey Fishman, Justine Bornstein, and Brett Bonthron. 2018. The rise of mobility as a service. Deloitte Review, 20: 112–129. Retrieved from https://www2.deloitte.com/insights/us/en/deloitte-review/issue-20/smart-transportation-technology-mobility-as-a-service.html

[12] David Gray, Jon Shaw, and John Farrington. 2006. Community transport, social capital and social exclusion in rural areas. Area 38, 1: 89–98. http://doi.org/10.1111/j.1475-4762.2006.00662.x

[13] Jean Hardy, Susan Wyche, and Tiffany Veinot. 2019. Rural HCI research: Definitions, distinctions, methods, and opportunities. Proceedings of the ACM on Human-Computer Interaction 3, CSCW. http://doi.org/10.1145/3359298

[14] Hanna Hasselqvist, Mia Hesselgren, and Cristian Bogdan. 2016. Challenging the car norm: Opportunities for ict to support sustainable transportation practices. Conference on Human Factors in Computing Systems - Proceedings: 1300–1311. http://doi.org/10.1145/2858036.2858468

[15] David A. Hensher. 2017. Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change? Transportation Research Part A: Policy and Practice 98: 86–96. http://doi.org/10.1016/j.tra.2017.02.006

[16] Jani Pekka Jokinen, Teemu Sihvola, and Milos N. Mladenovic. 2017. Policy lessons from the flexible transport service pilot Kutsuplus in the Helsinki Capital Region. Transport Policy, May: 1–11. http://doi.org/10.1016/j.tranpol.2017.12.004

[17] Zhili Liu, Xudong Jia, and Wen Cheng. 2012. Solving the Last Mile Problem: Ensure the Success of Public Bicycle System in Beijing. Procedia - Social and Behavioral Sciences 43: 73–78. http://doi.org/10.1016/j.sbspro.2012.04.079

[18] Maas-alliance. MaaS-alliance.eu/what is MaaS. Retrieved from http://maas-alliance.eu/homepage/what-is-maas/

[19] Gary Pritchard, John Vines, and Patrick Olivier. 2015. Your Money's No Good Here: The Elimination of Cash Payment on London Buses. Proceedings of the ACM CHI'15 Conference on Human Factors in Computing Systems 1: 907–916. http://doi.org/10.1145/2702123.2702137

[20] Sunil Rodger, John Vines, and Janice McLaughlin. 2016. Technology and the Politics of Mobility. 2417–2429. http://doi.org/10.1145/2858036.2858146

[21] Yvonne Rogers and Marshall Paul. 2017. Research In the Wild. Morgan & Claypool, London.

[22] Kevin Sanders and David Geerts. 2019. You can't go your own way: Social influences on travelling behavior. Conference on Human Factors in Computing Systems - Proceedings: 10–15. http://doi.org/10.1145/3290607.3313079

[23] Caleb Southern, Yunnuo Cheng, Cheng Zhang, and Gregory D. Abowd. 2017. Understanding the cost of driving trips. Conference on Human Factors in Computing Systems - Proceedings 2017-May: 430–434. http://doi.org/10.1145/3025453.3025686

[24] Martin Stein, Johanna Meurer, Alexander Boden, and Volker Wulf. 2017. Mobility in later life - Appropriation of an integrated transportation platform. Conference on Human Factors in Computing Systems - Proceedings 2017-May: 5716–5729. http://doi.org/10.1145/3025453.3025672

[25] Michael K. Svangren, Mikael B. Skov, and Jesper Kjeldskov. 2018. Passenger Trip Planning using Ride-Sharing Services. Proc. of CHI: 1–12. http://doi.org/10.1145/3173574.3174054

[26] UITP. 2017. UITP Awards: North Denmarks's "Around Your World" increases accessibility in low density areas.

Retrieved from http://www.uitp.org/news/awards-NT-denmark

[27] Roni Utriainen and Markus Pöllänen. 2018. Review on mobility as a service in scientific publications. Research in Transportation Business and Management, July: 1–9. http://doi.org/10.1016/j.rtbm.2018.10.005

[28] Nagendra Velaga, John Nelson, Steve Wright, and John Farrington. 2012. The Potential Role of Flexible Transport Services in Enhancing Rural Public Transport Provision. Journal of Public Transportation 15, 1: 111–131. http://doi.org/10.5038/2375-0901.15.1.7

PAPER 2: TRANSPORTATION AND TECHNOLOGY IN RURAL DENMARK: COMMUNITIES OF MOBILITY

Authors:

Maria Kjærup, Mikael B. Skov

Abstract:

Rural areas have experienced little attention in HCI research, much less rural areas in high income and developed countries. We investigated how digital technologies have influenced mobility in rural areas, through interviews with 19 people living or frequently traveling in rural areas of the North Region of Denmark. We found that rural mobility was predominantly centered around access to private cars, however it was also characterised by often being multi-modal. We present several ways that technologies played a role in coordinating mobility across public and private transportation modes. We found that communities of mobility existed on different levels; household, neighborhood and local area. We explore the conditions for suitability of Mobility as a Service (MaaS) initiatives in a rural area context, as we discuss two distinct contradictions that emerged from our findings and relate them to research challenges that we see for future development of digital technologies for rural mobility.

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PAPER 3: AVAILABLE ANYTIME ANYWHERE: INVESTIGATING MOBILE VOLUNTEER RESPONDERS FOR OUT OF HOSPITAL CARDIAC ARREST

Authors:

Maria Kjærup, Mette Elsborg, Mikael B. Skov, Anders Bruun

Abstract:

Out of hospital cardiac arrest is a life-threatening event that requires immediate resuscitation actions. Therefore, digital volunteer responder initiatives integrate nearby users who can be activated anytime, anywhere through mobile technologies to assist in administering first aid. While research has found that such initiatives increases the chances of surviving, we know little about how responders use the digital services, and how they organize themselves before, during, and after responding. We conducted interviews with volunteer responders (N=16) to address how they perceive these initiatives and in particular how they negotiate availability temporally (anytime) and spatially (anywhere) for such life-threatening events. Our findings show that our responders exhibited strong perceptions of how and why one should volunteer. Also, the temporal aspect of being available anytime integrates several dimensions, while being available anywhere is highly related to safety, community and group roles. Finally, we discuss implications for design of volunteer responder initiatives.

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Available Anytime Anywhere: Investigating Mobile Volunteer Responders for Out of Hospital Cardiac Arrest

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ABSTRACT

Out of hospital cardiac arrest is a life-threatening event that requires immediate resuscitation actions. Therefore, digital volunteer responder initiatives integrate nearby users who can be activated anytime, anywhere through mobile technologies to assist in administering first aid. While research has found that such initiatives increases the chances of surviving, we know little about how responders use the digital services, and how they organize themselves before, during, and after responding. We conducted interviews with volunteer responders (N=16) to address how they perceive these initiatives and in particular how they negotiate availability temporally (anytime) and spatially (anywhere) for such life-threatening events. Our findings show that our responders exhibited strong perceptions of how and why one should volunteer. Also, the temporal aspect of being available anytime integrates several dimensions, while being available anywhere is highly related to safety, community and group roles. Finally, we discuss implications for design of volunteer responder initiatives.

CCS CONCEPTS

• **Human-centered computing**;

KEYWORDS

health, cardiac, mobile, volunteer, availability

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1 INTRODUCTION

Cardiac arrest is when the heart abruptly stops beating and where every passing minute decreases the chances of survival by 10% [18]. Timely delivered resuscitation efforts has the potential to increase survival from cardiac arrest. Cardiopulmonary Resuscitation (CPR) is recognized as the standard of resuscitation emergency care [1]. Furthermore, automated external defibrillators (AEDs) are effective tools for resuscitation, and are widely distributed in public areas for bystanders to retrieve and use [2].

Activating bystanders in retrieving an AED and initiating CPR can greatly improve the response time to cardiac arrests. However, studies show that bystanders rarely react accordingly to cardiac arrests in a public area due to difficulty in recognizing the arrest and doubting their abilities to perform CPR [4, 26]. To respond to these challenges, mobile technology has been utilized to activate volunteers who have committed to being available to respond to perform resuscitation [2, 4, 5, 21, 24, 26, 33]. Recent studies have investigated implementation challenges [4], bystander defibrillation [2, 24], response time [26, 33], and variation in how notifications are received [5]. These studies all take a clinical perspective, whereas Ozcan et al. conducted a study from a CSCW perspective to uncover barriers to respond through a simulated responder program [21]. Ozcan et al. presents a framework of the temporality of non-response barriers, and furthermore defines design implications for overcoming them. To build on this, our study takes an HCI approach and emphasizes the perception and expectations of actual volunteer responders' commitment to availability based on real-life experiences from an existing volunteer responder scheme.

Multiple examples of separate, region-based volunteer responder schemes utilizing mobile technology for out of hospital cardiac arrests have existed in Denmark throughout the past decade, but currently changes are implemented towards a vision of a uniform national initiative ([2]). In some cases this means merging or substituting existing schemes, in other cases the new scheme is allowed to co-exist with already implemented local schemes. We wanted to explore the interaction between volunteer responders and mobile technology, where the two are dependent on each other to make an impact in a life or death situation, while also being very time sensitive. We conducted interviews with volunteers about their real-life experiences of responding to out-of-hospital cardiac arrests, with a focus on their view of having committed to being available to respond anytime, anywhere. The participants represent five different responder schemes to understand how the implications, benefits and drawbacks of the various organizations are experienced, as well as how the schemes co-exist.

We present an empirical understanding of how volunteer responders negotiate availability in a life-and-death, time sensitive HCI case through various volunteer responder schemes as well as the tensions associated with the introduction of a uniform national scheme. We found that frequency of alarms impacted volunteers readiness to respond. Additionally, we saw the way in which different technologies implement distance had an impact on volunteers perceived availability, and trust in technologies, respectively GPS and SMS. A key finding is volunteers' fear of finding themselves in a situation where they are the sole responder, alone with the many

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demanding tasks on the site of a cardiac arrest. We unfold how local volunteer communities operated and how informal roles were assigned to volunteers within these communities. We discuss the implications for this on design of functionality for mobile technologies and adoption of new to volunteers technological solutions.

2 RELATED WORK

Here we present relevant literature that expands our understanding of mobile technologies and volunteering in a health domain. For the framing of availability, we include literature that unfolds the implications of use of mobile devices both professionally and privately as these often overlap.

2.1 Constant Connectivity, Availability and Negotiating Boundaries

Constant connectivity is afforded by the accessibility of data connections and technologies with connective capabilities. With these follow an expectation of availability. Availability is expected to such a degree in business settings that it is commodified, often to the detriment of workers' health [14].

Mattern et al. understands constant connectivity as *"the inability of individuals to detach effectively from their digital and mobile companions"* ([20]) and found that despite detrimental expectations of availability often being associated with work ethics and culture, study participants were more likely to have an emotional connection to their smartphone rather than viewing it as a tool to conduct work with. In this regard, studies have been willingly subjecting people to let go of that availability e.g. by turning off notifications for 24 hours [22], withholding work e-mails for five consecutive workdays [13] or getting rid of their cellular communication device for years [12]. Pielot and Rellot found that while device notifications often distracted individuals in their work by creating interruptions, they also facilitated feelings of being connected to people you care about. Importantly, notifications were essential for meeting social expectations of availability and if ignored could lead to conflicts with friends, colleagues and partners and even present as a source of anxiety [22].

Cecchinato et al. saw how smartwatch users employed so-called microboundaries to regain control of their availability [6]. These bodily worn devices would be expected, in particular by non-users, to increase the availability to respond - imagined as *"digital handcuffs"*. However, user strategies such as temporal microboundaries (e.g. turning off notifications at night) facilitated users in regaining control through connecting more selectively and reducing the urge to reply immediately to notifications [6]. While a lot of research on availability relates to work - often work extending into the private/domestic sphere - a recent study relates to volunteer work carried out by medical professionals outside of work hours. Ding et al. carried out a study of volunteer patient-provider communication in China, where they emphasized the boundary negotiation strategies that became apparent in interviews with patients and doctors in volunteer follow-up conversations outside of institutional frames. Keeping in mind that doctors were aware and supportive of the fact that this service provided a real benefit for patients [10].

2.2 HCI on mHealth and Volunteering

Research in HCI has focused on the role of mobile technologies in delivering healthcare services or to enable caring for someone. While much of this research concerns obligations due to institutional demands or moral obligations based on relations, some research also concerns volunteering to deliver health service or caring for others out of intrinsic motivations. Often people with no professional health background are obligated to manage their own health or the health of a person they are caring for. The role of the informal caregiver has been vaguely defined in HCI research. To this end, Miller et al. presented five caregiving roles for patients during hospital admissions and emphasized their importance [15]. Technologies can help prepare caregivers for this task. Mobile applications (hereafter referred to as apps) have been advantageous in supporting people with a wide range of health issues ranging from physical well-being to mental disorders and chronic illnesses [3, 8, 16, 25, 27].

Technology has been utilized to facilitate the support of volunteer caregivers in the health domain. The motivation for involving volunteers include scarce number of professionals in e.g. rural regions [19], health clinics managed by non-profit organisations for underprivileged populations [29] or to bridge the gap between professionals and lay people in terms of language barriers [11]. Volunteers are also advantageous for medical and caregiving needs that are emergent and time sensitive e.g. for volunteer doula programs [23] or in the case of out-of-hospital cardiac arrests.

2.3 Cardiac Arrest Volunteers Facilitated through Mobile Technology

While efforts go into educating the general public in stepping up to perform first aid and administer CPR, records of bystander CPR are on the rise but remain relatively low, in particular in residential areas [31]. Mobile technologies may aid in locating a publicly available defibrillator. Additionally, mobile technologies have been utilized to activate volunteer responders to locate cardiac arrests based on GPS signal or area code and respond by facilitating timely delivered first aid. This provides a dual-response emergency medical service (EMS) dispatch of local or nearby volunteers and traditional trained EMS e.g. paramedics [2, 4, 5, 24, 26, 33].

Brooks et al. ([4]) studied the PulsePoint Respond mobile application that facilitates volunteer dispatching by means of GPS, notifying volunteers in a 400 meter radius of a person with suspected cardiac arrest, although solely in public places. Based on 1274 surveys from volunteers who received a notification, they concluded that it was feasible for the app to recruit nearby volunteers to perform resuscitation, however a few challenges remained for optimal implementation. Challenges included the technical characteristics of the app resulting in volunteers not noticing the notification, too many false alarms and a low density of volunteers in the community. Furthermore, 42% of volunteers receiving the notification were not able to respond and in 61% of the cases, where volunteers responded, professionals had already arrived before the volunteer [4]. Meanwhile, Ringh et al (2015) studied a similar system where volunteers within a 500 meter radius received a computer-generated phone call as well as an SMS with location information of a suspected cardiac arrest nearby. Ringh et al. ([24]) conducted a blinded, randomized, controlled trial where the intervention group received the notification while the control group did not. They found that bystander-initiated CPR was significantly improved when volunteers were notified through their mobile devices compared to when not receiving a notification [24]. Similar results where found for Andelius et al. [2]. In both ([4]) and ([24]), about a third of volunteers did not notice the notification, and less than a quarter arrived on site timely. Despite this, Ziljstra et al. ([33]) similarly studied a scheme where laypersons registered with an address <1000 meters from a suspected out of hospital cardiac arrest, were instructed by SMS to retrieve AEDs. They focused mainly on response time and early defibrillation and surprisingly concluded that layperson responders started defibrillation with a mean of 2,39 minutes earlier than EMS responders [33]. Although, Caputo et al. ([5]) found that when comparing SMS and app notifications, lay responders arriving to the site significantly increased with the app notifications.

The above studies are mainly focused on determining the effectiveness or efficiency of volunteer schemes through quantitative data, thus not unfolding volunteers' experiences. Ozcan et al. ([21]) conducted a study to explore the barriers to volunteers not receiving notifications and furthermore, provided design implications for implementation of mobile technology to facilitate volunteer responders to cardiac arrests. [21] identified four categories of barriers based on a diary study and focus groups with 12 participants receiving simulated alarm calls. The identified barriers were related to volunteers wanting to temporarily opt-out of the system, volunteers not noticing the notifications, barriers to leave their current situation and finally, concerns of not being able to correctly perform the resuscitation when arriving on site [21].

Layperson responders will often have received training in CPR but do not always have the psychological training and extensive experience in the same manner as trained professional responders. The commitment to these mobile schemes puts them in a situation of constant availability to respond to cardiac arrests and thus test their physical and psychological competences in responding to these time sensitive, life or death events. Zijlstra et al. noted that layperson responders may experience severe short-term psychological impact, albeit this does not present as PTSD-related symptoms long term [32]. Research has shown that debriefing procedures post-responding have a short-term positive effect as well as retention of this effect over months [17].

3 OVERVIEW OF DANISH HEARTRUNNER SCHEMES

This section gives an overview of the different volunteer cardiac arrest responder schemes that is represented in this study. The information is primarily informed by our participants, where not otherwise stated.

3.1 App-Based Initiatives

Two app-based initiatives are represented in our findings, namely 'Trygfonden' and 'Danmark Redder Liv' (DRL). Whereas DRL was an initiative with combined efforts of the respective regions, a non-profit organisation and a medical equipment company, Trygfonden is a large non-profit foundation that incorporates a taskforce for several nationwide safety-initiatives and the main owner of an insurance company. Both require a smartphone, GPS and data connection. When a suspected cardiac arrest is called in at the nearest emergency dispatch center, the 20 volunteers that are closest within a radius of 1800 meter (Trygfonden) or up to five kilometers (DRL) are called to the site of a suspected cardiac arrest. Volunteers must then confirm the alarm call by choosing to decline or accept the alarm call in the app. Upon accepting alarms, volunteers will be asked to choose from to navigation options; a) retrieve the nearest defibrillator and bring to the site or b) navigate directly to the site of the cardiac arrest. Other features in the current version of the app consists of a demo of receiving an alarm with dummy data to get acquainted with the procedure before receiving alarms. Additionally, the app has a video feature that demonstrate use of a defibrillator and a feature that will facilitate pressure frequency during CPR. Trygfonden scheme was implemented in 2017 in the Capitol Region and followed in the Central Region. Since its implementation more than 80.000 volunteers have downloaded the app [2]. In 2020 the scheme was implemented for Region North Jutland. The DRL project was implemented medio 2018 in Region Zealand and Southern Denmark Region and planned to last for 20 months; it was evaluated in Spring 2019. From May 2020 DRL was replaced by Trygfonden scheme. Thus by 2020 covering all of Denmark. Criteria for volunteering differs as DRL demanded approved documentation of first-aid competences prior to signing up, whereas Trygfonden volunteers sign up by simply downloading the respective app ([2]).

3.2 Local Text Messaging Initiatives

The local text messaging schemes are implemented for region North Jutland. Each individual local group is created bottom-up and consists of one or a few key volunteers, who will typically have been the local initiator(s) and a group of 15-25 local volunteers and up to 50 volunteers if covering a large geographical area. A contact person is tasked with managing the local group of volunteers through a web-portal supplied by the region. This scheme will continue alongside Trygfondens app-based Scheme in Region North Jutland from Spring 2020.

When a suspected cardiac arrest is recognized at the dispatch centre, a text message via short message service (hereafter abbreviated SMS) is sent to every volunteer covering the respective local area. The SMS states the condition in a few words and a location and volunteers are expected to take appropriate action without giving a response. No documentation of first aid competences is needed for signing up, however a clean criminal record must be obtained. Volunteers are approved by local key persons, who are also often volunteers themselves.

3.3 Other Initiatives

Trygfonden is in charge of keeping a register of all defibrillators nationwide, this register is a separate initiative that predates the heart runner scheme, although the functionality is also implemented in the app. When a person registers a defibrillator they are asked to provide a phone number for one or more people who will be available to bring out the defibrillator if a cardiac arrest happens nearby ([2, 31]). The fourth scheme present in our study, is based on this register and resembles the local text messaging scheme in its composition, however instead of push messages one contact person will be contacted by the dispatch centre and initiate a phone chain to alert volunteers to an incident.

The fifth scheme, referred to as Acute scheme, concerns volunteers who are called for multiple incidents, including cardiac arrests. Geographically they cover areas that are furthest away from ambulance dispatch centrals. These volunteers have been trained extensively and regularly in first aid and have access to more advanced medical tools.

4 METHOD

This study explores how volunteers in various heart runner schemes consider and negotiate availability before, during and after being called to an out-of-hospital cardiac arrest. We present ethical and methodological considerations for this study design *e.g.* discussions of obtrusiveness and facilitating respect for participants professional secrecy oath, as well as reflections on researchers' role. We account for the recruitment of participants, the interviews carried out by declaring their aims and ongoing changes to procedures.

4.1 Ethical and Methodological Considerations

Like previous HCI studies (e.g.[28]), we had some ethical and methodological considerations before carrying out the study. People participating in these heart runner schemes are faced with time-sensitive and life-critical situations and thus, our participants could have faced situations of receiving calls on real life alarms. Waycott et al. note the necessity of HCI researchers' adherence to ethical principles while studying HCI in sensitive settings with participants who might be considered vulnerable in varying degrees [30].

We chose to conduct traditional interviews as an unobtrusive way of collecting data as opposed to contextual interviews or observational studies. Further, all our participants had been subject to professional secrecy as part of the heart runner volunteer agreement, which we discussed with all participants before or during the interview. We informed them about data processing in accordance with the EU General Data Protection Regulation (GDPR) and ensured that no personal identifiable information, such as street names or local affiliations, could be identified from the interviews. We took care not to encourage violations of secrecy by advising participants to not mention compromising details of alarms received or accepted. Finally, transcripts were sent to the individual participant for transparency and approval. For one interview we had to redact a portion of the transcription per request of the participant.

Dickson-Swift et al. draw attention to how qualitative researchers should deal with situations in which sensitive and emotional distressing topics occur during data collection [9]. During interviews researchers should aim to suppress their own felt emotions to seem more professional in interactions with participants. Inspired by [9], we conducted debriefings among the involved researchers immediately after each interview, as participants' narratives at times triggered emotional responses. Such examples could be when conversation concerned the death of a close relative or witnessing suicide attempts, car accidents or other incidents with severe or fatal outcomes.

4.2 Participants

16 people (10 females) participated in our study (age between 22-74, M=43.4). Participants were recruited based on three conditions 1) being 18+, 2) currently affiliated with a scheme and 3) having received an alarm call. Although not adhering to condition 3, P8 was included because s/he helped show a diversity of schemes and technologies, representing the phone chain scheme. We found that her interview added to issues related to e.g. motivation, anticipation and concerns of recognizing and receiving notifications that was broguht up in related work. Eight volunteers represented a local text message scheme (two of these were also volunteers for Trygfonden scheme), five volunteers represented the app-based scheme by Trygfonden only and one from DRL (later merged with Trygfonden). Two participants represented other schemes.

Eight of the 16 participants (P1, P5, P8, P9, P13-P16) self-identified as having a professional background in healthcare (e.g. paramedic, nurse, carer for patients with complications and medical lab technician). The other half self-identified as not having a professional background in health (e.g. entrepreneur, student, teacher, firefighter, coach or retired). Almost all of them (15/16) had received and responded to at least one alarm, and this varied significantly from one to 48 alarms. They had been volunteering between one to six and a half years. One participant (P15) had received a disproportionate number of alarms due to the nature of the volunteer scheme.

Eleven participants were recruited through private local social media pages, where site administrators accepted to pass on our study and contact information to volunteers in closed forums. An additional five participants were recruited through authors' social network. All participants were presented with written information on study purpose, activities and processing of data prior to interviews. Participants did not receive compensation for participation.

4.3 Procedure

Our procedure followed two steps where we conducted our main interviews followed by interviews on how participants dealt with the restrictions related to social distancing after the COVID-19 outbreak in Europe.

Main Interviews. We carried out a total of 16 interviews over the phone and in one case in-person. Interviews were semi-structured and followed an interview guide that, besides demographics, featured questions regarding motivation for volunteering, organization of schemes and preferences, thoughts about future directions and wishes for technology facilitation. For example: *"What guidelines have you set for yourself regarding use of your mobile phone following volunteering?"/"If given the choice, would you prefer a scheme organized around GPS technology or text messaging?".* Interviews lasted between 25 and 50 minutes. Interviews were carried out in the researchers' and participants' native language (not english). One participant additionally supplied documents that were handed out to volunteers prior to a meeting in their local organization.

Follow-Up Interviews. As eight of our participants were interviewed prior to the COVID-19 outbreak, they were invited to participate in an individual follow-up phone interview specifically investigating (self-)imposed guidelines. Five participated in these follow-up interviews that were held in week 15 during a national lock down with state recommendations of social distancing.

Table 1: Table of participants demographics; age, gender, approximate years of volunteering, scheme affiliation(s). Additionally, alarms received and accepted (from memory).

P#	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Age, Gender	63, F	33, M	52, M	74, M	27, F	23, F	55, M	25, F	47, F	37, F	22, F	37, M	55, F	47, M	72, F	26, F
Years of Volunteering	3	6, 5	1	3	1, 5	1, 5	2	1, 5	1	1, 5	0, 5	4	3	0, 5	3	0, 5
Scheme Affiliation(s)	SMS	SMS	SMS	SMS	App	App	DRL	Phone Chain	SMS, App	SMS	App	SMS, App	SMS	App	Acute, App	App
Alarms Received	17	48	3	17	1	2	2	0	4	16	3	35	25	1	700	2
Alarms Accepted	7	37	3	6	1	1	0	0	1	15	3	N/A	15	1	N/A	2

4.4 Data Collection and Analysis

All interviews were audio-recorded with consent from participants. Interviews were transcribed verbatim by the authors for analysis. Analysis was carried out as the thematic analysis mentioned in [7]. First, authors familiarized themselves with the data by condensing the transcripts into units of meaning. Secondly, authors compared the condensed transcriptions and in collaboration worked out a mind map of initial codes and sub-codes. These were; availability, use of technology, safety, motivation and expectations, practical organization of schemes, preference of schemes. Thirdly, full transcriptions were coded in Nvivo. To align understanding of codes, the coders separately analyzed the same paragraph of transcription and discussed until consensus was reached. Ensuing, coding was divided between two of the authors, who discussed their applied codes on few occasions of doubt. Codes were reviewed and grouped based on relations through affinity diagramming and iteratively formed the themes that were found relevant to report in our findings.

5 FINDINGS

Our findings are presented in five main themes: 1) Motivation and Expectations, 2) Responding to Alarms and Returning to Life, 3) Area and Familiarity, 4) Safety and Role Assignment, 5) Technology Opportunities and Challenges. Participants are referred to as P1-P16, in accordance with table 1.

5.1 Motivations and Expectations

All participants (16/16) expressed a clear motivation for joining the heart runner schemes, which took an outset in the intrinsic value of helping other people and thus potentially saving lives. Seven of them articulated that they were motivated by putting their professional health competences into use outside of work hours, as an example **P1**: *"I was already working within cardiology and cardiac rehabilitation as part of my job, so it was straightforward to also volunteer in this area"*, while four participants were primarily motivated based on their previous experiences from intervening as bystanders in cases of road or workplace accidents, or relatives experiencing sudden medical emergencies. A few of them were either prompted by reacting to advertisements, or as **P2** who was prompted to initiate a local group based on the knowledge of infrequent use of otherwise available defibrillators in the local area.

Besides own motivation, interestingly we found that several participants (8/16) were concerned with the motivation of other volunteers. Most remarkably, participants who were key organizers of local groups stated that they would regularly check up on volunteers motivations, particularly in cases of repeated *"no-show"* in connection with alarm calls. Thus, for these participants it was important to determine actual availability to avoid having passive runners in their schemes, as an example **P3** argues: *"It is easy to volunteer for an app or an initiative, but to feel ownership and the right commitment, I think that is the hard part"*. Somewhat surprisingly, it was even suggested that people might volunteer just out of morbid curiosity, as **P2** asked fellow volunteers: *"Is this something that you would like to do, or are you just curious about where cardiac arrests happen?"* In particular they request more demands on sign-up procedures to validate identity, proof of first aid competences and a clear criminal record. A few of the participants had heard rumours of the possibility in the app-based scheme that they implemented such a relaxed validation feature that you could sign up fictional characters, pets or even deceased relatives. The other half of the participants emphasized that although they can't know volunteers' motivations, they have to assume that they are there for the same reasons as themselves. **P7** in particular rejected scrutinizing volunteers intentions and motivations: *"Here you have the volunteer amateur help... You don't need to set the bar higher than necessary"* (**P7**). S/he had experienced how demands on volunteers to report a number of documents had introduced bottlenecks in administration.

In continuation of their motivation, participants expressed that their expectations regarding receiving alarm calls were characterized by contradictions; on one hand, they wanted to help others by putting their competences to use as exemplified by **P3** who argued that the CPR training efforts will otherwise have been wasted. On the other hand, **P11** underlined that no volunteer wished for a cardiac arrest to happen to anyone: *"When you volunteer, however odd it may sound, you hope to be called on and of course you shouldn't hope for that, but it is new and exciting"* **(P11)**.

Participants mentioned that expectations of how they would react to receiving alarm calls and reality clashed. **P16** explained that for weeks after their first alarm call, they would constantly check their phone, to a degree that they deemed unhealthy and noted feeling like their body was in heightened stress in response to the anticipation of another alarm call. A few of the participants who joined recently (e.g. **P11, P14, P16**) could clearly recall their first alarm received and connected it with some to a large degree of confusion and anxiety, however noted that it passed over time and with more experience.

5.2 Responding to Alarms and Returning to Life

All participants (16/16) stressed the importance of noticing incoming alarms as soon as they were received. Quick response is extremely important for the survival rates according to previous research (e.g. [2, 31]), and all our participants were strongly aware of this fact. To address this, they deliberately used functionality inherent in mobile phones to distinguish the heart runner alarm calls from all other notifications. Participants from the text messaging schemes (8/16) would set specific sounds, lights or vibration patterns in their mobile phones to easily recognise alarms, for example **P2**: *"It [phone] has a specific sound when the SMS arrives and it vibrates in a certain way and it blinks in a certain way. So I can tell them apart"*, and most of them assisted each other with this. We only noted one instance where this manual setting was not ideal, **P1** missed two alarms as their newly acquired phone did not transfer the settings from their previous phone. On the other hand, the app participants would receive a loud and very distinct siren-like notification (set as default in the app), while the phone chain scheme did not have any immediate way of distinguishing alarm calls from regular incoming phone calls: *"... you just pick the phone up immediately when the call comes."* - **P8**.

Responding to an alarm basically required the participant to decide whether to run or not and particularly two considerations were highlighted. First, most participants said that they had experienced receiving an alarm while occupied with activities that could not be easily terminated, e.g. **P5** mentioned taking a shower or **P9** being at home while looking after young children. **P6** illustrated it like this; *"... can I respond when at work, and I am the only adult at work ... can I then leave the store to make a difference?"*. Most participants stated that they had a (domestic) spouse, partner, older siblings or someone they could inform when running for an alarm, which they could trust to inform others when e.g. leaving a dinner party or who could supervise younger children. Secondly, all participants stressed that they would normally be available any time of the day, however and interestingly, they also all agreed upon the fact that they would not be available at times where they had consumed alcohol as they would not trust themselves to perform critical work (resuscitation), and some also argued that they would not be available if they were unable to transport themselves to the site of the patient by car. The latter was surprising as the schemes are referred to as heart *runners*, but transportation by car was argued as the preferred mode of transportation and for few participants essential to manage the physical strain of transporting themselves - "*I am too old to run for these alarms ... I don't have the fitness level or lung capacity to run for example one kilometer*" **P1**. Volunteers do their best to facilitate patients in returning to life and a normal cardiac rythm, afterwards the volunteers return to their (everyday) life - whatever activities preceded and proceeds alarm calls. These might be sleeping, cooking, or working, etc. **P15** stressed that it was (sometimes) necessary to prepare for a safe return from responding to an alarm; one time s/he came home to a burnt meal in the oven that s/he had completely forgotten when s/he got the alarm and responded immediately. While the core of the heart runner schemes is that anyone can aid in saving lives, we also found that the efforts could be draining on the participants. In particular, not knowing the outcome of the efforts as illustrated by: "*We don't get any information on how everything went, this is also something that you should be able to deal with, namely that you never know whether you actually succeeded [in resuscitating] or not.*" **P1**. Except for one occasion where **P10** mentioned that an elderly man, at the anniversary of the alarm call, showed up and even brought flowers as thanks.

Arriving on site can be hectic due to the severity of the situation, but the participants also stressed the need to make quick judgement calls, and the uncertainty of the situation. All text message participants reported that they would be wearing a brightly colored reflective vest with writing, while only a few from the app based initiatives had access to one. A background in healthcare might not be sufficient to prepare volunteers for the pressure when arriving on site **P2, P5** and **P13** noted, as the setting is unlike a hospital and the same medical tools are not available. Even **P13** experienced an initial barrier to enter a strangers house in a rush, but s/he found that wearing the vest had an immense signal value of legitimacy, as well as facilitated getting into a certain state of mind. Several participants articulated that an important task when arriving is clearing the site, as next of kin, bystanders, or furniture may be in the way of properly administering CPR and creating a clear path for ambulance handover. In these cases more volunteers might be needed, as **P3** exemplifies: "*... last time I responded to an alarm was an afternoon and we were approximately 10 heart runners present at the site, and therefore we could also handle family members including children and pets*". **P5**, who is also a paramedic, agreed that the volunteers on site may provide useful assistance before, during and after handover to paramedics, they may also assist in psychological first aid.

Participants indicated that there was an inherent temporality concerning frequency of alarms received and perceived readiness to respond. While participants expressed that they signed up with an expectation of being *"activated"* (to run), the frequency of calls varied greatly and participants argued feeling either like being on *"standby"* for several months at a time or being called several times in one week. Participants (**P10, P11, P12, P13 and P15**) noted that when alarms were received infrequently, their sense of availability and perceived readiness would steadily increase. **P10** argued that since it had been two months without an alarm, s/he was expecting an alarm very soon. Although, when alarms were received too frequently, it would present as a nuisance. Despite that, more participants noted that it would rarely deter them from responding to run, as articulated by **P13**: "*... when you have responded to alarms several nights during the last couple of weeks, you start to think about alarms when you go to bed ... tonight I hope there will be no alarms as I don't have the energy for it*".

Due to the sensitivity of the contexts to which the volunteers are called, they needed to consider the emotional strain that comes with committing to being available for responding to resuscitation. Participants generally argued that it was especially difficult when called to younger patients. The included Volunteer schemes in our study do not dispatch volunteers to children under 8 years old. The local schemes had varying organization around debriefing after responding to an alarm. Either one person was in charge of contacting affected volunteers, or volunteers were expected to organize themselves afterwards based on assessed needs. For the local scheme of **P2**, they had an implemented a routine where volunteers would meet up afterwards and reconstruct a narrative starting with the first volunteer on site, then the next one, and so on. Although **P2** also recognized that for some volunteers that have been on call extensively debriefing had perhaps become more of a routine than an urgent, actual need. Meanwhile, **P3** and **P8** recognized that there might be a need to make debriefing a standard practice in their respective schemes. In the app-schemes, after responding to an alarm call volunteers were asked to fill out a questionnaire inquiring about their perceived psychological strain and if they required a professional consultation. While not all volunteers express a need for professional help, volunteers agree on the need to talk to at least someone about their experience: *"I think that there is a need for talking together to avoid having these experiences alone ... especially for such activities that pushes boundaries of what we normally do for each other"* **P7**. **P14** (app) expressed a fondness for the acknowledgement of their efforts in the message that followed the questionnaire, although aware that it was a generated message.

5.3 Area and Familiarity

The geographical area in which heart runners would receive alarms played an important role for the participants. In general, they expressed a strong awareness that the areas where they were most likely to be called were areas they spent time in (lived) and therefore they could know or be familiar with people living or working there. Thus, when running on an alarm, several of them said that it often happened that it was someone they knew, e.g. friends, neighbors or just acquaintances. While all participants imagined the thought of recognizing the address as uncomfortable and their response worth extra consideration, they all clearly articulated that they would most likely respond to an alarm where they know the victim, illustrated by **P2**: *"Some [runners] will rather not respond to an alarm where they know the person, but that is completely up to them ... I will definitely respond, because you can really make a difference."*. However, a potential disadvantage of the local communities was expressed by **P9** as s/he had heard someone state that they did not want heart runners in their homes, as they were afraid that they would judge them and gossip about their *"ugly curtains"*. To this end, s/he firmly noted that volunteers were sworn to professional secrecy. On the other hand, familiarity with the area of operation had other advantages as participants argued that they knew the physical surroundings, and in fact a few of them were not at all comfortable responding in areas they were less familiar with, although 12/16 participants said they would respond but they would have increased focus on their own safety and would depend on technology for way-finding.

Participants emphasized repeatedly that while defibrillation is invaluable when administered timely, CPR was perceived as the most important task to start immediately. Locating and retrieving defibrillators in the area was first and foremost an individual decision in-situ. The app-based solutions demanded that volunteers reported their decision up front and was guided accordingly. The local text messaging scheme featured little negotiations within the groups on this responsibility. Here, participants (e.g. **P2**) argued that it was a waste of time with fatal consequences if attention was directed to retrieving defibrillators rather than going straight to the site of the cardiac arrest. In particular for the schemes fixed on a local area, volunteers have had a say in the strategic placement of defibrillators and have memorized where they are placed. Whereas, **P6** from the app-based scheme mentioned that they were not familiar with the placement of defibrillators at their specific location (during the interview). That being said, **P6, P8** and **P11** (app and phone chain-scheme) also argued that they have adopted a heightened awareness of where defibrillators are placed when they enter a new area or building.

A common theme for the local text message schemes was a strong desire to feel a sense of local anchoring and a shared belief that it will have negative consequences if someone from the outside was dictating their local practice, and this was argued in two ways. One was security in the known; geographic area, fellow volunteers: *"... when you arrive in private homes, I find it comforting if I am acquainted with the area in advance"* **P1**. The other way that local anchoring manifested was on site of a cardiac arrest, where volunteers had practiced or routinely been on calls together. Although the local text message participants expressed that it was to their advantage that they knew each other well within the groups, none of the other participants saw this as a disadvantage for them.

> *"The times we've been out [on alarm calls], we've learned how we're supposed to work together and practiced the routines around what you do, that is time saved."* - **P3**
> *"... and we don't talk about it, we're just going, because we've practiced this on our courses. You know, we've been rolling around on the floor and climbing under all sorts of stuff, because patients rarely just collapse in the middle of the room."* - **P13**

Geographical areas were also portrayed in terms of population density and addressed as urban or rural. For example, **P7** mentioned feeling more responsible to respond in less populated and local areas due to a lower number of volunteers, but s/he also pointed out that s/he did not perceive this as a flaw of the scheme itself. Traffic flow and population density was also mentioned, as these would impact the response time from receiving the alarm to arriving on the site of the suspected cardiac arrest. In line with this, participants argued that slower EMS/ambulance response times motivated locals in rural areas to engage more in the scheme, e.g. *"I believe that smaller communities are in extra need of these services ... because the response time [ambulance] is longer"* **P6**.

5.4 Safety and Role Assignment

While safety and familiarity played important roles for the geographical areas, we further found other dimensions of safety, and in particular perceived safety was stressed by all 16 participants as a crucial element when conducting this type of volunteer work. For participants this meant having the right equipment, that private insurance would cover you in case you injured yourself or made damage to possessions, or even in cases of 'do not resuscitate' legal

Table 2: Table of key and illustrative findings for each theme.

Motivations and Expectations	Participants' emotions concerning receiving alarms were characterized by contradictions; they were excited to put their training to use, but they sadly knew it also meant that a person was in a life-threatening situation.
	Many participants experienced doubts about whether other volunteers are motivated for extrinsic reasons, such as being perceived as 'heroes' or even out of morbid curiosity.
Responding to Alarms and Returning to Life	Participants expressed two imminent considerations when receiving an alarm; First, that current activities could be responsibly left in a hurry. Secondly, that their competences were not imparied e.g. by any amount of alcohol consumption or showing symptoms of illness.
	Most participants stated that for debriefing, local SMS volunteers lean on their community of volunteers and the app volunteers rely more on their personal network. While the local schemes pointed to their model as a clear advantage, the app participants didn't express a lack of debriefing.
Area and Familiarity	Most participants were aware of the fact that they are often called to respond in familiar areas, and therefore it is likely that they may risk knowing the patient.
	Some participants expressed a stronger obligation to respond in rural areas due to a lower volunteer pool, but also due to the fact that ambulance response times are often longer.
Safety and Role Assignment	Most participants emphasized that one thing they feared was being the sole responder to a cardiac arrest, as the many tasks and physical strain was too demanding for one person.
	Some participants expressed that they feel more comfortable with certain tasks, e.g. providing psychological first-aid or CPR - as such participants assigned roles ad-hoc based on their knowledge of other volunteers' strengths. However, there was no transparency on these decisions between volunteers prior to arriving on site.
Technology Opportunities and Challenges	Although not an explicit demand, all participants had changed their habits around mobile phone use after signing up to volunteer e.g. frequent charging, phone always nearby, notification settings.
	Some participants had experienced technical difficulties e.g. GPS coordinates not updating frequently enough to have a correct overview of available nearby heart runners or had experienced receiving the wrong address or none at all. Although mobile navigation and positioning via GPS are crucial elements.

measures (as mentioned by **P4**), as well as managing and overcoming guilt from non-response. But the single most important aspect of safety and being insecure was the experience (and thought) of being the only volunteer on site of a cardiac arrest, as illustrated by **P13**: *"It's incredibly comforting that we're a group, because then you don't have to be on your own with this..."* and *"... Their fear is not that they are called on [to run], but that they arrive as the only one"* (on new volunteers in particular). Being alone in such a situation was considered mentally, but also physically demanding. Several of the participants argued that administering CPR is hard work and rotation between volunteers is usually needed. **P10** stressed that it was not unusual to have to administer CPR to someone who was almost double their own weight and usually after five minutes s/he needed a break. But also, being alone at the site made it difficult or even impossible to carry out all the different tasks that are necessary beyond the actual CPR, which was illustrated by **P13** in this way: "*the difficult part is not the 30 pushes of chest compression and two mouth-to-mouth breathing, the difficult part is to work effectively together ... what does the first person do, and what does the second person, but also where do you put the cars - small practical problems that actually means a lot ...*"

While the app-based schemes only send alarms to 20 volunteers at a time. Some of the local text message groups have had to set up rules for how many volunteers should be on site, as the entire local volunteer pool receives alarms simultaneously. e.g. **P2** mentions that they locally agreed on five volunteers in total, while **P3, P4, P9, P13** mentioned that it's not clearly agreed upon beforehand. **P13** express a very organized approach depending on whether volunteers arrive first, second or fifth, etc. To accommodate several people working together during alarms, participants assigned roles to themselves and others - usually based on shared experiences from previous alarms. As an example, **P9** (text-message) mentioned that s/he was aware that two local volunteers (a couple) were hospital staff and both had professional healthcare equipment that they usually brought along when called for an alarm. S/he also told that one was an incredibly fast runner, whereas the other would often follow in car or on bike with the equipment. Additionally, **P6** (app) recalled an experience where s/he recognized that two volunteers were already administering CPR, so instead s/he comforted the patient's wife. **P6** further emphasized that s/he did not feel inadequate in this situation, although there was no hands-on contact with the patient. On the contrary, one somewhat mocking role assigned by **P7** underlined how s/he got the impression that some people craved to assume the "*hero*" role, liked to be "*where the action is*", or "*be acknowledged*". Additionally, some expressed a desire to be first on site to work directly with administering CPR (e.g.**P13**). As they admitted, that the rush of adrenaline when receiving an alarm could be a little exciting - *"... because we all get this adrenaline kick, which makes us somehow excited ..."* - **P13**. But also because they expressed that they have confidence in their competences in managing the situation.

While all app volunteers have to accept or reject alarms and to respond whether to bring a defibrillator, there is no transparency on these decisions between volunteers prior to arriving on site. For the text message schemes no response is required, however for the local group of **P3** they had implemented their own system of responding within the group on a private chat with a thumbs up for *"on the way"* and a heart for *"bringing a defibrillator"*. Meanwhile, one participant (**P6**) suggested a functionality to be implemented in the app that would provide transparency of volunteers, in the form of a counter. Despite this, **P14** acknowledged that in the rare case that no one responded it would be a disadvantage. Additionally, it would not be transparent across schemes how many volunteers in total would show up and if some non-registered bystanders had stepped in while the volunteers where on their way, *"... you can sometimes feel guilty for having signed up for this ... I may be a little cynical, but you need time off once in a while and I am not employed [in the scheme]..."* **P14**

While the focus in our study was not on COVID-19, it became inevitable to talk about the effects of the global pandemic on the heart runner schemes and the associated volunteer work. Perhaps somewhat surprisingly, only one participant (**P1**) had deliberately declined alarm calls during the pandemic due to being a person with increased risk. All participants had received information on COVID-19 guidelines, and some of them had modified or changed the way they handled alarms. Nine participants had become more reluctant to provide assisted breathing (mouth-to-mouth), more aware of washing and/or sanitizing often and properly before arriving and upon returning to not expose other people (in the household). But three of the participants had not implemented any changes to their practice and they were rather skeptical about the provided guidelines, as they argued that if not all usual measures were taken patients would not get the best possible resuscitation effort. That being said, **P5** who worked as a paramedic, questioned the effect of volunteers' access to safety measures as s/he was used to wearing a great deal of professional safety equipment in their daily work.

5.5 Technology Opportunities and Challenges

Despite our expectations there seem to exist no explicit rules or guidelines for volunteers in regard to mobile phone use in order to be available. All participants express that as the work is volunteer work, it is counterproductive to dictate changes that intervene with their personal lives. However, all participants mentioned that they had experienced a change in habits around use of the mobile phone after volunteering in order to be easier to reach at all times, e.g. always charged (**P8**) or always carried with them or set up to ignore *"do not disturb"* modes at night (**P9**). On the other hand, for events where phone alarms were not considered appropriate participants used simple strategies, for example, phone in flight mode when attending class (**P11, P14**), or simply blocking the number where text messages were received for going on vacation or taking breaks from the scheme for whatever reason.

Interestingly, one participant mentioned using technologies on the site of a cardiac arrest (besides a defibrillator). The local group of **P2** was instructing each other to use a CPR-tempo app; *"... There are always three-four smartphones around the patient."*. Other participants relied on the help program in defibrillators that guide the user both in administering defibrillation but also in monitoring the pulse and the quality of the CPR administered (pressure, frequency). While **P7**, who was also a local first aid instructor, urged volunteers to keep it as simple as possible in order not to let technologies distract from intervening.

Participants expressed that the information received in connection with an alarm is short and simple across all schemes, it will usually display an address with a hyperlink to a map and for the text message schemes additionally, the current condition of the patient e.g. unconscious, abnormal breathing. All participants were satisfied with the amount of information received. Although, participants had on a few occasions experienced that the address was incorrect or that a hyperlink was missing and they had to look up the address themselves. For example, **P2** recalls a situation where the received address was not actionable, as the call was received from a stretch of country road with no nearby buildings or houses. 10/16 participants critiqued the navigation feature across schemes, as they would like the opportunity to choose the transportation form, to more accurately display convenient routes. Illustrated by **P6** who emphasized that some routes could be easier navigated while biking or on foot than by car.

The biggest difference between schemes is the use of either app or text message to send alarms and whether or not volunteers were located via GPS or not. Participants repeatedly stressed that for this highly time-sensitive task it is vital that the technology is working correctly. For the interviews prior to the national implementation of the app-based scheme, text message participants voiced concerns and assumptions about the GPS technology, as they had read on social media forums or discussed among themselves that GPS was not working as intended. After the implementation, we interviewed eight participants where three had signed up for both schemes and thus experienced these issues first-hand (**P10, P12, P13**). All three had experienced GPS not updating frequently enough to be reliable, as **P10** experienced a shocking 25 minute delay from initial text-message to app-notification to an alarm regarding their neighbor - at the time of the app-notification an emergency helicopter had already arrived. **P12** experienced that when opening the app to accept the alarm, the GPS signal updated to their current position and consequently disappeared as it was too far from the originally registered position. Despite these accounts, none of the participants from the app-based schemes experienced being consistently delayed. **P11** mentioned having heard about problems with the app, but have not experienced them, but **P16** had experienced being guided to the wrong address by the app. Participants stressed often that on site all volunteers must work together regardless of affiliation, **P10** mentions aiding *"our colleagues from the app"*. **P13** adds that it must never come down to *"us versus them"*, but express a commonly noted worry that the app-based schemes are not adequately equipped to take care of the individual volunteer in the same way that local text message groups do.

6 DISCUSSION

Committing to availability through mobile technology has been a central point for this study, as previous studies have centered on non-response in connection with volunteering to be called for delivering first aid. We present the ways availability is argued temporally and spatially, as well as the role we imagine establishing volunteer communities may have on individual increased safety.

6.1 Extending Existing Framework of Temporal Barriers to Respond

Ozcan et al. conducted a simulated study of volunteer responders and constructed a temporal framework based on their work including commitment, notification, leave, and perform [21]. Our study compliments this work, primarily on frequency of alarms and perceived readiness, negotiating micro-boundaries and what role technology play in this negotiation as well as introduce an additional temporal barrier that emerged from our findings. Our findings indicate a relation between frequency of alarm calls and perceived readiness, as infrequent alarm calls would cause participants to have a heightened awareness of the lack of alarms received. Whereas alarm calls clustering on a daily or weekly basis would leave participants exhausted and more prone to consider not responding. Our findings underscores that the frequency of alarm calls introduced in the study by [21] was disproportionately higher than our responder initiatives, potentially introducing a higher level of response fatigue. That being said, factors like population density, socio-demographic composition, etc. may be factors in the frequency of cardiac arrests and is not easy to generalize to all geographical contexts. Although all our participants emphasized that they were not *"on call"* and that response was completely voluntary, we noticed that non-responses (rejecting alarms or missing alarms) would sometimes provoke feelings of guilt. In line with Mattern et al. [20] and Pielot and Rellot [22], our findings show that social expectations of availability do exist, in particular within local groups. However, it was also evident that participants had a clear perception that *someone* would always respond, that non-response is status quo and that volunteer response is an addition to existing EMS response. This comes up when volunteers negotiate micro-boundaries for when they are available to respond, similar to the study by Ding et al. [10]. In contrast to ([4, 21, 24]) which assert that barriers related to receiving notifications was by far the most eventful, our findings point instead towards barriers related to leaving current engagements. In line with Ozcan et al., we believe that the two have very different design implications [21]. In contrast to the suggestion made by Ozcan et al. to implement functionality of marking time slots when the individual volunteer is not available, our findings showed that manual, low-tech solutions were utilized successfully for this purpose. Our Findings show that it is rarely a pre-determined time frame of availability, but rather a situational judgement and in worst case time boxing features can increase volunteers' *fear of missing out* and add to non-response guilt if informed of missed calls by other volunteers.

Our findings seem to point to an additional element compared to the framework of Ozcan et al. that introduces a fifth temporality - after responding and upon returning to what you were previously engaged in. This is afforded by our study design, as simulated alarm calls do not cover all temporalities of the framework. Here lies interesting implications both for response and non-response for debriefing practices, where technologies may play a role in accommodating non-response guilt.

6.2 The Implications of Area and Familiarity on Availability

While Ozcan et al. indicate some spatial and geographical aspects, we identify two dimensions related to this. First, we argue that familiarity with an area and understanding of local traffic flow have an impact on response. Secondly, how technologies currently incorporate distance and how this conflicts with how volunteers understand distance. These understandings have the potential to lead to better design of technologies that support increased perceived and actual availability to respond timely.

Our findings showed that participants emphasized how they felt better equipped to respond in areas they were familiar with. In areas where volunteers were less familiar, they were more dependent on mobile technology for way-finding and locating defibrillators. The navigational features are therefore essential to the volunteers. Despite that, our findings show a request to have navigational features be more customizable to transportation forms, while still taking into account that the circumstances are time-sensitive and the interaction must be accordingly fast. As our findings suggest that most transportation is done by car, real-time traffic information could be ideal for route planning. Additionally, some major technical issues in regard to updating GPS position across operating systems have already been reported but still presents as a critical concern. As opposed to findings from [5], showing that app notifications (utilizing GPS) were preferred over SMS.

A core difference between the schemes is how distance is built into the technologies. For the app-based schemes relying on GPS, volunteers are called based on their proximity to the cardiac arrest, while the text message volunteers are called based on their local affiliation. Our findings show that when participants speak of distance, many other factors than proximity are crucial. Two important factors are EMS/ambulance response time and population density. The local schemes, in particular, voiced concerns that the way the app-based schemes considers distance presents a different reality than the one they are facing in more rural areas with a low population-density. From spring 2020, the app-based scheme features nationwide coverage. If the goal is to consider a uniform national effort towards responding to out-of-hospital cardiac arrest, this is one of the main reasons why participants are unwilling to adopt this.

6.3 Increasing Individual Safety Through Establishing Communities

A key finding for this study was, what volunteers feared most of all is to be the sole responder on site, as many diverse tasks are imminent and CPR is physically straining. In response to this, we highlight findings concerned with assigning roles and imagining means to increase individual safety.

Our findings revealed that mainly on-site but also prior to response, informal roles are assigned to volunteers. Some volunteers are fast runners for fetching defibrillators or arriving first on site to gain an overview, while others are good at administering CPR and checking vital signs, some due to a health professional background some from a lot of experience. Not least, some are very good at providing psychological first aid and comforting both bystanders and fellow volunteers. One volunteer may be assigned multiple roles, but some feel most comfortable in the same role. The local schemes expressed a higher awareness of fellow volunteers and their preferred role and underlined this as an advantage on-site. They have often engaged in first aid courses, scenario drills and socializing together, in comparison to the app-based schemes. The now discontinued DRL-scheme (app-based) operated in a sort of geographically determined cluster formation not unlike the local schemes, however the participant (**P7**) who was head of their local cluster expressed that it was mainly for administrative reasons. While other participants from the app-based scheme mentioned social media, it was never accentuated as an essential part of their volunteer experience.

We argue that these group formations and communities may come to play an essential part in networking with other volunteers and keeping up to date with first aid competences, to increase confidence to intervene, familiarity with preferred roles and perceived safety on-site.

6.4 Implications and Future Work

Based on our work and also previous research, we see a number of implications for heart runner schemes. In the following, we consolidate our findings by listing three implications and future work directions. These include volunteer qualifications, transportation and navigation, and organization between schemes.

First, we saw that our participants were split on whether volunteers should undergo more rigorous validation of their qualifications, for example their first aid competences, or whether schemes should continue to be highly trust-based with few demands or requirements as a trade-off in order to ease central administration tasks, but also to maximize the volunteer pool.

Secondly, we saw that transportation and navigation when responding to an alarm was both a conceptual and implementation issue for the participants. In fact, participants knowledge and perception of distance in urban and rural areas affects how the schemes should assign volunteers, as more than just proximity defines volunteer availability to respond. Future work could investigate navigation that is better suited for certain modes of transportation, for example by considering how to relay real-time traffic information.

Thirdly, we saw that volunteers with different scheme affiliations may result in conflicts or misunderstandings partly due to the fact that these schemes currently co-exist. While some participants had strong opinions on their scheme preference, they would like to see more collaborations between schemes or even a uniform model where the local experiences and differences are better accounted for, e.g. community building or role assigning. Future work may study what functionalities from different schemes may be implemented into either a uniform scheme and how these translate from local scale to national scale. One example is whether transparency of response can be disclosed to other volunteers. One such instance is mentioned by Ozcan et al. in the form of a suggestion of a system pairing up volunteers to augment actual safety[21]. For role assignment, we encourage future work to specify the different existing roles, with inspiration from *e.g.* [15]. We see the potential for these suggestion and implore future work to envision these types of functionalities. Another challenge for future work will be how to accommodate non-response guilt and who has this responsibility.

6.5 Limitations

We acknowledge that this study has limitations in the fact that we have no control over alarm calls received, although we also view this is a great strength. However, it presents itself as a weakness in the form of potential recall bias, as we did not inquire about the duration from the last alarm call received and some participants have had to recall experiences. While it would have been interesting to study responders in-situ or as a participant, we could not defend this ethically. Additionally, a large part of our participants hold key positions in their local groups with regard to administration and planning and have in most cases constituted these. They may hold different perspectives than participants who are not as engaged with these tasks, but we don't have sufficient empirical evidence that this is the case. Geographically, our recruitment did not represent a national coverage and is not directly generalizable to all areas of Denmark. We imagine that there can be differences on schemes that cover variations on rural or coastal areas and schemes that cover capitol or dense urban areas.

7 CONCLUSION

For this study we interviewed 16 volunteer responders across different heart runner schemes, to investigate how they organize themselves through mobile technologies and the consequences of being available anytime, anywhere. We found that temporal (anytime), as well as spatial (anywhere) aspects play key roles for volunteers. We argue that social expectations of availability exist within these initiatives and distrust in motivations and commitment exist both within, but in particular across schemes. We extend previous frameworks for similar volunteer initiatives, supplementing barriers to response concerning returning to (everyday) life. We also conclude on how familiarity with a (local) area impacts volunteers barriers of response, in particular how current navigation features often conflicts with practice. Additionally, we empirically underscore the role of community in heart runner volunteer initiatives. We urge future research to engage in imagining suitable community-building features on- and offline to encourage volunteers to feel prepared for, and confident in, taking on emergent, urgent and collaborative tasks.

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REFERENCES

[1] American Heart Association. 2019. *American Heart Association Annual Report: 2018-2019.* Technical Report. http://www.heart.org/idc/groups/heart-public/@wcm/@cmc/documents/downloadable/ucm{_}490853.pdf

[2] Linn Andelius, Carolina Malta Hansen, Freddy K. Lippert, Lena Karlsson, Christian Torp-Pedersen, Annette Kjær Ersbøll, Lars Køber, Helle Collatz Christensen, Stig Nikolaj Blomberg, Gunnar H. Gislason, and Fredrik Folke. 2020. Smartphone Activation of Citizen Responders to Facilitate Defibrillation in Out-of-Hospital Cardiac Arrest. *Journal of the American College of Cardiology* 76, 1 (jul 2020), 43–53. https://doi.org/10.1016/j.jacc.2020.04.073

[3] Jakob E. Bardram, Mads Frost, Károly Szántó, Maria Faurholt-Jepsen, Maj Vinberg, and Lars Vedel Kessing. 2013. Designing Mobile Health Technology for Bipolar Disorder: A Field Trial of the MONARCA System. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13.* ACM Press, New York, New York, USA, 2627. https://doi.org/10.1145/2470654.2481364

[4] Steven C. Brooks, Graydon Simmons, Heather Worthington, Bentley J. Bobrow, and Laurie J. Morrison. 2016. The PulsePoint Respond mobile device application to crowdsource basic life support for patients with out-of-hospital cardiac arrest: Challenges for optimal implementation. *Resuscitation* 98 (jan 2016), 20–26. https://doi.org/10.1016/j.resuscitation.2015.09.392

[5] Maria Luce Caputo, Sandro Muschietti, Roman Burkart, Claudio Benvenuti, Giulio Conte, François Regoli, Romano Mauri, Catherine Klersy, Tiziano Moccetti, and Angelo Auricchio. 2017. Lay Persons Alerted by Mobile Application System Initiate Earlier Cardio-Pulmonary Resuscitation: A Comparison with SMS-based System Notification. *Resuscitation* 114 (may 2017), 73–78. https://doi.org/10.1016/j.resuscitation.2017.03.003

[6] Marta E. Cecchinato, Anna L. Cox, and Jon Bird. 2017. Always On(line)? User Experience of Smartwatches and their Role within Multi-Device Ecologies. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems,*

Vol. 2017-May. ACM, New York, NY, USA, 3557–3568. https://doi.org/10.1145/3025453.3025538
[7] Victoria Clarke, Virginia Braun, and Nikki Hayfield. 2015. Thematic analysis. *Qualitative psychology: A practical guide to research methods* (2015), 222–248.
[8] Pooja M. Desai, Elliot G. Mitchell, Maria L. Hwang, Matthew E. Levine, David J. Albers, and Lena Mamykina. 2019. Personal Health Oracle: Explorations of Personalized Predictions in Diabetes Self-Management. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*. ACM Press, New York, New York, USA, 1–13. https://doi.org/10.1145/3290605.3300600
[9] Virginia Dickson-Swift, Erica L James, Sandra Kippen, and Pranee Liamputtong. 2009. Researching sensitive topics: Qualitative research as emotion work. *Qualitative research* 9, 1 (2009), 61–79.
[10] Xianghua Ding, Yunan Chen, Zhaofei Ding, and Yiwen Xu. 2019. Boundary Negotiation for Patient-Provider Communication via WeChat in China. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (nov 2019), 1–24. https://doi.org/10.1145/3359259
[11] Pin Sym Foong, Shengdong Zhao, Felicia Tan, and Joseph Jay Williams. 2018. Harvesting Caregiving Knowledge: Design Considerations for Integrating Volunteer Input in Dementia Care. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, Vol. 2018-April. ACM Press, New York, New York, USA, 1–12. https://doi.org/10.1145/3173574.3173653
[12] Andrés Lucero. 2018. Living Without a Mobile Phone: An Autoethnography. In *Proceedings of the Designing Interactive Systems Conference 2018 - DIS '18*. ACM Press, New York, New York, USA, 765–776. https://doi.org/10.1145/3196709.3196731
[13] Gloria Mark, Stephen Voida, and Armand Cardello. 2012. "A pace not Dictated by Electrons": An Empirical Study of Work Without Email. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. ACM Press, New York, New York, USA, 555. https://doi.org/10.1145/2207676.2207754
[14] Melissa Mazmanian and Ingrid Erickson. 2014. The Product of Availability: Understanding the Economic Underpinnings of Constant Connectivity. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*. ACM Press, New York, New York, USA, 763–772. https://doi.org/10.1145/2556288.2557381
[15] Andrew D. Miller, Sonali R. Mishra, Logan Kendall, Shefali Haldar, Ari H. Pollack, and Wanda Pratt. 2016. Partners in Care: Design Considerations for Caregivers and Patients During a Hospital Stay. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work and Social Computing* (San Francisco, California, USA) *(CSCW '16)*. Association for Computing Machinery, New York, NY, USA, 756–769. https://doi.org/10.1145/2818048.2819983
[16] Sonali R. Mishra, Predrag Klasnja, John MacDuffie Woodburn, Eric B. Hekler, Larsson Omberg, Michael Kellen, and Lara Mangravite. 2019. Supporting Coping with Parkinson's Disease Through Self Tracking. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*. ACM Press, New York, New York, USA, 1–16. https://doi.org/10.1145/3290605.3300337
[17] Thea Palsgaard Møller, Carolina Malta Hansen, Martin Fjordholt, Birgitte Dahl Pedersen, Doris Østergaard, and Freddy K. Lippert. 2014. Debriefing Bystanders of Out-of-Hospital Cardiac Arrest is Valuable. *Resuscitation* 85, 11 (nov 2014), 1504–1511. https://doi.org/10.1016/j.resuscitation.2014.08.006
[18] Occupational Safety and Health Administration U.S. Department of Labor. 2017. Cardiac Arrest and Automated External Defibrillators (AEDs). https://www.osha.gov/dts/tib/tib{_}data/tib20011217.html
[19] Erick Oduor, Carolyn Pang, Charles Wachira, Rachel K.E. Bellamy, Timothy Nyota, Sekou L. Remy, Aisha Walcott-Bryant, Wycliffe Omwanda, and Julius Mbeya. 2019. Exploring Rural Community Practices in HIV Management for the Design of Technology for Hypertensive Patients Living with HIV. *DIS 2019 - Proceedings of the 2019 ACM Designing Interactive Systems Conference* (2019), 1595–1606. https://doi.org/10.1145/3322276.3322348
[20] Erick Oduor, Carolyn Pang, Charles Wachira, Rachel K. E. Bellamy, Timothy Nyota, Sekou L. Remy, Aisha Walcott-Bryant, Wycliffe Omwanda, and Julius Mbeya. 2019. Exploring Rural Community Practices in HIV Management for the Design of Technology for Hypertensive Patients Living with HIV. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. ACM, New York, NY, USA, 1595–1606. https://doi.org/10.1145/3322276.3322348
[21] Kerem Ozcan, Dawn Jorgenson, Christian Richard, and Gary Hsieh. 2017. Designing for Targeted Responder Models: Exploring Barriers to Respond. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*. ACM, New York, NY, USA, 916–924. https://doi.org/10.1145/2998181.2998334
[22] Martin Pielot and Luz Rello. 2017. Productive, Anxious, Lonely - 24 Hours Without Push Notifications. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services*. ACM, New York, NY, USA, 1–11. https://doi.org/10.1145/3098279.3098526 arXiv:1612.02314
[23] Rebecca A. Kuehl;Jenn Anderson. 2015. Designing Public Communication about Doulas: Analyzing Presence and Absence in Promoting a Volunteer Doula Program. *Communication Design Quarterly* (2015). http://delivery-acm-org.ez54.periodicos.capes.gov.br/10.1145/2830000/2826979/p75-kuehl.pdf?ip=200.130.19.182{&}id=2826979{&}acc=ACTIVESERVICE{&}key=344E943C9DC262BB.0F5B8E3859CA5567.4D4702B0C3E38B35.4D4702B0C3E38B35{&}{_}{_}acm{_}{_}=1537233884{_}04e53bab82a3fe35b
[24] Mattias Ringh, Mårten Rosenqvist, Jacob Hollenberg, Martin Jonsson, David Fredman, Per Nordberg, Hans Järnbert-Pettersson, Ingela Hasselqvist-Ax, Gabriel Riva, and Leif Svensson. 2015. Mobile-phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest. *New England Journal of Medicine* 372, 24 (2015), 2316–2325.
[25] Ana-Maria Salai and Lynne Baillie. 2019. A Wee Bit More Interaction: Designing and Evaluating an Overactive Bladder App. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*. ACM Press, New York, New York, USA, 1–14. https://doi.org/10.1145/3290605.3300933
[26] Laura Sarkisian, Hans Mickley, Henrik Schakow, Oke Gerke, Gitte Jørgensen, Mogens Lytken Larsen, and Finn Lund Henriksen. 2020. Global Positioning System Alerted Volunteer First Responders Arrive Before Emergency Medical Services in More than Four out of Five Emergency Calls. *Resuscitation* 152 (jul 2020), 170–176. https://doi.org/10.1016/j.resuscitation.2019.12.010
[27] Jessica Schroeder, Chelsey Wilkes, Kael Rowan, Arturo Toledo, Ann Paradiso, Mary Czerwinski, Gloria Mark, and Marsha M. Linehan. 2018. Pocket Skills: A Conversational Mobile Web App to Support Dialectial Behavioral Therapy. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. ACM Press, New York, New York, USA, 1–15. https://doi.org/10.1145/3173574.3173972
[28] Mikael B. Skov, Pauline G Johansen, Charlotte S Skov, and Astrid Lauberg. 2015. No News is Good News: Remote Monitoring of Implantable Cardioverter-Defibrillator Patients. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, Vol. 1. ACM Press, New York, New York, USA, 827–836. https://doi.org/10.1145/2702123.2702192
[29] Charlotte Tang, Yunan Chen, Bryan C. Semaan, and Jahmeilah A. Roberson. 2015. Restructuring Human Infrastructure: The Impact of EHR Deployment in a Volunteer-Dependent Clinic. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*. ACM Press, New York, New York, USA, 649–661. https://doi.org/10.1145/2675133.2675277
[30] Jenny Waycott, Greg Wadley, Stefan Schutt, Arthur Stabolidis, and Reeva Lederman. 2015. The Challenge of Technology Research in Sensitive Settings: Case Studies in 'Sensitive HCI'. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI '15*. ACM Press, New York, New York, USA, 240–249. https://doi.org/10.1145/2838739.2838773
[31] Mads Wissenberg, Freddy K. Lippert, Fredrik Folke, Peter Weeke, Carolina Malta Hansen, Erika Frischknecht Christensen, Henning Jans, Poul Anders Hansen, Torsten Lang-Jensen, Jonas Bjerring Olesen, Jesper Lindhardsen, Emil L. Fosbol, Søren L. Nielsen, Gunnar H. Gislason, Lars Kober, and Christian Torp-Pedersen. 2013. Association of National Initiatives to Improve Cardiac Arrest Management With Rates of Bystander Intervention and Patient Survival After Out-of-Hospital Cardiac Arrest. *JAMA* 310, 13 (oct 2013), 1377. https://doi.org/10.1001/jama.2013.278483
[32] Jolande A. Zijlstra, Stefanie G. Beesems, Rob J. De Haan, and Rudolph W. Koster. 2015. Psychological Impact on Dispatched Local Lay Rescuers Performing Bystander Cardiopulmonary Resuscitation. *Resuscitation* 92 (jul 2015), 115–121. https://doi.org/10.1016/j.resuscitation.2015.04.028
[33] Jolande A. Zijlstra, Remy Stieglis, Frank Riedijk, Martin Smeekes, Wim E. van der Worp, and Rudolph W. Koster. 2014. Local Lay Rescuers with AEDs, Alerted by Text Messages, Contribute to Early Defibrillation in a Dutch Out-of-Hospital Cardiac Arrest Dispatch System. *Resuscitation* 85, 11 (nov 2014), 1444–1449. https://doi.org/10.1016/j.resuscitation.2014.07.020

PAPER 4: E-SCOOTER SUSTAINABILITY – A CLASH OF NEEDS, PERSPECTIVES, AND EXPERIENCES

Authors:

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Abstract:

Electric stand-up scooters (e-scooters) are introduced in several cities worldwide, providing new means for people to travel around the city. While praised for their flexibility, e-scooters are also met with negative sentiments due to fatal accidents and chaotic parking. In this paper, we seek to understand the mobility of shared e-scooters and point to gaps in the user interaction between the digital and physical world. We carried out three data collections, including interviews, *in situ* observation, analysis of news media coverage. Our findings illustrate integration with alternate modes of transportation in urban context, and how technologies facilitate or hinder (micro-) mobility. We found that users of e-scooters primarily view these devices as an alternative to walking rather than other transportation forms. Additionally, we found that users' and non-users' needs, perspectives and experiences of e-scooters clash, in particular with regard to perceptions of sustainability. Based on these findings, we present three relevant perspectives of sustainability, extending the ongoing debate of sustainable HCI research. We contribute with an empirically supported understanding of the perception of mobility and sustainability for e-scooters in a Scandinavian urban context.

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