




Going Car-free: Investigating Mobility Practice Transformations and the Role of ICT

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Abstract: With the debates on climate change and sustainability, a reduction of the share of cars in the modal split has become increasingly prevalent in both public and academic discourse. Besides some motivational approaches, there is a lack of ICT artifacts that successfully raise the ability of consumers to adopt sustainable mobility patterns. To further understand the requirements and the design of these artifacts within everyday mobility adopted a practice-lens. This lens is helpful to get a broader perspective on the use of ICT artifacts along consumers' transformational journey towards sustainable mobility practices. Based on 12 retrospective interviews with car-free mobility consumers, we argue that artifacts should not be viewed as 'magic-bullet' solutions but should accompany the complex transformation of practices in multifaceted ways. Moreover, we highlight in particular the difficulties of appropriating shared infrastructures and aligning own practices with them. This opens up a design space to provide more support for these kinds of material-interactions, to provide access to consumption infrastructures and make them usable, rather than leaving consumers alone with increased motivation.

1 INTRODUCTION


Against the background of climate change and common transport-related problems such as noise, congestion, and air pollution, a change in the nature and extent of car use is necessary (Hasselqvist et al., 2016). Although the private car offers high flexibility and comfort (Şimşekoğlu et al., 2015), it is rather unsustainable compared to public transport alternatives (Wright and Fulton, 2005; Girod et al., 2013).


However, according to Kemp and van Lente (2011) changing consumption patterns towards such sustainable modes "include[s] two challenges: on the one hand a long-term change to various technologies and infrastructures, while on the other hand ensuring that consumer criteria change in the same move". The development of new infrastructures and technologies related to low-emission vehicles and sustainable modes of transport is an ongoing challenge addressed by various parties. However, supporting consumers to


change their consumption practices is an often overlooked challenge (Kemp and van Lente, 2011).

Research already explored such transformations of consumption practices for other domains (Twine, 2018) and highlighted the opportunities of ICT to support consumers (Lawo et al., 2020). For mobility, such a practice-based HCI focus is missing. Here, "research on mobility and transport has been dominated by a focus on the automobile" (Glöss et al., 2020) or the use of a motivational lens (Anagnostopoulou et al., 2018). For public transport, there is very little ethnographic research on ICT use in HCI, according to Wulf et al. (2019). Therefore, there is a lack of an understanding of how ICT artifacts can facilitate and simplify more sustainable mobility practices beyond motivational aspects only.

Research Gap: Designing artifacts to support the transformation of consumers' practices and the adoption of new modes of transport, requires a more nuanced understanding of consumer trajectories. Therefore, we address the research question of "How consumers appropriate car-free multimodal mobility practices and which role ICT artifacts play?".

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To answer this research question, we conducted a qualitative study with 12 participants using semi-structured interviews. The focus was on consumers' narratives about their car-free practice transformation journey and the associated ICT use. Similar to other other research on sustainable practices, we interviewed consumers who had already changed their habits as a source of knowledge about the difficulties and how they have addressed them (Lawo et al., 2020). We used as a practice-theoretical lens (Entwistle et al., 2015) to understand the role of ICTs and their relationships with infrastructures and practices.

From this retrospective perspective, our findings show how the appropriation of sustainable mobility practices comes with a tinkering into new practices rather than a motivational process only. Participants use ICT artifacts that mediate between their own practices and the inherit schedule of the infrastructures they use. This perspective on sustainable practices contributes to the design of ICT artifacts, by, on the one hand, presenting the dynamic needs of consumers for infrastructure-related practices that can be addressed by designers, but, on the other hand, also by critically reflecting on the role of ICT and the boundaries of design solutions.

2 RELATED WORK

2.1 From Car Dependency to Multimodal Mobility

One of the main drivers of consumption related carbon emissions is transport. It is responsible for about one third of the energy consumption in western societies (Gabielli et al., 2014). Especially private motorized transport plays a particularly problematic role (Miehe et al., 2016). In contrast to public transport and shared mobility, the private car is less environmentally friendly and less resource-efficient (Girod et al., 2013). Nonetheless, the car is still the number one mode of transport and it is even considered to be growing in ownership (Wright and Fulton, 2005).

The car plays an important role in the modal split of many people because it offers a certain freedom. Urry (2004) stated that a large part of social life would even not be possible without the flexibility of the car and its 24-hour availability. The modal split describes the extent to which certain modes of transport are used. In the context of personal mobility, it can be considered equivalent to the individual choice of transport mode. It therefore provides information about consumers' mobility behavior from an abstract

perspective on their daily mobility patterns (Qu et al., 2015).

To be able to address traffic-related problems, the share of motorized individual transport in the modal split must be reduced (Girod et al., 2013). In this context, multimodality means the use of several modes of transport for daily mobility. In order to close this gap, the integration of innovative mobility services, such as public bicycle sharing, into traditional public transport is an important step towards promoting multimodal practices. After all, such practices are only possible if appropriate alternatives to the private car are available. Through this integration, traditional public transport gains flexibility and attractiveness, which are traditionally understood as motivators for car-dependent mobility (Şimşekoğlu et al., 2015). For sustainable mobility, it is therefore crucial to promote walking, cycling and public transport, and to avoid or limit motorized private transport wherever possible.

2.2 Designing ICT for Sustainable Mobility

Over the past decade, HCI research has increasingly focused on the provision and consumption of mobility services (Loos et al., 2020). "However, for various reasons, research has been dominated by the car"(Glöss et al., 2020). Although others modes have received less attention, we find research on public transport (Väänänen et al., 2016), walking (Winstanley et al., 2014), cycling (Reddy et al., 2010), and car or ride-sharing (Brewer and Kameswaran, 2019). Nevertheless, studies on ICT and public transport are still rare (Wulf et al., 2019).

Within this research, *persuasive design* to motivate consumers has been one of the dominant themes. In particular, various prototypes were used to stimulate and motivate sustainable mobility with eco-visualizations, social comparison, and emotional appeals (Anagnostopoulou et al., 2018). These attempts to promote sustainable consumption (DiSalvo et al., 2010) primarily rely on theories of environmental psychology (Froehlich et al., 2010), as well as gamification and persuasiveness (Fogg, 2002). Nevertheless, the focus on motivation has been criticized for having positive short-term impact on behavior change motivation, but no long-term impact (Brynjarsdottir et al., 2012; Dourish, 2010; Maitland et al., 2009; Schwartz et al., 2013, 2015). Along with this critique, research on eco-feedback concludes that it needs to be incorporated into multimodal travel planning and that access to and use of infrastructure is a practical difficulty that is not solved with higher motivation and can even be demotivating (Cellina et al., 2019b,a; Meurer

et al., 2019; Stein et al., 2017). In short, there is a lack of ICT artifacts that successfully support the simplicity and ability to conduct new behaviors (Fogg, 2009).

To overcome this focus on rational consumers that just need to have enough motivation and more broadly consider ability factors (Fogg, 2009), sustainable consumption studies in HCI have used a practice lens (Meurer et al., 2019; Hasselqvist et al., 2016; Hasselqvist and Hesselgren, 2019; Stein et al., 2017). Still, the settings were rather limited by the provision of electric vehicles in urban areas (Hasselqvist et al., 2016), or the provision of a planning platform for the specific group of elderly consumers (Stein et al., 2017; Meurer et al., 2014). Moreover, it lacks a multimodal and public transport perspective (Wulf et al., 2019) that develops an understanding of the role of ICT artifacts and their design.

2.3 Theoretical Framing

To give greater attention to the ability and simplicity factors that facilitate sustainable routines (Fogg, 2009), this research adopts a practice lens that "increase[s] the understanding of the complexity of what influences how we do things and to create support for more sustainable practices" (Hasselqvist et al., 2016).

Practices are the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood" (Reckwitz, 2002). They exist in a context of materials, competences, and meanings (Shove and Pantzar, 2005; Shove et al., 2012). Meanings are the "symbolic meanings, ideas and aspirations" (Shove et al., 2012), e.g. the perception of biking as healthy (Hasselqvist et al. (2016)). Competences are skills and know-how, practical knowledge, or techniques needed (Shove et al., 2012), e.g. knowing the city or which train to catch (Hasselqvist et al. (2016)). Lastly, materials are all "objects, infrastructures, tools, hardware and the body itself" (Shove et al., 2012), e.g. the train, the station or the phone to buy a ticket. In HCI, this lens has been adapted to understand the relationship between infrastructures (shared materials) and ICT artifacts (near/owned material) (Entwistle et al., 2015). Infrastructures can, thereby, be seen as the "entirety of devices, tools, technologies, standards, conventions, and protocols on which [...] the collective rely to carry out the tasks and achieve the goals assigned" (Pipek and Wulf, 2009). From a consumption perspective, this entails the production and distribution mechanisms of consumable goods, that are shaped by shared usage but not steered and controlled by individual consumers (Entwistle et al., 2015). Such mechanisms entail, e.g., the public

transport-system, streets and shared vehicles.

Given the question of how mobility practices transform to a more sustainable state, we have to consider the dynamics of practices as well. In daily consumption routines, the elements are stably connected, creating a kind of equilibrium (Stevens and Pipek, 2018). Still, an imbalance or "crisis of routine" (Reckwitz, 2002) could lead to a dynamic that comes with the appropriation of (proto-) practices and their respective elements (Shove et al., 2012). In the course of dynamic practices, the near materiality of the ICT artifact is also dynamic (Bødker and Klokmoose, 2012), e.g., the acquisition of new artifacts for new situations or the abandonment of artifacts after the practice has stabilized (Lawo et al., 2020). In this sense, it begins with an unsatisfactory state, followed by exploration and testing of new options and ideas (excited state), and finally a new equilibrium in a stable state (Bødker and Klokmoose, 2012).

3 INTERVIEW STUDY

In line with the research question, the goal of our interview study was to understand consumers' car-free practices and the supporting role of ICT artifacts. A particular focus was on comparing different stages of the transformation of mobility practices.

We, therefore, conducted and analyzed 12 (P1-12) interviews (24 - 74 min.) with consumers. The sample was recruited using a snowball sampling approach (Noy, 2008), starting from contacts in the authors' extended social network. The final selection criterion, in terms of purposive sampling (Tongco, 2007), was the renunciation of prior car use. This approach did not aim for a representative sample, but rather a broad and diverse sample in terms of mobility practices, life situations, and personal experiences with practice transformation. This diversity is reflected in the selection of participants (see Table 1). Our sample includes participants living in rural, suburban, urban, and metropolitan areas. In addition, motivations for adopting a multimodal practice range from leaving home, migrating to Germany, moving to another city, and environmental reasons.

The semi-structured interviews (Ayres, 2008) followed an interview guideline that covered (1) the participants' reasons for car abandonment, (2) their current mobility practices, and (3) the transformation of their practices, and (4) the appropriation of ICT for both current and transforming mobility practices. All interviews were transcribed and analysis was conducted by two researchers using the inductive approach of thematic analysis. As an initial tem-

Table 1: Participants.

#	Age	Gender	Education	Residence	Time Car-Free	Modes
P1	25	f	University Degree	Urban	6 years	bike; train
P2	24	m	University Degree	Sub-Urban	few months	bike; bus; train
P3	24	m	University Degree	Urban	3 years	bus; tram
P4	38	m	University Degree	Metropolitan	15 months	bus; train; taxi
P5	23	f	University Degree	Urban	4 years	bus; train; tram
P6	54	f	Middle School	Urban	since 1987	bus; train
P7	25	m	University Degree	Sub Urban/Rural	3 years	bike; bus; train
P8	28	m	University Degree	Metropolitan	2 years	bus; train
P9	30	f	University Degree	Rural	8 years	bus; train; taxi; ride-sharing
P10	32	f	University Degree	Rural	1 year	bus; train
P11	24	f	University Degree	Urban	4 years	bus; train
P12	20	f	High School	Urban	2 years	bus; train

plate for coding (King, 2004), we used the differentiation between pre-, on- and post-trip practices (Rehrl et al., 2007; Kramers, 2014) and the simplified action-theoretically informed constructs of stable practices and unstable practices (Bødker and Klokmoose, 2012). After coding, the codes were consolidated and the themes were developed collaboratively to achieve a mutual understanding of the material.

4 RESULTS

Our 12 participants were either car owners or had access to a car in their family. Accordingly, it can be said of all participants that they were socialized with individual motorized transport practices and carried them out for a certain phase of their lives. Thus, at the beginning of our study, the question arose how a change from car-oriented practices to multimodal practices occurred.

Unlike the change of other practices (Lawo et al., 2020), there was no careful tinkering into the new practices. Instead, all participants faced the challenge of adopting new practices from one day to the next due to a change in the personal situation. Examples of this are moving to a bicycle-friendly or a car-hostile city (P1, P2, P9), their own car breaking down (P4, P7), moving to another country (P8, P10) or even the fear of driving after an accident (P6) or due to a lack of routine (P12). In addition to these disruptive events as a crises of their routines, there are also participants who no longer own a car for financial reasons. It can thus be stated that a change of practice is enforced by a disruptive event, rather than influenced by ICT.

Over the course of practice transformation, consumers appropriated additional meanings. For example, the advantages of car-free mobility, e.g. the possibility of sports and leisure activities (P1, P8, P10), independence from one mode of transport (P1, P10), cost and time savings (P2, P3, P5, P7, P11), environ-

mental protection (P3, P6, P7, P11), efficient use of time (P4, P5, P9) and freedom from car-related worries (P2, P12) come to the fore. Similar meanings are also found in research on small electric vehicle practices (Hasselqvist et al., 2016).

I think it's really important. I mean, you always have your phone with you or you always have a piece of technology with you to check the best route, to check the schedule, to check different things. –P10

While ICT does not play a role as a trigger in our sample, the role of ICT increases with finding oneself in an unsatisfactory state, given by disturbed routines. Thus, participants used artifacts to re-establish stable routines. In the following, we look at the establishment of new routines in the pre-, on- and post-trip practices. In contrast to previous research (Stein et al., 2017; Meurer et al., 2014; Hasselqvist et al., 2016), the focus is on ICT artifacts (near materiality) and infrastructures (e.g. public transport, bicycle lanes, etc.) in relation to the practice transformation. From an analytical point of view, we further distinguish between artifacts that are used to re-stabilize practices, e.g. at the beginning of practice transformation, and artifacts that well established in stable multimodal mobility practices.

4.1 Pre-trip: From Planning Trips to Synchronizing with Infrastructures

4.1.1 Planning the Unseen

At the beginning of the practice transformation, our participants were confronted with a new uncertainty caused by the lack of knowledge about alternative mobility infrastructures.

While the previous use of the car was perceived as something familiar and simple, the new uncertainty had to be resolved by planning the trips in more detail.

"If I wanted to go somewhere, I could just get in my car, look at the GPS and go where I want to go. Now I have to look on the timetable to see, ok, at what time I can go, [...] I wanted to be there at 10, so I have to take the train earlier. [...] what time is the last train or what time do I have to be back so I don't miss the train. So I have to be really conscious with the time." –P10

The planning practices themselves are strongly interwoven with the appropriation and use of new technologies. It is noticeable that mainly the smartphone and partly also a computer are used for planning. Also, Google Maps is one of the most frequently used tools. In addition to information about the available modes of transport, other factors are also included into the planning process. P2, for example, also takes the difference in altitude into account for trips for which a bicycle would in principle be an option.

"If I'm about to do something new now, [...] I would just look on Google Maps on my phone, where is that, or look on my laptop, where is the address?" –P2

Although technology provides access to multi-modal planning and connecting of different mobility infrastructures, participants faced the problem of not finding the best solution directly. This problem seems to be caused by the technologies themselves. For example most apps do not take into account that taking a bike on a train ride could be faster than the subsequent bus. Other issues, arise from non-transparent pricing models, which need workarounds and explorative tactics to find the best price.

"And then I found a solution, but somehow I also tried out different things. First I tried [...] Bicycles that you can just rent [...] That was better [...] But somehow still not so optimal [...] And then I finally found out that you [...] can take your bike on the train for free. [...] And that is now the perfect solution for me to get there quickly. But it took a while to find this solution." –P1

But it is not just infrastructures and modes that need to be explored. Especially in the early stage of practice transformation, participants reported exploring and trying out different apps and technologies to find a suitable solution that worked for them and their information needs. Thereby, they reported that local apps, in particular, often provide better information, such as live transit schedules or the locations of sharing vehicles, while other apps provide a broader overview of cross-regional traveling.

"I also downloaded the [local mobility app] [...], but I've deleted it again because I use this [other local mobility app] and it basically has the same functions. And why should I have two of the same apps on my phone?" –P6

4.1.2 Daily Synchronization

However, all of this effort and exploration is not necessary in the long-term. Once multimodal practices become more stable, e.g. routinely conducted trips and the corresponding infrastructures are better known, participants did not need to use the artifacts that intensively.

However, the technological solution and the corresponding competencies to find a possible connection of modes to get from A to B, once appropriated, remained an integral part of their mobility practices. Although usage generally decreased, new situations, e.g., destination not yet reached, again create some type of instability that needs to be resolved through these technologies and competencies.

"So if I'm looking for an unknown route now, I still check busliniensuche.de to see if there's somehow a bus that goes there cheaply and in a reasonable time." –P11

But similar to the initial trigger of practice transformation, major life changes, such as moving to a new neighborhood or starting a new job, can cause a new instability that requires reflection and application of well-learned patterns to re-stabilize the own mobility routines.

In addition to this repetition of learning about infrastructures, the issue of synchronizing one's schedule and practices with the infrastructure's schedule emerges in long-term pre-trip practices. Here, our participants explained how they learned the departure and arrival times of their most frequently used modes and adjusted their routines to fit the schedule.

Somehow I adjust my timetable, my own timetable to the bus timetable. And that has affected my life, [...] it's just not spontaneous." –P8

This synchronization with the timetable goes hand in hand with another phenomenon, the use of apps to check whether the train or bus is on time. Most participants reported that even though they know the lines very well, they often check the live schedule if they need to hurry to miss the bus, or stay inside a little longer to not wait in the cold.

"Most of the time you don't have to wait that long, but I often check Quando or other

apps to see when the bus is coming and it leaves on time, and it happened to me so many times that the bus has even arrived too early.” –P3

”I usually activate this reminder function, so that you are notified when the train is delayed.” –P11

Again, our participants shared how they tried different solutions to have the best synchronization experience. Through trial and error, they tried different apps to see how up-to-date the data really is and how well the technology actually reflects the infrastructure. Still, a compromise had to be made between artifacts that aggregate multiple transport services but often lack real-time information, and detailed information provided by region-specific artifacts.

”In city C, I used the [local mobility app], [...] because it was somehow more accurate than the DeutscheBahn app. So for cities it’s maybe even better to use their own app because they can provide even better data and not all of them have forwarded that to the DB app.” –P7

Once matching artifacts are appropriated, they remain an integral part of consumers’ multimodal practices. But of course, the need for synchronization depends strongly on the chosen modes. In a situation where they use their bicycle, which can still be considered an individual mode of transport, there is less need to synchronize with the infrastructure. Still, for bicycle trips routines need to be aligned with the weather or the amount of traffic, which requires completely different apps.

4.2 On-trip: From Continuous Optimization to Enjoyment and Efficiency

4.2.1 Continuous Orientation and Optimization

Especially at the beginning of practice transformations, but also in uncertain new situations, our participants show a high need for information about the currently used mode of transport, even on-trip. When the environment is unfamiliar or the mode of transport seems slower than expected, participants reported using the service provider’s app to check for punctuality. They also look for alternatives if they guarantee a faster or safer arrival. This can be seen as a repeated synchronization with the infrastructure.

”To see when the next one is leaving or simply to have alternative routes suggested to

me, if the app then tells me that the bus is canceled, then the app can also tell you how you could [...] get there after all.” –P5

Similar to daily synchronization, the use of artifacts is highly dependent on the chosen modes. When biking or walking, there are obviously far fewer opportunities to use ICT. In this sense, technology use for these more individual modes of transport is mostly limited to navigation.

”I then usually go to satellite and zoom in a bit closer and then look at some of the surroundings and then look at anchor points where I basically have to search for. [...] I recently had to walk from work to another practice and didn’t know one hundred percent how to get through the side streets. So I used Google Maps, for example, and then I sort of walked according to Google Maps. I use that, too, but otherwise I wouldn’t know what to do to get to the [local destination] [...] Yes, well, I also use the train app.” –P6

But again, the interaction between the technology (near materiality) and the infrastructure is prevalent. Our participants chose the technology that provides the appropriate level of detail and features for navigating the mode. This is particularly interesting because it is the technologies that include a wide variety of modes that lack a certain level of information for specific modes. For example, while Google Maps provides a good overview of the entire route, navigation with a bicycle requires different apps that provide more detailed bicycle maps.

”I sometimes do not use Google Maps, but another map, MapsME it is called, because the bike paths were still somehow better shown or drawn.” –P1

4.2.2 Time Exploitation and Enjoyment

In the long term, uncertainty decreases as our participants reported being more aware of schedules and alternatives and simply becoming more comfortable using different modes of transport. Therefore, exploitation of time, efficiency, and enjoyment become more important within the ecology of artifacts used on-trip. Nevertheless, some participants have developed a routine of checking live information at least once.

”So I definitely look at it at least once before I get on the train, because a lot can change. And the station usually has the most up-to-date information.” –P11

However, this established routine is not only used to check the infrastructure’s schedule, but also to

reach the subsequent modes of transport. This can be done, as the example of P10 shows, through a simple communication via messenger or call to ensure a certain synchronicity, but also checking one's own location to get off at the right stop or to reach subsequent modes in time and space.

"I would just text the person that I'm there and where we're going to meet. And sometimes if you're not sure where you are, because for me it's like I'm traveling there for the first time, so then I make sure I'm in the right city or where I'm going, for example, I look around to see if there's some kind of signal. Or I even look in Google Maps to see if I'm at the right stop."
-P10

In addition to these routines, which are still predominantly focused on the functionality of the transport infrastructure, the participants also explained how a certain routine emerged over time and the use of travel time came to the fore as a new space that can be shaped. On the one hand, this shows, from a practice-theoretical perspective, how the new modes of transport are also gradually seen as an opportunity for more leisure time. On the other hand, the design of this new time is as different as the participants and the modes they use. For example, they reported that they use the time to rest, to consume media, but also to study or work.

"Play games, listen to music, read. Work. I think I forgot to mention working, because it's often the case that you do have something that you can do on the laptop. It's just not as effective as at home, I have to admit. But I used to watch movies from time to time, but I haven't done that for a few years now." -P2

This involves adapting the ecology of artifacts to the particular mode and the established routines. Specifically, our participants reported exploring which applications can be used without an internet connection (offline mode) if their route passes through an area with low internet coverage or only use certain features of their applications. Participants also reported preparing accordingly, such as downloading content for later consumption.

"With Spotify, it's just my previously downloaded playlists that I listen to, in Netflix then also only the downloaded stuff, because for this my network flat is not enough [...] WhatsApp just write messages, also no video calls or so, simply because the connection would be too bad for that." -P5

Similarly, some participants explained how they chose to refrain from certain activities because their

chosen mode of transport does not provide the necessary infrastructure in terms of WiFi or charging options. While routines and artifacts are mostly aligned with the infrastructure in use, in some cases participants also report choosing a different mode of transport and making trade-offs between how they can use their time and how fast, comfortable, or expensive the mode is.

"I think it's stupid that train don't have WiFi, which means you can't work there well. [...] When I really find a cheaper train, that's mostly such train. And sometimes I decide against it when I really want to work on something, but I'm prevented from doing because they don't have WiFi." -P7

4.3 Post-trip: From Reflection on Practices to Routinized Non-usage

4.3.1 Optimizing Practices and Improving Infrastructures

Even for post-trip practices, our participants reported using artifacts to predominantly stabilize their practices. Optimizing the route previously taken and comparing the recommendation or time predictions of the travel planning systems with the real travel time arose as an important theme, especially in early practice transformation.

"If you have the navigation that you want to be guided from A to B, then you can track, for example, how long it took me to get there by bike. I sometimes find that quite interesting, especially if it's a new route, because then I can also estimate for the future, okay I need 20 minutes to get there." -P1

The example of P1 shows how the participants, depending on the mode, compared the planned travel time with the actual time. This optimization approach for one's own routines is explained by the fact that one can better estimate the time needed to travel either earlier or later. Such optimization is not limited to bike rides or walks, but also to transfer times between bus rides, where the consumer might get an earlier ride because the app underestimates the walking speed.

In addition to optimizing their own routines, by reflecting on their own use of infrastructures, some participants began to optimize the infrastructure themselves. This optimization is sometimes focused towards the digital infrastructures, such as OpenStreetMap, where they record their trips or label

roads, such that other consumers have access to better data and route recommendations.

”I came across OpenStreetMap at that time through my dad, because he also liked to enter data there, so when he made bicycle tours, where no one has entered that there is a bike path and has taken the GPS data, [...] which was then recorded on this map, okay there is a bike path. I thought that was cool because it was somehow filled in by the people and because it also took into account all those little paths that maybe only the people who live in the place know.” –P1

Besides, participants tried to share their experiences and optimize the physical infrastructures. For example, they went to demonstrations for better bike lanes after realizing that certain areas are dangerous or do not provide good riding conditions. Other examples include writing letters of complaint about certain bus routes, their service or the schedule.

4.3.2 Routinized Non-usage

Since post-trip ICT usage itself is less prominent, it plays a marginal role for stable practices in the long term. Most of our participants reported that they are just happy to have arrived at their destination without uncertainty and that they already used their smartphone or computer a lot during the trip.

”I’m usually glad when I’ve arrived, especially after longer trips, you’re glad when you’ve arrived and can do the other stuff.” –P2

Still, there are situations where they want or even need to check for bonus programs or travel-related news, such as upcoming constructions. But non-use of artifacts remains the majority case for the post-trip practices.

”What I might check is the rail bonus status later to see if it’s enough for a free ride again.” –P10

5 DISCUSSION

To answer our research question, we discuss our findings from two perspectives. First, from a theoretical perspective that sheds light on the appropriation of sustainable mobility practices by consumers and the respective role of ICT. Second, building on this understanding, we discuss design implications that put a different focus on the design for sustainable mobility practices.

5.1 Practice Transformation as Mediating between Practices and Infrastructures

At the beginning of our participants’ practice transformations, a change in their personal situation or a breakdown in their mobility infrastructure forces them to rethink their mobility practices. For our participants, the obvious outcome was to give up their cars and adopt multimodal mobility practices. This immediate change is quite similar to the Hasselqvist et al. (2016) experiments, but consumers still gave up motorized personal transport completely. Interestingly, while in other transformations of consumer practices (Lawo et al., 2020) media and ICT triggered the questioning of infrastructures and practices, in mobility it seems that — speaking with a practice-lens in mind — transformation is triggered by a change in the material context, e.g., moving to a new city or abandoning the car, rather than by a change in meanings.

While the motivational aspects of persuasive design (Fogg, 2002) are a major focus of HCI research on sustainable mobility, it does only play a small role in our sample. Of course, we cannot draw broader conclusions about all consumers due to our sample size, but nonetheless, motivation tends to come from material change. Nonetheless, there seems to be an initial meaning that changed and influenced the decision even before the material change that initiates the moment of transformation. This meaning is, for example, the high price of a car or the inflexibility in finding a parking space. In addition, this meaning changes and stabilizes as the transformation progresses towards other perspectives, e.g. the environmental benefit. Here, despite the observed non-use of motivational design, this branch of ICT could play its role in practice transformation, e.g., preparing consumers for a transformation decision when the material context provides an opportunity. Moreover, to stabilize practices and support sustainable practice transformation, persuasive features could provide information to develop new positive meanings.

Given the material-focused initiation of practice transformation, the simplification of the interplay of technologies and infrastructures was much more prevalent in our sample. This, as our results show, is not just a matter of planning the routes to take, but an ongoing synchronization of practices and infrastructures. While planning has already been observed by Hasselqvist et al. (2016); Stein et al. (2017), our research emphasizes that multimodal practices require not just planning but also information about the interconnectivity of modes, their schedules, and real-time

information. This need for information exists not only before the trip, but also on-trip, e.g. when changing the mode. Given this perspective, a main lever to facilitate multimodal mobility is ICT, which supports consumers in connecting to, appropriating and using the infrastructure, in short, getting familiar with the new material that suddenly became part of mobility practices without adapting the other elements, neither skills, nor meanings, nor other materials.

This observed role of ICT use is not just an intermaterial relationship between ICT and infrastructures, but is highly related to the acquisition of knowledge about infrastructures. This knowledge acquisition is reflected in the decreasing need for planning, but constant synchronization to deal with everyday problems before and during the trip. Moreover, ICT is even used for learning about the infrastructure in the post-trip phase, e.g., reflecting on the duration of different mode combinations. But the appropriation of the various ICT solutions is also accompanied by learning about their use, the data they provide, and tinkering with a useful ecology of artifacts that fits the ecology of the multimodal infrastructures. In this sense, access to infrastructures proved to be the more relevant issue, as current ICT designs hardly support consumers in accessing infrastructures, but in contrast make it more difficult for them, as mobility modes are interconnected while ICT remains isolated.

Lastly, ICT plays an important role in the use of additional travel time. Although this role seems quite trivial at first, it should not be underestimated when designing ICT. Behind this are the different needs of consumers and their desire for efficient use of time and space when traveling (Stevens et al., 2019). Furthermore, the ability to use time in the intended way even shapes meanings toward sustainable mobility, as a way to travel and have an enjoyable and/or efficiently used time.

5.2 Implications for Design

Reflecting on our research, we will discuss the design implications for supporting multimodal practice transformation using ICT from different perspectives in light of our empirical findings.

5.2.1 Motivation beyond Instability

Given the initiation of a practice change motivated by a changing material context, it appears that current persuasive design approaches, that strongly focus on motivational aspects, are either not prevalent in the actual app offering or simply play a marginal role for mobility consumption. Nevertheless, in our view, there is room for such motivational approaches.

While they may not be well suited to address initial instability in practices, motivational artifacts could prepare consumers for infrastructural and material changes when they are in their work routines, so that the decision in these cases is in favor of alternative modes. In addition, (eco-)feedback technologies could help shape meanings even after consumers have started their multimodal journey, i.e., the design could help them see how long it actually takes them to travel a distance, how much workout or time in the fresh air they spend, how much money they saved, or even how much extra work they were able to do. As our results show, these meanings form slowly with stabilizing routines, but given the sample, we still do not know how many consumers reverse their change for lack of positive meanings toward their new situation. Moreover, motivational approaches could encourage the sharing of data and the active participation in shaping the sustainable infrastructure, as seen in 4.3.1.

5.2.2 Facilitating Multimodal Infrastructure Access

Although one can identify sweet spots for the use of motivational artifacts, the main issue is access to and connected use of infrastructures. Current designs force consumers to plan their trips by combining different apps, measuring their walking/biking times between different steps of their trip, and summarizing to find a suitable multimodal trip on their own. In this context, it is particularly important to ensure a region-specific adaption of ICT to be able to support mobility practices in line with local conditions. Local information and integration of all mobility services in the region can provide a platform. This integration should also include new shared mobility services that can complement existing services to solve problems such as the last mile or switching between modes. Here, consumer-centric design approaches could facilitate infrastructure appropriation by supporting trip planning in a personalized way. Personalization here refers to one's own capabilities, tickets, and needs for time use. Helpful information could be, e.g., network coverage along the route, the availability of WiFi in a train, or seat occupancy.

5.2.3 Pro-active Infrastructure Synchronization

In addition to planning, synchronization the own practices and their schedules with the infrastructure turned out to be an issue, even for long-term routine multimodal mobility users. To the best of our knowledge, this synchronization has not been the focus of design approaches to support multimodal mo-

bility users. Even in the wild, we observe that it is the consumers who actively check the status of the infrastructure pre-, on- and even post-trip. Here, a more proactive design approach could support consumers to travel more comfortably and waste less time waiting for public transport or get information about weather conditions for the whole trip. It is especially important to not only provide the real-time information pro-actively, but to assist in finding alternative routes that consider the proprieties of the consumer's practices.

5.2.4 Data Sharing beyond Regional and Modal Borders

While infrastructure access requires smart design concepts from a consumer-centric perspective, the backend of such technologies must enable data sharing and processing across regional or modal mobility service boundaries. Currently, different mobility providers are rather reluctant to share their data. As a result, consumers need different apps for different information, ranging from real-time information about bus delays to comprehensive information about how their bus connects with the train in the next city. The situation is even more complex when it comes to integrating novel mobility services from the shared mobility context into practices. Accordingly, ICT should rely on shared data to support better planning and access to infrastructure so that searching for and selecting the right information is not a burden on consumers. Moreover, such data sharing could facilitate planning by providers themselves to offer better and more coordinated services to their customers.

5.3 Critical Reflection on the Scope of ICT

In addition to the implications presented for the design of ICT to support the appropriation of multi-modal mobility practices and the corresponding infrastructures, we want to use the space to reflect on the scope of ICT itself. Sustainable ICT design has been criticized for conforming to the neoliberal agenda that places the burden of transforming society toward sustainability on consumers (Dourish, 2010). However, it must be admitted that the presented roles of ICT and the corresponding implications are mostly focused on consumers and thus create expectations for their behavior and practices. On the one hand, such an approach is necessary given the urgent need to rapidly reduce our environmental impact. On the other hand, at least the providers of mobility services would also need to change some of their practices, such as shar-

ing data, providing real-time information, facilitating bicycle trips to catch a train, or providing more consumer-oriented services. Nonetheless, we want to emphasize that consumers and providers are not the only actors in this process and that ICT is not a 'magic bullet'. As our results show, ICT can facilitate multimodal mobility, but providers still need to optimize and expand their offerings, and likewise policymakers need to support such forms of mobility (Meurer et al., 2019). Local authorities could address this on a higher level, since they do not primarily pursue their own economic interests but instead seek to improve mobility as a whole. Public digital mobility infrastructure could promote the emergence of both novel mobility services and new types of providers, also in suburban and less densely populated areas.

Still more and better information and increased connectivity with infrastructures, could facilitate consumers' political participation and allow them to practice some power over policymakers and providers (Meurer et al., 2019).

6 CONCLUSION

In this paper, we presented an interview study with 12 car-free mobility consumers who changed their mobility consumption practices. By analyzing the data from a practice-theoretical lens, we show how ICT mediates and simplifies the interaction between practices and infrastructures. This is defined by different modes of planning, synchronization, and optimization of use, and even optimization of the infrastructures themselves. Based on these results, we contribute to HCI research by discussing a nuanced understanding about the transformation of mobility practices and the role of ICT artifacts in particular for the use of shared infrastructures (Entwistle et al., 2015), which is currently lacking (Wulf et al., 2019) but important to better support sustainable practices rather than leaving consumers alone after having increasing their motivation (Lawo et al., 2020; Hasselqvist et al., 2016).

Still, our research is limited by the sample selection for two reasons. First, our sample is rather young, although it reflects the trend of young adults abandoning their cars. This raises the need for broader generalization with other age groups, as they might have different ICT preferences and usage patterns. And second, by interviewing "survivors" of practice transformation, we can only suggest that ICT plays an important role in individual journeys based on consistent reports, but cannot show that its absence makes a difference. Future research should, therefore, focus on a broader sample as well as the (non-)appropriation

of ICT and its influence on the practice transformation. Moreover, our research only emphasizes future design, but does not provide and evaluate any instance of a solution yet. Therefore, in future research we need to focus on prototyping the consumer-facing artifact as well as the backend that enables collaboration and organization of mobility providers.

REFERENCES

- Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J., and Mentzas, G. (2018). Persuasive technologies for sustainable mobility: State of the art and emerging trends. *Sustainability*, 10(7):2128.
- Ayres, L. (2008). Semi-structured interview. *The SAGE encyclopedia of qualitative research methods*, 8:811–813.
- Bødker, S. and Klokmoose, C. N. (2012). Dynamics in artifact ecologies. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction Making Sense Through Design - NordiCHI '12*. ACM Press.
- Brewer, R. N. and Kameswaran, V. (2019). Understanding trust, transportation, and accessibility through ridesharing. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–11.
- Brynjarsdottir, H., Håkansson, M., Pierce, J., Baumer, E., DiSalvo, C., and Sengers, P. (2012). Sustainably unpersuaded: how persuasion narrows our vision of sustainability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 947–956.
- Cellina, F., Bucher, D., Mangili, F., Veiga Simão, J., Rudel, R., and Raubal, M. (2019a). A large scale, app-based behaviour change experiment persuading sustainable mobility patterns: methods, results and lessons learnt. *Sustainability*, 11(9):2674.
- Cellina, F., Bucher, D., Veiga Simão, J., Rudel, R., and Raubal, M. (2019b). Beyond limitations of current behaviour change apps for sustainable mobility: Insights from a user-centered design and evaluation process. *Sustainability*, 11(8):2281.
- DiSalvo, C., Sengers, P., and Brynjarsdóttir, H. (2010). Mapping the landscape of sustainable hci. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 1975–1984.
- Dourish, P. (2010). Hci and environmental sustainability: the politics of design and the design of politics. In *Proceedings of the 8th ACM conference on designing interactive systems*, pages 1–10.
- Entwistle, J. M., Rasmussen, M. K., Verdezoto, N., Brewer, R. S., and Andersen, M. S. (2015). Beyond the individual: The contextual wheel of practice as a research framework for sustainable hci. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 1125–1134.
- Fogg, B. J. (2002). Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002(December):2.
- Fogg, B. J. (2009). A behavior model for persuasive design. In *Proceedings of the 4th international Conference on Persuasive Technology*, pages 1–7.
- Froehlich, J., Findlater, L., and Landay, J. (2010). The design of eco-feedback technology. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 1999–2008.
- Gabrielli, S., Forbes, P., Jylhä, A., Wells, S., Sirén, M., Hemminki, S., Nurmi, P., Maimone, R., Masthoff, J., and Jacucci, G. (2014). Design challenges in motivating change for sustainable urban mobility. *Computers in Human Behavior*, 41:416–423.
- Girod, B., van Vuuren, D. P., Grahn, M., Kitous, A., Kim, S. H., and Kyle, P. (2013). Climate impact of transportation a model comparison. *Climatic change*, 118(3):595–608.
- Glöss, M., Tuncer, S., Brown, B., Laurier, E., Pink, S., Fors, V., Vinkhuyzen, E., and Strömberg, H. (2020). New mobilities: A workshop on mobility beyond the car. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–8.
- Hasselqvist, H. and Hesselgren, M. (2019). Bridging citizen and stakeholder perspectives of sustainable mobility through practice-oriented design. *Sustainability: Science, Practice and Policy*, 15(1):1–14.
- Hasselqvist, H., Hesselgren, M., and Bogdan, C. (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*, pages 1300–1311.
- Kemp, R. and van Lente, H. (2011). The dual challenge of sustainability transitions. *Environmental Innovation and Societal Transitions*, 1(1):121–124.
- King, N. (2004). Using templates in the thematic analysis of text. *Essential guide to qualitative methods in organizational research*, page 256.
- Kramers, A. (2014). Designing next generation multimodal traveler information systems to support sustainability-oriented decisions. *Environmental Modelling & Software*, 56:83–93.
- Lawo, D., Esau, M., Engelbutzeder, P., and Stevens, G. (2020). Going vegan: The role (s) of ict in vegan practice transformation. *Sustainability*, 12(12):5184.
- Loos, E., Sourbati, M., and Behrendt, F. (2020). The role of mobility digital ecosystems for age-friendly urban public transport: A narrative literature review. *International Journal of Environmental Research and Public Health*, 17(20):7465.
- Maitland, J., Chalmers, M., and Siek, K. A. (2009). Persuasion not required improving our understanding of the sociotechnical context of dietary behavioural change. In *2009 3rd International Conference on Pervasive Computing Technologies for Healthcare*, pages 1–8. IEEE.
- Meurer, J., Lawo, D., Pakusch, C., Tolmie, P., and Wulf, V. (2019). Opportunities for sustainable mobility: Rethinking eco-feedback from a citizen’s perspective. In *Proceedings of the 9th International Conference on*

- Communities & Technologies-Transforming Communities*, pages 102–113.
- Meurer, J., Stein, M., Randall, D., Rohde, M., and Wulf, V. (2014). Social dependency and mobile autonomy: supporting older adults' mobility with ridesharing ict. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1923–1932.
- Miehe, R., Scheumann, R., Jones, C. M., Kammen, D. M., and Finkbeiner, M. (2016). Regional carbon footprints of households: a german case study. *Environment, Development and Sustainability*, 18(2):577–591.
- Noy, C. (2008). Sampling knowledge: The hermeneutics of snowball sampling in qualitative research. *International Journal of social research methodology*, 11(4):327–344.
- Pipek, V. and Wulf, V. (2009). Infrastructuring: Toward an integrated perspective on the design and use of information technology. *Journal of the Association for Information Systems*, 10(5):1.
- Qu, Y., Gong, H., and Wang, P. (2015). Transportation mode split with mobile phone data. In *2015 IEEE 18th international conference on intelligent transportation systems*, pages 285–289. IEEE.
- Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European journal of social theory*, 5(2):243–263.
- Reddy, S., Shilton, K., Denisov, G., Cenizal, C., Estrin, D., and Srivastava, M. (2010). Biketastic: sensing and mapping for better biking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1817–1820.
- Rehrl, K., Brunsch, S., and Mentz, H.-J. (2007). Assisting multimodal travelers: Design and prototypical implementation of a personal travel companion. *IEEE Transactions on Intelligent Transportation Systems*, 8(1):31–42.
- Schwartz, T., Deneff, S., Stevens, G., Ramirez, L., and Wulf, V. (2013). Cultivating energy literacy: results from a longitudinal living lab study of a home energy management system. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1193–1202.
- Schwartz, T., Stevens, G., Jakobi, T., Deneff, S., Ramirez, L., Wulf, V., and Randall, D. (2015). What people do with consumption feedback: a long-term living lab study of a home energy management system. *Interacting with Computers*, 27(6):551–576.
- Shove, E. and Pantzar, M. (2005). Consumers, producers and practices. *Journal of Consumer Culture*, 5(1):43–64.
- Shove, E., Pantzar, M., and Watson, M. (2012). *The Dynamics of Social Practice: Everyday Life and how it Changes*. SAGE Publications.
- Şimşekoğlu, Ö., Nordfjærn, T., and Rundmo, T. (2015). The role of attitudes, transport priorities, and car use habit for travel mode use and intentions to use public transportation in an urban norwegian public. *Transport Policy*, 42:113–120.
- Stein, M., Meurer, J., Boden, A., and Wulf, V. (2017). Mobility in later life: Appropriation of an integrated transportation platform. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pages 5716–5729.
- Stevens, G., Bossauer, P., Vonholdt, S., and Pakusch, C. (2019). Using time and space efficiently in driverless cars: Findings of a co-design study. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–14.
- Stevens, G. and Pipek, V. (2018). Making use: understanding, studying, and supporting appropriation. In *Socio-Informatics*. Oxford University Press.
- Tongco, M. D. C. (2007). Purposive sampling as a tool for informant selection. *Ethnobotany Research and applications*, 5:147–158.
- Twine, R. (2018). Materially constituting a sustainable food transition: The case of vegan eating practice. *Sociology*, 52(1):166–181.
- Urry, J. (2004). The 'system' of automobility. *Theory, culture & society*, 21(4-5):25–39.
- Väänänen, K., Ojala, J., Hilden, E., Karlsson, M., Wallgren, P., and Turunen, M. (2016). Improving attractiveness of public transportation with interactive experiences. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, pages 1–2.
- Winstanley, C., Davies, N., Harding, M., and Norgate, S. (2014). Supporting walking school buses. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication*, pages 291–294.
- Wright, L. and Fulton, L. (2005). Climate change mitigation and transport in developing nations. *Transport Reviews*, 25(6):691–717.
- Wulf, V., Misaki, K., Randall, D., and Rohde, M. (2019). Travelling by taxi brousse in madagascar: An investigation into practices of overland transportation. *Media in Action*, (1):57–97.