Exploring Lived Experience and the Role of Technology in Cycling for People Who Have a Mobility Disability

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Abstract

Cycling is a popular leisure activity and a sustainable mode of transportation, but various accessibility barriers thwart the inclusion of people who have a mobility disability in this activity. Our work presents their perspectives on cycling and addresses the role that technology plays in this context. Through semi-structured interviews with 15 cyclists who have a mobility disability and use diverse accessible cycles, we concentrated on their lived experience and their current and envisioned use of technology. We applied Reflexive Thematic Analysis and crafted three themes, focusing on (1) disabled people's heterogenous approaches to accessible cycling, (2) wellbeing and social relationships emerging through accessible cycling, and (3) how technology improves accessible cycling and why it is carefully applied by disabled cyclists. Grounded in these results, we propose design goals, calling for dependability of technology, opportunities to self-manage accessibility, and preservation of the original cycling experience, and we appraise the grand challenges of CyclingHCI in the context of accessibility.

CCS Concepts

• **Human-centered computing → Accessibility**.

Keywords

Mobility disability, cycling, technology, lived experience

1 Introduction

Cycling is a leisure activity, sport, and a sustainable mode of transportation that comes with many benefits for riders and society: It increases physical and social well-being [21, 37] and contributes to a cleaner environment and reduced traffic in urban areas [17]. Despite these compelling reasons to engage in the activity, cycling is associated with various accessibility barriers that thwart the facilitation of all its benefits for disabled people. Barriers include a lack of (accessible) infrastructure, a poor supply of affordable and accessible cycles[1] for people who have a mobility disability in particular [7, 9], and a generally limited representation of the lived reality of disabled people in cycling [25], e.g., through the design of cycling infrastructure that favours the *bi*cycle [9]. Consequently, disabled cyclists remain under-represented in the cycling community [1, 25].

Human-Computer Interaction (HCI) research has previously leveraged technology to improve cycling for non-disabled persons (e.g., [33]), and the SportsHCI community has questioned the state-of-the-art design that predominantly focuses on normative bodies [18, 44]. Yet, despite a growing CyclingHCI community with a claimed focus on inclusive cycling [34], little is known about disabled people's requirements and their experience with cycling technology.

For example, becoming "one with the bike" [13] may open up a different discussion if cycles are simultaneously considered mobility aids by riders who have a mobility disability [9]. Hence, involving these communities in research and exploring their perspectives on accessible cycling presents a unique research opportunity that can inform the design of novel embodied technology for accessible cycling.

We therefore raise the following research questions:

RQ1: How do people who have a mobility disability engage with cycling, and how can we characterise their cycling experiences?

RQ2: What role does technology play in this context, and (how) could it contribute to accessible and enriching cycling experiences?

Adopting a qualitative research approach, we conducted semi-structured interviews (n=15) with people with mobility disability who have previous cycling experience or wish to start cycling in the future. To synthesise results and craft themes that illustrate participants' perspectives on cycling and technology, we applied Reflexive Thematic Analysis [6], and crafted three themes: *Disabled people's approaches to cycling are heterogeneous* and *Accessible cycling fuels wellbeing and social relationships* (both RQ1), as well as *Technology used for cycling offers many improvements for accessibility but is carefully curated and not broadly employed* (RQ2).

Our results show that disabled people's diverse biographies and lived experience are reflected through heterogenous approaches to cycling, and that cycling sparks wellbeing and self-determination while also bringing along new social relations and interplays. Technology plays an important role in accessible cycling, but always needs to centre the cycling experience. If reliant, it can be a true facilitator of access, primarily through motorised cycles, but also digital planning, navigation and tracking tools.

Our paper makes the following contributions:

(1) We report nuanced lived experience of disabled cyclists and elaborate on their current use of technology for accessibility, and highlight conditions that influence its (prospective) usage.
(2) Crafting three design goals, and contextualising the grand challenges of CyclingHCI [33], we outline future avenues of technology for accessible cycling.

[1] Including accessible cycles with more than two wheels (also see [39]), in the following, we either use the general "cycle" or specify the type, e.g., "bicycle" or "tricycle" (abbr. "bike and "trike") depending on the context. We use "e-bike" to refer to all electrified cycles.

2 Related Work

The following presentation of related work includes general research on accessible cycling (see Section 2.1) and relates to recent works in CyclingHCI that cover a wider span of application cases of cycling technology for non-disabled riders (see Section 2.2).

2.1 Accessible Cycling

General research on accessible cycling is situated within transportation and disability studies, examining barriers and facilitators of accessible cycling in the material and infrastructure, but also in sports science with an emphasis on cycling for leisure and exertion.

Researchers examine adaptations or alterations of bicycles that aim to remove barriers that disabled people face [8, 9], and explore their (social) context of use [39]. When addressing people with mobility disability, efforts often focus on mitigating impairment, e.g., a lack of stability or muscle strength [7]. Reflecting a diverse disabled cycling community [26], riders may switch to tricycles, handcycles or various other types of adapted cycles that improve balance and rely less or do not rely on leg strength [8, 42]. In that context, the introduction of electrical bikes (e-bikes) offered new opportunities as they can compensate limited arm or leg strength [29].

Research on accessible cycling often also concerns the design of the built environment as barriers frequently emerge from poor infrastructure design due to old cycling infrastructure being built for the cycle with two wheels [9]. Examples for inaccessible infrastructure include signage which excludes other forms of cycles and reduces disabled cyclists' visibility [1, 20], narrow cycling paths which do not fit larger, accessible cycles, or the design and location of bicycle stands for standard cycles [9], often overlooking the role of the cycle as mobility aid . There also exist barriers that all cyclists face to some extent, with disabled people being at higher risk, for instance, vulnerability in traffic [9], poor infrastructure design [8, 9, 16], or awareness of other road users and limited visibility in traffic [16, 26]. Consequently, researchers call for more inclusion in the planning and testing of new infrastructure [20].

Complementing transportation and disability studies, sports science has further explored accessible cycling in the context of leisure and exertion. Mosser et al. [37] conducted a literature review, highlighting the short-term and long-term potential that accessible cycling has on improving physical and mental health as well as quality of life in general. Sorraghan et al. [43] focus on disabled cyclists' perspectives and lived experience in sports and recreational activities, and report positive effects on health and fitness, but also stressed the importance of cycling for independence and inclusion.

2.2 CyclingHCI

In contrast to technology for disabled cyclists, HCI addressed many aspects of cycling, primarily around wearable and on-bike technology for urban transportation and exertion that targets cyclists with normative bodies. Application areas range from (safe) cycling experiences in and navigating through urban traffic (e.g., [32, 47]) to engaging in virtuous exertion (e.g., [48]) and social cycling (e.g., [19]). Technological artefacts comprise wearable, on-body, and on-bike technology [41], as well as setups for virtual cycling simulations (e.g., [2, 35]). Notably, recent research on e-bikes evolved around their potential to level the athletic imbalances [36] while also making cycling more accessible for elderly people [4].

At a meta-level, there exist research community-driven elaborations on the field. Drawing on their expertise and vision of CyclingHCI, Matviienko et al. [33] proposed a set of ten grand challenges for the field comprised in the following categories (1) Pushing the technological boundaries for cycling, (2) Understanding and protecting cyclists (3) Spatially situated cycling. While Elvitigala et al. [11] cover accessibility in their grand challenges of SportsHCI, i.e., acknowledge the "[l]ack of understanding of how to overcome barriers to sports access", CyclingHCI's grand challenges miss this discussion. But recent research endeavours in the CyclingHCI highlight this gap and underline the need for involving disabled communities in research [33].

Similarly, work at the intersection of HCI and transportation misses a discussion on cycling as means of mobility for disabled people, e.g., by referring to disabled people and cyclists separately in the context of vulnerable road users [22]. Likewise, considerations on future mobility only cover accessible cycling superficially [10], missing the lived realities of disabled cyclists (cf. [7, 26]).

Specific research on accessibility, cycling, and technology remains limited. For instance, work exploring cycling with physical disabilities with focus on rehabilitation or health-intervention technology only superficially touch the underlying issues (e.g., [12, 14]). These works continue to perpetuate inequalities, and reinforce medical perspectives on disability [44]. In contrast, recent endeavours in SportsHCI argue for more inclusion of marginalised groups [18] and for holistic perspectives on disability, cycling, and technology. In that context, researchers call for acknowledging cycling's values besides fitness and health (cf. [38]) and providing new opportunities for accessible technologies, i.e., facilitating equitable cycling experiences that focus on ability and not disability [25, 44].

3 Methodology

To answer our research questions, *RQ1: How do people who have a mobility disability engage with cycling, and how can we characterise their cycling experiences?* and *RQ2: What role does technology play in this context, and (how) could it contribute to accessible and enriching cycling experiences?* , i.e., to explore the lived experiences of disabled cyclists and their relationship with technology, we conducted semi-structured interviews with the target group. Here, we give an overview of our interview approach, give detail on participants and procedure, document how we applied Reflexive Thematic Analysis [6] to craft themes inductively, and discuss the research teams' positionality.

3.1 Interview Guide

The interview comprised three main parts. We first collected demographical information and asked about the participants' cycling background. Here, we wanted to get a first impression on how (long) they cycle, why they cycle, and which cycles they use. In the second part, we then detailed on their (accessible) cycling experience and focused on positive and negative aspects as well as their motivation for cycling, e.g., *What are your facilitators for a good cycling experience?* or *How does your disability interact with your experience of cycling?* Here, we further wanted to learn about their experience with indoor and social cycling, as well as how their disability affected their cycling experience in general. We finally covered their use of technology. We first focused on specific technology (cf. [41]), covered individual solutions, and concluded with how participants envisioned the role of technology for accessible cycling in the future, e.g., *What are your perspectives on the technologies that you currently use?* or *Are there technologies currently not available to you that would improve your cycling experience?*

3.2 Participants and Procedure

We recruited participants via personal contacts, sports clubs, non-governmental organisations (for cycling), and communal representatives for inclusion. Participants needed to be at least 18 years old and to self-identify as having a mobility disability. In addition, participants had to either have experience with accessible cycling, or alternatively, wish to try accessible cycling in the future. In total, 15 people (8 women, 6 men, 1 non-binary person) took part in the interview (see Table 1). Participant age was between 29 and 66 years (M=49.67, SD=13.7). Depending on their disability, participants reported using different kinds of bi- or tricycles. For instance, P2 has a left-side paralysis and regularly uses an e-bike with two wheels. P9 has reduced muscle strength and spasms mostly in his legs, and uses a recumbent trike with leg propulsion and a motor, and P8 permanently uses a wheelchair which is turned into a handcycle with an extension.

The interview procedure and guideline were approved by the ethics board at the Karlsruhe Institute of Technology. All interviews were audio recorded. At the beginning of each session, we informed the participants about the procedure and asked for informed consent. Afterwards, we started the interview by collecting demographic information and the participants' individual backgrounds. We then proceeded with questions about their overall cycling experience and finished the interview with their current and envisioned technology use. On average, interviews took a little over an hour (M=67.01 min, SD=19.54 min) and participants were compensated for their time with 30€.

3.3 Data Analysis

Given that we collected rich data pertaining to lived experience, we opted for Reflexive Thematic Analysis [6] as analytical approach. Following Braun and Clarke [5, 6]'s process, the first author transcribed interviews and familiarised themselves with the data. They then inductively assigned codes to the participants' quotes and crafted initial themes. For example, the statement "For a long time, my disability did not restrict cycling much until I realised that dismounting is getting more difficult as well as the difficulty to keep the balance when I moved slowly" (P9) was coded as *the bicycle became more complicated with time.* This analysis followed an inductive approach, i.e., coding and themes were not guided by existing frameworks. After this coding stage, both authors met and discussed the conceptualisation of these themes to further increase the robustness thereof. Afterwards the first author refined the themes, followed by a second review together with the second author before finalising the thematic map and writing down the report. Through this process, three final themes were crafted, focusing on disabled people's individual approaches to cycling, wellbeing and enhanced social relationships as effects of accessible cycling, and the well thought out use of technology for accessible cycling.

3.4 Positionality Statement

In line with the subjective nature Reflexive Thematic Analysis [6], and therefore, to contextualise our results, we report our positionality that contributed to this report.

We are researchers in Human-Computer Interaction and accessibility, and have previously researched the potential of technology to facilitate engaging and enriching physical activity. The first author has grown up with cycling, and used the bicycle for sport, transportation, and travelling. Additionally, they are interested in watching cycling live (on television). Despite a walking disability, they have not tried tricycles, but instead, switched to an e-bike, which they currently use for leisure. The second author has likewise grown up with cycling, and has previously used it as a regular means of transportation, but rarely cycles for leisure.

4 Thematic Synthesis

We present our results and map them onto our two research questions, *RQ1: How do people who have a mobility disability engage with cycling, and how can we characterise their cycling experiences?* and *RQ2: What role does technology play in this context, and (how) could it contribute to accessible and enriching cycling experiences?* Specifically, we crafted three main themes describing accessible cycling: *Disabled people's approaches to cycling are heterogeneous* and *Accessible cycling fuels wellbeing and social relationships* (both RQ1), as well as *Technology used for cycling offers many improvements for accessibility but is carefully curated and not broadly employed* (RQ2). For each theme, we present sub-themes that further illustrate the corresponding participants' perspectives (see Figure 1 for an overview).

4.1 Disabled People's Approaches to Cycling are Heterogeneous (RQ1)

Participants reported diverse lived experience of cycling in relation to their disabilities and personal biography. Two themes were central to this individuality: The highly individual accessible cycle that needs to be found through a complex process, and making individual adaptations to the cycle as well as the cycling activity.

4.1.1 An accessible cycle is highly individual and complicated to find. Participants in our study reported diverse experiences finding accessible cycles. Key factors that shaped this process include the type of disability, the progression of symptoms, and both the availability of information and cycles. As a result, acquiring a suitable cycle is a complex, long, and often still ongoing process.

Like participants' diverse (dis)abilities (see Table 1), the cycles they use vary greatly as well, ranging from low-entry standard bicycles to larger electrified recumbent tricycles. While some participants use their feet to power the cycle, others only pedal with their hands. Here, P3 demonstrated that this may also be a choice that depends on the purpose of the activity, "[For the handbike] rather the sport and for the other one, mobility, or that I am faster than on foot" (P3), choosing the propulsion according to whether they want to exercise or be mobile within the city. Likewise, P7

ID	G	Age	**Disability** and mobility aid in use	**Cycle**(s) in use and customisation	**Purpose** of cycling	**Technologies** most used in cycling
P1	m	44	Trouble lifting right leg, decreased sensitivity in right hand, and balance issues, uses walking aids and knee orthesis (for cycling)	Various bicycles without motor	Recreational rides and everyday routes (e.g., grocery shopping)	Mobile apps and sensors for activity and heart rate tracking
P2	m	47	Right-side paralysis with spasms and restricted vision	Bicycle with motor, low seating position and high handlebars for balance	Recreational rides and commuting	Navigation system that came with the e-bike
P3	m	36	Walking disability with spasms and balance issues, uses mostly crutches and occasionally a wheelchair	Tricycle and recumbent handcycle without a motor	Sport and inner city mobility	Komoot for route planning and Strava for reviewing and sharing activities with friends
P4	f	66	Walking disability, uses walker and (motorised) wheelchair	Recumbent tricycle with motor	Leisure rides and small everyday routes (e.g., to medical appointments)	Komoot for route planning and navigation
P5	f	60	Walking disability and secondary (neurological) symptoms, uses wheelchair, walker, and walking sticks	Recumbent tricycle with motor, luggage space for folding walking sticks	Leisure rides and everyday routes	Komoot for route planning and navigation, earphones for navigation instructions
P6	f	61	Left-side paralysis affecting leg and hand, uses walking stick and wheelchair	Recumbent tricycle with motor, individual adaptations for usage with one hand/leg	Leisure rides to stay active with partner	Only little use when searching for accessible locations on the internet
P7	m	46	Left-side paralysis, reduced motor function in leg and arm, uses wheelchair, walking stick, and electrical stimulator of the leg	Handcycle conversion for wheelchair as well as tricycle that is powered by both arms and legs, both with motor	Exercise and everyday routes (e.g., medical appointments)	Komoot and Google Maps for route planning, Strava for documenting and reviewing activities
P8	f	63	Paraplegia and secondary (neurological) symptoms, uses wheelchair permanently	Handcycle conversion for wheelchair without motor, added weight above front wheel for uphill balance	Commuting to work and leisure rides	No regular use of technology for cycling
P9	m	62	Reduced muscle strength and spasms mostly in legs	Recumbent tricycle and velomobile, both with motor	Commuting to work and leisure rides	Navigation system, Bikerouter and OpenStreetMap for planning routes, and Komoot for peers support
P10	f	29	Disability affecting arm and leg muscles, uses non-motorised wheelchair indoors and motorised wheelchair outdoors, also has autism	Recumbent trike with motor, attached pole to push the cycle more easily	Everyday routes and leisure rides to stay active and explore the area	Route tracking for retrospective analysis
P11	f	62	Only has one lung, limits bodily strength and mobility and runs quickly out of breath	Bicycle with motor and low instep frame	Recreational activity and everyday routes	Komoot for route planning
P12	n	29	Limited mobility in the hip, uses cane, crutches, and wheelchair	Bicycle with motor, scratch protection for step-in and additional suspension	Everyday routes and recreational exercise	OpenStreetMap and Komoot for accessible route planning, and tracker for theft protection
P13	m	64	Walking disability, uses wheelchair permanently	Handcycles (conversion for wheelchair and a tricycle) primarily used with a motor, additionally adapted gear ratio	Recreational activity	Navigation tools for route planning
P14	f	44	Walking disability with balance issues and limited body tension on one side, uses cane as walking aid	Standard cargo tricycle with motor, handlebar adjusted as close to body as possible with controls on the left	Everyday routes and leisure rides	Cyclometer to review distances
P15	f	32	Walking disability with other orthopaedic impacts (such as pain), uses ortheses, cane, walker, and wheelchair	Standard bicycle without a motor, ergonomic hand rest	Small everyday routes	Apps to track route and heart rate, Google Maps to plan and navigate

Table 1: Key characteristics of the participants as reported by them (G = Gender). If not specified otherwise, cycles are propelled by feet.

Disabled people's approaches to cycling are heterogeneous T

An accessible cycle is highly individual and complicated to find S

Disabled cyclists' backgrounds and the availability of information and cycles shape a complex process to acquire an individually suitable cycle.

Adaptation of cycle and cycling behaviour is key to managing barriers S

Disabled cyclists further customise their cycle and cycling behaviour to address their individual requirements and barriers.

Accessible cycling fuels wellbeing and social relationships T

Cycling facilitates self-determination and sources of wellbeing S

On top of various psychological benefits, a large gain in mobility is empowering and provides additional independence.

Cycling opens up connections with others but comes with (inter)dependencies S

The mobility gain also enables more participation in group cycling and social life, but also new situations where help is needed can emerge.

Accessible cycling changes the perception of disabled people S

Disabled cyclists may not be perceived as such, which can have advantages, but may also imply an obligation to articulate abilities in certain situations.

Technology used for cycling offers many improvements for accessibility but is carefully curated and not broadly employed T

Leveraging digital planning and navigation tools to cater for individual accessibility needs S

Before and during the activity, map-based planning tools and route navigation can help addressing individual barriers based on abilities, equipment, or location.

Observing and reacting to abilities with tracking tools S

Tracking tools allow for assessing and predicting abilities better to find suitable adjustments to cycling, making it more manageable and accessible.

Technology already facilitates access, but needs to be dependable S

Especially e-bikes account for the increased accessibility of cycling, but technology also requires dependability to avoid new dependencies and really make it accessible.

Cycling is viewed as an opportunity to get away from technology, which should not detract from the enriching experience thereof S

The purity of the cycling experience is valued greatly, and disabled cyclists are cautious when technology foregrounds it.

T = Theme

S = Sub-Theme

RQ1: How do people who have a mobility disability engage with cycling, and how can we characterise their cycling experiences?

RQ2: What role does technology play in this context, and (how) could it contribute to accessible and enriching cycling experiences?

Figure 1: Compressed representation of all themes and corresponding sub-themes that illustrate the participants' perspectives.

owns a bike that allows him to "provide an additional minimal input with the legs" (P7) to their hand-propelled cycle, showing that the choice of using hands and/or legs may also happen during the activity.

Additional choices that participants made are selecting the number of wheels (bi- or tricycle) for reasons of balance and stability as well as the integration of a motor. But other accessibility requirements can also influence these choices. For instance, to be able to switch modes of transportation on their cycling journey, P14 who has a walking disability uses the transportation box of her cargo trike to "always carry the walking stick" (P14).

Often, these decisions were affected by a participant's current abilities, while taking the (expected) progression of their disability into account. For example, the planned transition to a tricycle and/or a motorised cycle was mentioned by many participants, e.g., "[…] but in the back of my head there is the tricycle, which, due to reasons of balance, will be coming surely, sooner or later" (P1), and "[…] that I will need to transition to e-mobility a bit, is foreseeable" (P8).

However, several aspects, such as the limited information available and the missing opportunities to test or rent more accessible cycles, can thwart the process of identifying accessible cycles and/or adapting them. For example, one participant was surprised and became emotional when hearing about the possibilities, "And my husband and I said 'How is this possible?' […] And at this point […] it has some kind of self-efficacy that one thinks 'Oh, there is still something possible'. It also has an emotional meaning, because in your whole life […] everything was gone" (P6), demonstrating the need to better address these aspects to benefit more people. Ultimately, the high cost of accessible technology paired with little to no financial support further complicates this process, e.g., "I would wish for external support from the state […] You know what I did? I simply took a loan […] with high interest rates which I am now paying off" (P2).

Consequently, the current processes of finding and acquiring an accessible bike is long and complex. Given the participants' diverse circumstances, this process is highly individual, and can carry an emotional component for some.

4.1.2 Adaptation of cycle and cycling behaviour is key to managing barriers. In addition to the complexity of finding an accessible cycle (see Section 4.1.1), participants reported that specific requirements and barriers afford further individual adaptations. While some of these adaptations concern the bike itself, others affect the cycling behaviour.

Due to the diversity of disabilities represented in the sample, participants' solutions to make cycling easier accessible varied accordingly. For instance, some disabilities do not equally affect both sides of the body and require adaptations allowing people to rely on one side of their body, e.g., P6 who has a left-side paralysis disability has all controls, including brakes, bell, and gear shift, on the right side of the handlebar, "The left [hand] is tied to my body and I now do everything with the right side" (P6). Likewise, P12 who has limited mobility in their hip needs to step up onto the bike from the right side by putting their foot on the frame and added a protective film "to not scratch the frame" (P12).

In addition to adapting the cycle, it was equally important for participants to adapt their cycling behaviour in response to barriers they regularly face. To avoid inaccessible infrastructure, participants increasingly plan their activity ahead "as much as possible […] to be safe" (P1). This may include, "if possible, riding when it is bright outside" (P8), avoiding "stop [and go situations]" (P12) at intersections or "narrow spaces and […] entanglements" (P5), as well as triggers of "stress-induced dizziness" (P1) in situations where keeping balance is difficult. Consequently, disabled cyclists strongly engage in planning (with digital tools) (also see Section 4.3.1). Such adaptations may also be applied by the entire cycling community, but appear to be more pronounced in the disabled cycling community.

Finally, various social settings influenced participants' cycling experience (see Section 4.2.2). Consequently, they mentioned to cycle "more defensively" (P2, P11) in the presence of other traffic participants, e.g., to avoid arguments that would, given their condition, "lead to trouble breathing" (P11), demonstrating that in some cases, disability had implications beyond immediate interactions with the cycle and also expanded to interactions with others in traffic.

4.2 Accessible Cycling Fuels Wellbeing and Social Relationships (RQ1)

Participants primarily reported cycling for leisure, sometimes with athletic ambitions, but also leveraged cycling as a more accessible means of transportation. In these contexts, our results show that accessible cycling facilitates sources wellbeing and contributes to self-determination as it provides an accessible means of transportation, and that it affects social relationships and inclusion. Likewise, accessible cycles change how disabled people are perceived as the association with traditional mobility aids is lacking.

4.2.1 Cycling facilitates self-determination and sources of wellbeing. Cycling provides the participants tools and opportunities to live an improved live. This manifests through the large gain in mobility and opportunities to exercise as well as the independence that accessible cycles offer in comparison to more traditional mobility aids. Participants also reported diverse psychological benefits that can ultimately lead to a more active, healthy, and virtuous life.

Compared to other mobility devices, cycles were praised for their potential to enable their user a larger reach in mobility, while being faster (P8, P10) and less exhausting (P8, P13) than wheelchairs, as well as less difficult than walking (P9, P11). The majority of participants consequently associated cycling with freedom and independence. For example, before having this freedom, P10 reported "being way more restricted by the inaccessible environment" (P10). Likewise, P12 described cycling as a "self-determined mode of transportation" (P12) that would allow them to independently get groceries without "relying on the punctuality of the bus […][or someone] who pushes [them] there with [their] wheelchair" (P12). This mobility also translates into opportunities for exercise, e.g., being able to "do sport, when there are not so many options" (P12), but also being able "to preserve mobility and strength" (P3) that can be affected by the underlying medical conditions.

Furthermore, cycling can elicit joy, for example, when "enjoying nature" (P1). Participants also indicated that they enjoy and value discomfort during cycling, e.g., "Sometimes, one sits on the cycle and is annoyed because one gets all wet or something, but I am actually never unhappy when riding the bike" (P14) or "The rain does not bother me, the snow does not" (P8). Likewise, some participants leveraged cycling to fuel their curiosity to self-dependently explore new environments, e.g., by "filling blank spots [on the heatmap]" (P10). Through cycling in nature and fading-out athletic ambitions, they were also able to elicit reverie, e.g., "jump on it and start daydreaming" (P1) and see "meadows instead of screens" (P1). Finally, cycling can also provide relief, e.g., due to the absence of stress (P15), pain (P12), and over-stimulation (P11). Because of these sources of wellbeing, participants described cycling as "game changer" (P2) that would offer "a different quality of life" (P4), and even mentioned the "emotional significance [of getting] the cycling activity back in [their] life" (P6). Thus, from a philosophical perspective, accessible cycling enables participants to life a more fulfilling and virtuous life (cf. [38]).

4.2.2 Cycling opens up connections with others but comes with (inter)dependencies. Our results show that accessible cycling provided participants with many opportunities for participation. At the same time, new social (inter)dependencies and tensions emerged.

The large increase in mobility (see Section 4.2.1) has positive effects on the participation of disabled people in social life, e.g., as P7 framed it, "And now I am actually part of society again" (P7). Participants primarily valued the newly acquired ability to cycle with friends and family. For instance, P2 enjoyed family trips that were possible with his e-bike, "There are trips, which are decided upon by the whole family and I can participate in that and it is great"

(P2). Likewise, P12 emphasised the flexibility when participating in group activities with friends, "We do not have to think about, well, do we take the bus together or does someone take the car [...] How can I get back if they do not drive past my place? I can rather join them with the bike" (P12). Despite these cycling opportunities with non-disabled people, like-minded, disabled cycling communities were something that participants missed, "But I do not find anyone. There are either people who say 'I would like to cycle, but the cycle itself is too expensive' or they say 'I am not confident to do that any more' or 'I am too old'" (P6), highlighting the potential for initiatives that link disabled cyclists with each other.

However, the implications of accessible cycling for participants' relationships also came with strings attached, with many of them observing new (inter)dependencies. For example, cycling companions provided assistance during the ride for some participants, for instance, to provide "help for turning so that [the] cycle is lifted into a certain direction" (P10), which adds another layer of coordination if cycling needs to be done together with company. Participants also pointed out that outsiders can also play an important role during the cycling activity, providing help to get out of inaccessible situations, such as "if there are inclinations [due to roots under the cycling path][...] and I am too fast there or do not pay attention, then I fall" (P7).

4.2.3 Accessible cycling changes the perception of disabled people. Accessible cycles share characteristics of cycles and mobility devices, i.e., their purpose extends beyond the one of standard bicycles. But at the same time, this purpose is not necessarily revealed, and challenges how disabled people approach this ambiguity.

On the one side, these characteristics were well appreciated (see Section 4.2), and offered people an opportunity to shift away the focus on disability if needed, for example, as P10 phrased it, "I am not perceived as disabled any more, but as a cyclist" (P10). But at the same time, as they do not necessarily reveal their users' disabilities as much as traditional mobility devices, such as wheelchairs, their users are not necessarily perceived as disabled.

Consequently, it is often expected that they follow the rules and norms of non-disabled cycling. For instance, P13 demonstrated the conflict as a user of a handbike conversion for wheelchairs who needs to choose the most accessible path, "I can say 'I am a wheelchair user and use pavements' as well as 'I am a cyclist and use cycling paths'" (P13). It can, however, also cause resentment, "I do not want to always explain that I cannot dismount and that I usually sit in a wheelchair. Now I am just quiet, because I think 'What is the benefit of discussing this?'" (P7), questioning the perceived obligation to communicate one's disability. Additionally, when sharing space with cars, visibility becomes a primarily technical issue, "Because my recumbent cycle is lower [...] I disappear between parked cars. That, I have to factor in [...]" (P9), demonstrating that safety is also a critical issue in this context.

Some disabled cyclists ultimately avoid using regular accessible cycles if possible. For instance, P14 prefers to use her standard cargo trike instead of an accessible cycle as she explained, "If one can be identified as disabled and cycles [...] the chances that someone says some shit [...] are 100%" (P14).

Overall, these experiences reflect how accessible cycling still appears special, and that it is not yet part of the general cycling community.

4.3 Technology Used for Cycling Offers Many Improvements for Accessibility But Is Carefully Curated and not Broadly Employed (RQ2)

Our results highlight three distinct ways in which different technology was integrated into participants' cycling activities: First, participants chose cycles with electrified propulsion as it offers more mobility, freedom, and participation (also see Section 4.2). Second, tools for planning and navigation help avoiding barriers and carrying out accessible cycling trips. Third, tracking distance, speed, or heart rate enables them to observe personal health capacities and adjust future activities accordingly. We first provide detail and limitations on these ways, and then conclude how cycling experiences were given priority over technology when it was possible.

4.3.1 Leveraging digital planning and navigation tools to cater for individual accessibility needs. Digital technology offers various software to plan and conduct accessible trips. Map-based planning tools, such as Komoot, OpenStreetMap or Google Maps can be used to customise routes based on individual accessibility criteria. Depending on the power of the motor or, in absence of one, the power of legs and arms, planning around thresholds for inclines and distance can be critical for accessible activities, primarily in rural areas. While this criterion remains important for non-disabled cyclists as well, disabled cyclists stressed that failing to overcome these barriers can have more severe consequences, "I fell there. And then I am just laying there like a ladybug [on the back]. I have to wait until someone picks me up or until someone happens to pass by and helps me getting up" (P7).

When moving inside the city, cycling infrastructure details become more important. As such, traffic volume and the design of cycling lanes were most relevant when preparing for or navigating shorter trips. For instance, P5 explained that she regularly used Komoot and stated "So they would not provide a notification like 'Caution! This is a bidirectional cycling path and here and there are narrow spaces'" (P5), showing how she envisions to enhance Komoot's navigation feature for moving around the city more easily.

Many handbike users also mentioned the lateral inclination as key feature that determines the accessibility of a path as there is a "risk of tipping over if the path is inclined" (P13), but such data can usually not be inferred from these planning tools. Together with the unavailability of information on narrow spaces, this opens up opportunities to extend current application to cater for more accessibility needs.

Finally, participants underlined that accessibility information about points of interest along the routes are missing as well. For instance, P1 suggested "points of interest that one can configure" (P6), and mentioned (accessible) accommodations, grocery stores, and medical supply along the route.

In contrast, navigation once a trip had commenced was less used or requested in comparison to (digital) information for preparation.

Nevertheless, two participants mentioned additional disabilities that they used visual or auditory way-finding instructions for. P2 explained that a simple guidance on his bike display would help him reduce visual complexity and improve orientation amid his impaired vision, "That offers additional security that I do not need to look around as much, but that the display actually shows me the way [...]" (P2). Likewise, P5 mentioned her difficulty to process visual information due to her disability, and therefore, used headphones with instructions, "I am really happy to have that, because my brain cannot manage this any more. So I just need it. I need the navigation" (P5).

This demonstrates that state-of-the-art digital planning tools bear potential to inform about the accessibility of cycling routes, but require more efforts to consolidate and distribute this knowledge. However, it also reflects the current state of accessibility in cycling infrastructure which is yet not hostile to disabled cyclists, and requires significant re-design as well. Likewise, there are opportunities to employ navigation tools to lower cognitive efforts during the ride, although current implementations do not focus on this use case.

4.3.2 Observing and reacting to abilities with tracking tools. Tools for tracking cycling activities that were initially designed for athletic ambitions are repurposed by the people in our sample to assist them during and after activities to better adapt to their abilities.

Through reviewing activity statistics, disabled people can better assess their current abilities, and avoid situations where they get stuck due to fading power. For instance, P1 explained, "But the computer tells me then [...] how is my reach, is it a constant reach or does it progressively get larger or smaller; in order to be aware of it and know 'Well, the disability currently really stands in my way'" (P1).

Participants also mentioned metrics such as heart rate and cadence that provide valuable feedback on their condition during the activity. This can be especially relevant when disabilities are less predictable and vary depending on the day. Here, P15 explained how she utilises a smartwatch, "to look at the route and the corresponding heart rate, respectively" (P15) to understand "if symptoms get worse" (P10). Further P10 observed the cadence to see if she could "pedal faster" (P10), and adjusts it according to the abilities and planned route.

Consequently, when using sensing and tracking technology, disabled cyclists can observe the current fitness and health status during and after the activity. This provides added value as it eases on-the-go adaptations, and prevents situation where help may be required.

4.3.3 Technology already facilitates access, but needs to be dependable. For the majority of participants, existing technology played an integral role for achieving access to cycling; however, this predominantly concerned the electrified bike used by many participants (see Table 1) rather than other, digital technologies.

For instance, P11 emphasised, "I found out that I can do larger cycling trips again" (P11), and P1 explained "that with an e-bike, you can keep up with the others again" (P1). This highlights that cycling technology directly enables faster and longer cycling activities, and by extension also contributes to social inclusion in group rides.

Some participants also envisioned how novel technology could further enhance accessibility of cycling. For instance, smart retractable training wheels (P1, P13) and (semi-)autonomous cycling (P1, P2, P15) were suggested in response to balance issues and fatigue. Participants also highlighted how solutions already present in cars could be applied to increase the accessibility of cycling, e.g., adding a wheelchair lift to tricycles in order "to independently transfer from the wheelchair [to the tricycle] and fold and store [the wheelchair in the tricycle]" (P5).

While technology offers various tools to improve accessibility (also see sections above), lacking dependability and the corresponding dependencies lead disabled cyclists to scrutinise its applications: "The problem is that every technology brings some kind of error-proneness, and for this, the bike is too important" (P14). This call for dependability was also echoed by P7, "[Dependability] is immensely important for me, because I simply cannot ride this route, because I just cannot put the cycle under the arm and walk away" (P7), illustrating how failure can affect disabled people disproportionally. Here, P14 elaborated how failure reinforces dependencies for maintenance and repair, "So my husband is very important, because he looks at everything technical, because I would not be able to care for some things myself" (P14), an issue that has previously been discussed in the context of assistive technology in low-resource settings [40].

But also in the absence of errors, technology introduces new dependencies. For instance, as a response to the progression of her disability and the decreasing strength in her legs, P5 is required to frequently visit a specialist cycling shop, "They certainly said 'Yes, we can change the torque control so that it gets easier for you'. And I notice that again and again. I have to come again and again and say 'You have to do it again'" (P5). Likewise, access to infrastructure to support technology also played an important role, with one participant outlining that an "opportunity where one can charge the cycle" (P10) is more relevant for cyclists who may not be able to ride their cycle without motorised support.

Thus, disabled people face a trade-off: Using a technology for more cycling abilities and risking failure or discarding a technology and keep certain limited abilities. Consequently, designing dependable technology can strongly effect the empowerment of disabled people.

4.3.4 Cycling is viewed as an opportunity to get away from technology, which should not detract from the enriching experience thereof. Participants in our study strongly appreciated the purity of the cycling experience, and viewed it as a means of getting away from technology, focusing on "meadows instead of screens" (P1), and commenting that "I was always on the phone [...] If it gets boring now and then, taking out the phone, is not possible. That is good" (P12). As a consequence, they preferred a simplification of the used technology. For example, P12 mentioned that "[they] intentionally chose [an e-bike] that has no smartphone app" (P12) in an effort to avoid technology while cycling.

Participants made similar remarks when considering the potential of digital technology to track their cycling experience. For instance, regarding the measurement of performance and health parameters, P13 pointed out that "For me, the outdoor exercise and to get to places is paramount and the pleasure when exercising, not some measuring profiles" (P13). Likewise, P2 explained why he uses a simple colourless display for navigation instead of Google Maps on the smartphone, pointing out that "I think, on the bike, I want to process as little information as possible in my brain [...] this rudimentary simple information 'Ride straight on along the dash' is just really comfortable" (P2). Thus, while technology and its opportunities were acknowledged, unobtrusive integration was highly relevant in an effort to protect their cycling experience.

Analogically, indoor cycling was generally not preferred, e.g., "So I rather like to ride outside when the weather is bad than ride in this boring room, where I put myself in the cellar and pedal against the wall" (P13). Instead, participants rather associated indoor cycling with disability (to be active outside) and found little motivation except for health care, e.g., "So I had more health issues for some time, and then I used it more, because there it was pretty good. And now, I prefer to cycle outside" (P14).

Overall, this highlights that technology fuels accessibility but is moved into the background when possible, foregrounding the experience of outdoor cycling.

5 Discussion

Cycling for people who have a mobility disability presents diverse challenges and opportunities, emerging from a heterogeneous target group (cf. [26]) that has unique requirements for cycles, for example, ranging from non-motorised two-wheeled cycles with in-step adaptions to recumbent handcycles with strong motors (see Section 4.1).

Our results demonstrate that technology already greatly influences accessible cycling. E-bikes serve as critical facilitator of mobility. They offer its users more reach, speed, and less exhaustion in comparison to non-motorised cycles and traditional mobility aids (see Section 4.3.3). Planning and navigation tools can be repurposed to address accessibility as they already partially provide valuable information on accessible routes (see Section 4.3.1). Additional tools, including route tracking and heart sensing applications, that help disabled users assess their current cycling abilities and plan accordingly complement the usage of technology (see Section 4.3.2). Our results partially align with Khurana et al. [28]'s findings on adaptive sports: The complex (maintenance of) equipment and the availability of data also appear to be key to accessible cycling. However, reflecting the limited athletic ambitions in our sample, (video) analysis and sports performance tracking were not central.

Further, while technology can contribute to making cycling more accessible, there are currently important limitations to its usage, such as lacking dependability of hardware and missing accessibility data and features of software. Consequently, technology fails to fully empower disabled cyclists, and interferes with the original cycling experience rather than promoting it, leading to a curated and reserved usage.

Our discussion contributes the following: (1) We relate our work on accessible cycling and technology to the broader efforts in the CyclingHCI community by appraising Matviienko et al. [33]'s grand challenges from the perspective of mobility disability, and (2) We draw on participants' perspectives to derive design goals and future avenues for technology to improve the experience of disabled cyclists.

5.1 Revisiting the Grand Challenges in CyclingHCI

In 2024, Matviienko et al. [33] proposed ten grand challenges in CyclingHCI on the basis of a literature study, focusing on three areas: (1) Pushing the technological boundaries for cycling, (2) Understanding and protecting cyclists, and (3) Spatially situated cycling interaction. Our work offers the opportunity to review the challenges from the perspective of disabled cyclists. We find support for *(C1) Reducing cyclist's reliance on technology*, *(C9) Facilitating cyclists' interactions with other road users*, and (*C10) Maintaining cyclists' connection to surroundings*, whereas *(C3) Create cycling technology suitable for intense exertion* and *(C4) Creating realistic, safe, and motion sickness-proof bicycle simulators* may not be central to disabled cyclists as only few participants showed interest in extensive exertion and indoor cycling (see Sections 4.2 and 4.3.4). Instead, we further propose an additional challenge that highlight the characteristics of CyclingHCI and accessibility.

For *C1*, minimising reliance on technological support as much as possible and relying on one's own judgements was relevant for many disabled cyclists in our sample (see Sections 4.1.1 and 5.2.2). Here, we propose to include the dependence on other people in case of failure as important consequence related to reliance on technology (also see Section 5.2.1). This includes ride companions (e.g., family, friends, or caregivers as assistance), cycling specialists (e.g., technicians for maintenance and repair), but also people initially unrelated to the activity (e.g., bystanders that offer in-situ assistance). Matviienko et al. also suggest that technology should rather be in the position of a coach, which, in the context of accessible cycling, could be especially useful when learning to operate a larger cycle. Regarding *C9*, interfaces promoting "prosocial behaviour on the road" may not only be relevant for car-to-bike communication, but also for bike-to-bike or bike-to-pedestrian communication, especially as many participants mentioned cases where the perception of an accessible cyclist was unclear (see Section 4.2.3). Lastly, *C10* calls for "engag[ing] with the act of cycling" as cycling does not detach from place, time, and community. This is in line with our results that highlight connecting with nature and the opportunities for social inclusion (see Section 4.2). Consequently, promoting this attachment could further strengthen the benefits of accessible cycling.

These extensions as well as the opportunities of accessible cycling and the various purposes of the corresponding cycles (also see Section 4.2) suggest that accessibility further extends how researchers need to reflect upon CyclingHCI in the context of accessibility. Here, we suggest the inclusion of a new challenge: *C: Improving accessibility in and through cycling*: CyclingHCI needs to adopt perspectives within accessibility research as an additional lens for the research of technology design, development, and usage in this context to fully reflect the lived experience and requirements of users of technology for accessible cycling (e.g., [3, 23]). In this context, a specific focus should lie on the conflation of the cycle and the mobility aid: Traditional cycling technology does not regard the cycle as mobility aid, and critical applications may be disregarded or not be regarded as such.

5.2 Design Goals for Accessible Cycling Technology

Grounded in the participants' lived experiences, we propose three design goals for future technology for accessible cycling, and give concrete use cases for accessible cycling that illustrates how each goal might be implemented.

5.2.1 Technology for accessible cycling must be reliable to keep users safe and support their self-determination. If dependable, i.e., if failure can be minimised, accessible cycling technology can boost mobility and inclusion, and therefore, personal freedom and independence[2] (see Sections 4.2.1, 4.2.2, and 4.3.3). If unreliable, disabled cyclists are likely to discard technology that, in case of failure, causes unsafe situations, limits independence and reinforces dependency on other people. This can become especially relevant if dependencies are "injected" [46], i.e., if technology is designed to require additional time and attention or regular maintenance.

Example implementation of the goal. In the case of e-bikes, the following measures could improve this ratio, i.e., increase dependability and minimise dependencies: Basic functionality of the cycle (e.g., starting the motor) should not require interaction with an app so that secondary sources of failure are eliminated, and all critical features should be implemented following the principle of redundancy (e.g., feedback on battery charging status could be displayed via an app as well as via functionality directly added to the battery, e.g., a button and lights). This way, technology becomes an add-on that supports the cycling experience, while cyclists can enjoy peace of mind that back-up systems are in place. Finally, reliable technology should not add further financial burden.

Avenues for future research. When optimising for accessibility, researchers may take into account the concept of *consequence-based accessibility* that opposes the duality of (in)ability and instead proposes that actions have consequences with a different degree of accessibility [30]. Here, disabled people calculate the consequences of an action, e.g., riding a cycle with a motor that increases their mobility and quality of life but which may fail during the ride and leave them stranded at a remote place. Consequently, before adding new technology to accessible cycles, researchers need to consult the target group early to collaboratively do this calculation and propose changes with a positive action-to-consequence ratio [31].

5.2.2 Technology should empower disabled cyclists by providing the tools to self-assess barriers and better understand personal abilities. Technology should empower disabled people to leverage their expertise of their bodies and abilities [45], reflecting the heterogeneity of requirements and experiences (see Section 4.1). Software and wearable technology that is not primarily designed to address accessibility needs, may be re-purposed for planning and navigating accessible routes (see Section 4.3.1) as well as ability observation (see Section 4.3.2). Planning, navigation, and tracking tools bear potential to extend beyond current use cases, offering more accessibility features, such as accessible routing that avoids barriers and incorporates accessible points of interest. However, this also entails continuous updates to and maintenance of these databases. Additionally, observation tools need to reflect the realities of disabled people, overcoming a disconnect between provided metric and perceived energy levels [27].

Example implementation of the goal. Route planning and navigation platforms such as Komoot could consolidate and supply more data on the accessibility of routes. While information like path surface is already provided, the width, lateral inclination, and illumination at night are not displayed. Further, barriers (such as bollards or curbs) and disability-friendly locations (such as accessible cafés or accessible bike parking) should be included as points of interest, e.g., by integrating currently available services like wheelmap[3]. Recent work in HCI by Hwang et al. [24] has also demonstrated how vision language models can complement such databases in the future by analysing streetscapes and finding barriers automatically to make personalised routing suggestions for cyclists. Additionally, designers of observation tools can specifically develop metrics that better reflect the disabled person's subjective energy level but also highlight how the support of the electric motor has affected it.

Avenues for future research. CyclingHCI research could further expand on personalised accessibility. Here, artificial intelligence (AI) tools, such as large language or vision language models, can address nuanced accessibility requirements, but may also compromise empowerment if self-assessment is restricted or dependability is lacking (cf. [15], also see Section 5.2.1). Consequently, a focus in human-AI interaction may lie on the preservation of empowerment: Research needs to reflect on methods that provide valuable and nuanced personal route planning and navigation and minimise intervention in self-assessment.

5.2.3 Technology needs to preserve the original cycling experience. Cycling provides various benefits, including connecting with nature, fostering social relationships, and enhancing mobility with disability in general (see Section 4.2). Therefore, efforts to integrate technology into accessible cycling should always centre these experiences and benefits. This may entail technology that is unobtrusive and can be disconnected easily. Particularly, it should not distract from the activity (i.e., require little interaction and attention), be trustworthy (i.e., offer carefree usage (also see Section 5.2.1)), and only be employed upon request (i.e., limited technological intervention should be given priority). Accordingly, this also entails that wherever possible, technology should not promote indoor cycling instead of outdoor cycling.

Example implementation of the goal. Instead of developing new navigation or tracking features that heavily rely on displays during the activity, designers could rather prioritise application cases before or after the activity. Here, in addition to accessible planning tools used before the activity, heatmaps or other forms of illustrating the completed activity, such as Relive[4], may accentuate the value of newly acquired mobility and further fuel curiosity and motivation to utilise the cycle. Likewise, systems that detail the performance on-the-go would distract from the valued experience in nature by overly focussing on performance aspects, which are not central to many disabled cyclists.

Avenues for future research. Research could further explore how the (non-)use of technology and the design of unobtrusive

[2]Here, we note that disability-justice perspectives acknowledge self-determined independence, and critically questions perspectives that view independence as superior and more healthy living with disability [49, 50].

[3]https://wheelmap.org (accessed on April 9th, 2026)

[4]https://www.relive.com (accessed on April 9th, 2026)

technologies can facilitate the cycling experience for disabled people. Here, frameworks, such as Mueller and Young [38]'s 10 Lenses to Design Sports-HCI, can serve as a basis to narrow down how the values of cycling interact with disability and to what extent technology can foster or undermine the cycling experience.

6 Limitations

To better contextualise our findings, we want to highlight limitations that we consider relevant for interpreting this account: Participants' lived and experienced accessible cycling mostly in Germany, and are accustomed to the country-specific cycling culture and history. For instance, some cities only slowly adapt to a growing cycling culture and retain a mostly car-centric infrastructure. In comparison to North American cities, this is a fast progress, but results in this study may rather reflect comparisons to Germany's neighbouring countries. Likewise, missing accessible infrastructure and administrative barriers for disabled people in Germany, such as complicated processes to receive financial support, translate to further barriers in accessible cycling. While we exploited diverse channels for recruiting, our sample had a high level of experience with accessible cycling and had already acquired (expensive) cycles for themselves. Consequently, the perspectives of those who cannot afford or could not find a suitable accessible cycle (yet) may be under-represented. Similarly, despite not excluding this community, our results do no cover lived experiences of people who cannot cycle alone, e.g., who use a rickshaw for their wheelchair. Thus, including these groups, but also other of disabled cyclists, such as cyclists who are blind or have low vision or cyclist who are neurodivergent, could further expand the discussion on technology in the context of accessible cycling. Finally, in line with the subjective nature of this method [6], this account may reflect our own lived experiences with (accessible) cycling (also see Section 3.4).

7 Conclusion

There are many challenges but also facilitators of accessibility, inclusion, and wellbeing in cycling for people who have a mobility disability. Our work highlighted the individuality of disability reflected through the heterogenous approaches to accessible cycling as well as how cycling can fuel wellbeing and social relationships. Technology plays an important role in accessible cycling through the electrification of cycles, but also through planning, navigation, and tracking tools. While this can positively affect accessibility, our results underline the curated use. Disabled cyclists request dependable technology that also does not conceal the purity of cycling experiences. These perspectives prepare the ground for the prospective use of technology in accessible cycling, centring reliability, self-management of barriers, and the original cycling experiences as critical goals.

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