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Cyclists' phone use in relation to proximate environmental characteristics - A qualitative study

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ABSTRACT

Introduction: The use of phones in traffic can cause distraction and thus affect the safety of cyclists. Unlike distractions external to the cyclists, phone use is initiated by the cyclists themselves, but is always performed in a contextual setting that affords, moderates, or constrains the action. The purpose of this study is to investigate how the proximate environment, including cyclists' personal items, affects cyclists' phone use with the aim of improving the development of preventive measures.

Methods: The empirical foundation is 19 qualitative, semi-structured interviews with cyclists in Denmark ($n = 9$) and the Netherlands ($n = 10$). We use thematic analysis and affordance theory to identify proximate environmental characteristics that facilitate or inhibit phone use while cycling and discuss the results in relation to cognitive dual-process theory's distinction between impulsive and reflective behaviours.

Results: Characteristics of bicycle design, clothes, and infrastructure design offer accessibility and suitable conditions for phone use and are associated with whether cyclists use their phone in traffic, how they use it, and for what purpose.

Conclusions: The distinction between impulsive and reflective phone use highlights a need for preventive measures that considers decision-making processes. Findings on associations between phone use and proximate environmental characteristics suggest use of phone accessories (e.g. headphones), inaccessible phone placement, and muting notifications as strategies to prevent impulsive use, while legal measures possibly limit reflective phone use.

1. Introduction

In this paper, we investigate how proximate environmental characteristics contribute to cyclists phone use. The possession of handheld electronic devices has increased over the recent years (Aguilera, 2018) and is a potential source of auditory, motor, and cognitive distractions (SWOV, 2017). As inattention is a contributing factor behind approximately 20% of cyclist crashes (Huemer et al., 2019; Møller et al., 2021) and cyclists are at particular risk of both severe injuries and fatalities due to their lack of exterior protection (Reynolds et al., 2009), phone use is likely to affect cyclists' safety (De Angelis et al., 2020). Cyclists listening to high volume and up-tempo music have delayed responses to auditory cues (De Waard et al., 2011) and engagement in demanding phone conversations decrease the peripheral visual detection (De Waard et al., 2010). While slowing down is sometimes used as a compensatory strategy for phone use while cycling, the use of portable electronic devices is known to be connected to a higher probability in crash

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risk among teenagers and young adults (Goldenbeld et al., 2012). Further, Terzano (2013) found an association between cyclists' engagement in secondary tasks and the performance of unsafe behaviours. Young et al. (2020) suggested cyclists' phone use might be more prevalent in high-cycling countries with designated cyclist infrastructure designed to forgive errors and violations (Dumbaugh and Li, 2010). These include countries Denmark and the Netherlands, who since 2000 have experienced a slower decline in the number of killed cyclists compared to car drivers (Buehler and Pucher, 2020; ITF, 2020; Santacreu, 2018). Though it is uncertain if phone use contributes to this, this trend in combination with technological advancements of phones and related services creates a demand for research on cyclists' phone use.

1.1. Factors and behavioural adaptions related to cyclists' phone use

Previous studies have identified several underlying factors and specific characteristics of cyclists' phone use. Huemer et al. (2019) found a higher prevalence of phone use during morning hours, and among female and young cyclists. Lower age was confirmed to increase the probability of phone use by other studies (Christoph et al., 2017; Young et al., 2020) and was additionally associated with particular high-risk phone use, for example using multiple functions at once (Jørgensen and Øhlenschlæger, 2020). Jiang et al. (2019) identified a number of psychological determinants predicting cyclists' phone use: Positive attitudes towards the behaviour, social norms, and perceived behavioural control were found to indirectly contribute to a higher probability of the behaviour mediated by the intention of phone use. Moreover, mobile phone addiction was found to contribute to both increased use and user intention. Specific personality characteristics were also linked to cyclists' phone related behaviours. An Australian study connected a high score in the trait extraversion with an increased probability of technology-based secondary task-engagement, while a high score on conscientiousness deceased the probability (Young et al., 2020). Additionally, high perceived distraction (Jiang et al., 2019) and perceived risk (van der Kint and Mons, 2019; Young et al., 2020) were associated with decreasing probability of technology-engagement while cycling.

In relation to this, some cyclists were found to make use of compensatory strategies. Slowing down, increasing visual scanning, using headphones (Adell et al., 2014; Ahlstrom et al., 2016; Jungnickel and Aldred, 2014; Stelling-Konczak et al., 2018) and further positioning from the curb (De Waard et al., 2015) were identified as behavioural adaptions among phone using cyclists. Such adaptions can be understood as a way for cyclists to manage risk (Chaloux and El-Geneidy, 2019; Ihlström et al., 2021), and are in support of risk homeostasis theory (Evans, 1986). Additionally, motivations behind phone use during transport include sensory stimulation (Jungnickel and Aldred, 2014), and easing the planning of everyday activities among family members (Hjorthol, 2008).

While the previous studies provide a foundation for understanding the underlying factors behind cyclists' phone and related behavioural implications, they do not address how the behaviour is initiated. Environmental factors have been explored in relation to cycling levels (e.g. Blitz and Lanzendorf, 2020; Kerr et al., 2016; Mertens et al., 2016; Nielsen et al., 2013), and a recent publication used hospital data to identify proximate environmental characteristics like clothing, road design, and specific bicycle defects as contributors to cyclists' crashes (Møller et al., 2021). In this paper, we focus on how characteristics of the proximate environment, including properties of the bicycles and phones, relate to cyclists' phone use.

1.2. Linking cyclist safety and affordance theory

Larsson et al. (2010) argue for a systems theory approach to traffic safety that include social, socio-technical, and biological aspects, in contrast to an isolated focus on the individual's decisions and responsibilities. Gibson's *theory of affordances* (1977) is among the most prevalent theories linking material objects with psychological representations and behavioural outcomes. With the concept of affordances, Gibson presents the idea that properties of material objects offer and encourage specific actions. What type of actions they encourage, depends on the cognitive processing, which is mediated by experiences and embodied characteristics of the recipient. We apply this approach and extend the concept of cyclists' phone use from a decision made by the individual to an outcome enabled and articulated by multiple factors. To discuss the identified affordances we use Strack and Deutch's (2004)two-system model as a framework. This theory, like other dual process theories (e.g. Kahneman, 2003), define psychological decision-making processes as part of either an impulsive system; that works by associative processes and heuristics, or a reflective system; that draws on active decision-making and conscious values. We further discuss implications of the results for traffic safety prevention.

2. Methods

2.1. Data collection

Using a cross-country approach, we conducted qualitative interviews in Denmark and the Netherlands, both known for their high cycling levels (see also Section 2.4). Inclusion of multiple countries enables identification of specific potentials, similarities, and differences (Fraboni et al., 2021; Haustein and Nielsen, 2016). Through the conduction of qualitative interviews we collected multiple and detailed descriptions of both proximate environment and reasoning across settings and time, which enabled us to identify whether the same cyclists had varying behaviours in relation to different environmental characteristics and how possible adaptions were reasoned. To secure a level of comparability across interviews, we developed a semi-structured interview guide, which allowed interviewees to raise additional themes (Brinkmann and Kvale, 2015). The guide was inspired by the existing literature on cyclists' phone use and covered the topics: *reasons for (not to) use phones while cycling*, *compensatory strategies, perceived risk of the behaviour*, *descriptions of phone use*, *social acceptance*, and *the role of the legislative measures*. In addition, we formed a short questionnaire to collect basic

descriptive information about demography and transport behaviours (see summary in Table 1). Upon request, the regional scientific ethics committee in the capital region of Denmark informed us ethical approval was not necessary for this project.

2.2. Procedure and participants

The sample consists of 19 cyclists between the ages of 17 and 61 years (see Table 1). To be included in the sample, the interviewees had to be minimum 17 years old, consider themselves cyclists, and live in the Copenhagen area (Denmark) or in South Holland (the Netherlands). We recruited all interviewees by word of mouth or through social media. During recruitment and again at the beginning of each interview, we informed the cyclists that participation was voluntary, and that data would be stored securely in compliance with existing data protection rules and only used for dissemination in an anonymous format. We then obtained their signature on a statement of informed consent. All interviews were conducted face-to-face by the first author, between December 2018 and May 2019, and lasted approximately 30–45 min. The language was either Danish or English. All interviews were audio recorded and transcribed verbatim by the first author.

2.3. Data analysis

Inspired by Braun and Clarke (2006), we used a thematic approach to guide the analysis. In this paradigm, analysis is a reflexive and inductive process of collating interview extracts into themes relevant to the specific research question. The initial transcription process and reading of transcriptions was used to familiarize with the data. To obtain an overview of the data, the first author coded all transcriptions inductively into preliminary themes (see Fig. 1), and exported a subset of extracts containing *material items and environmental characteristics* to a new document, as only these were relevant for the research question. With the focus on identifying characteristics that afford, moderate, or constrain cyclists phone use, the first author then coded the subset by summarizing extracts and assigning these inductively into codes constituting the themes: *Bicycle design, Phones and equipment, Clothing and bags,* and *Physical and social environment*. The final analysis was approved by all authors. Legal differences and associated law enforcement is included as part of the physical and social environment. All other aspects related to national differences are addressed under the relevant themes.

2.4. Study settings

Denmark and the Netherlands are both known for their high level of cycling, flat topography, and political measures to support cycling (Haustein et al., 2020; Koglin et al., 2021; Nielsen et al., 2015;Pucher and Buelher, 2007; Van Goeverden et al., 2015). In both countries, the youngest cyclists (Denmark: 10–19; the Netherlands: 0–17) use the bicycle for daily trips more than other age groups (Buehler and Pucher, 2012). Previous research has shown a relation between age and phone use, with the use being most widespread amongst Dutch cyclists between 15 and 34 years old. Among this age group, 71%–74% report using their phone occasionally while riding their bicycle (Christoph et al., 2017). At the time of the interviews, Danish law forbid handheld phone use for cyclists, while it was still legal in the Netherlands. Other differences include that Dutch cyclists on average ride longer distances and use bicycle for a greater share of trips compared to Danes (Buehler and Pucher, 2012). Helmet use is much more prevalent among cyclists in Copenhagen (19.9%) than in Amsterdam (1.1%) (Markus et al., 2019). Despite the differences, the relative risk of death by exposure is 0.9 per 100 million kilometres in both countries (Buehler and Pucher, 2020).

Table 1
Overview of interviewees, presented with a cover name, and relevant characteristics.

Name[a]	Country	Gender	Age	Bicycle type (most used)	Most used transport mean	Phone type
Viggo	DK	M	24	Regular two-wheeled bicycle	Walk	Smartphone
Mads	DK	M	25	Cargo bicycle (two wheels)	Bicycle	Smartphone
Louis	DK	M	30	Regular two-wheeled bicycle	Bicycle	Smartphone
Kasper	DK	M	34	Regular two-wheeled bicycle	Bicycle	Smartphone
Sarah	DK	F	28	Regular two-wheeled bicycle	Bicycle	Smartphone
Camilla	DK	F	28	Regular two-wheeled bicycle	Public transport	Smartphone
Ida	DK	F	32	Cargo bicycle (three wheels)	Walk, bicycle, + public transport	Smartphone
Susanne	DK	F	60	Regular two-wheeled bicycle	Bicycle	Push-button
Lisa	DK	N	29	Regular two-wheeled bicycle	Bicycle	Smartphone
Max	NL	M	24	Racing bicycle	Walk + Public transport	Smartphone
Ruben	NL	M	31	Racing bicycle	Public transport	Smartphone
Stijn	NL	M	42	Racing bicycle	Car	Smartphone
Julian	NL	M	49	Racing bicycle	Bicycle	Smartphone
Diederik	NL	M	61	Racing bicycle	Bicycle	Smartphone
Sophie[b]	NL	F	18	Regular two-wheeled bicycle	Bicycle	Smartphone
Olivia	NL	F	24	Regular two-wheeled bicycle	Walk + Public transport	Smartphone
Fenna	NL	F	42	Cargo bicycle (two wheels)	Car	Smartphone
Iris	NL	F	47	Regular two-wheeled bicycle	Bicycle	Smartphone
Elin	NL	F	59	Regular two-wheeled bicycle	Car	Smartphone

[a] Cover name.
[b] Dane living in NL. Abbreviations: DK: Denmark; NL: the Netherlands; M: Male; F: Female; N: Non-binary.

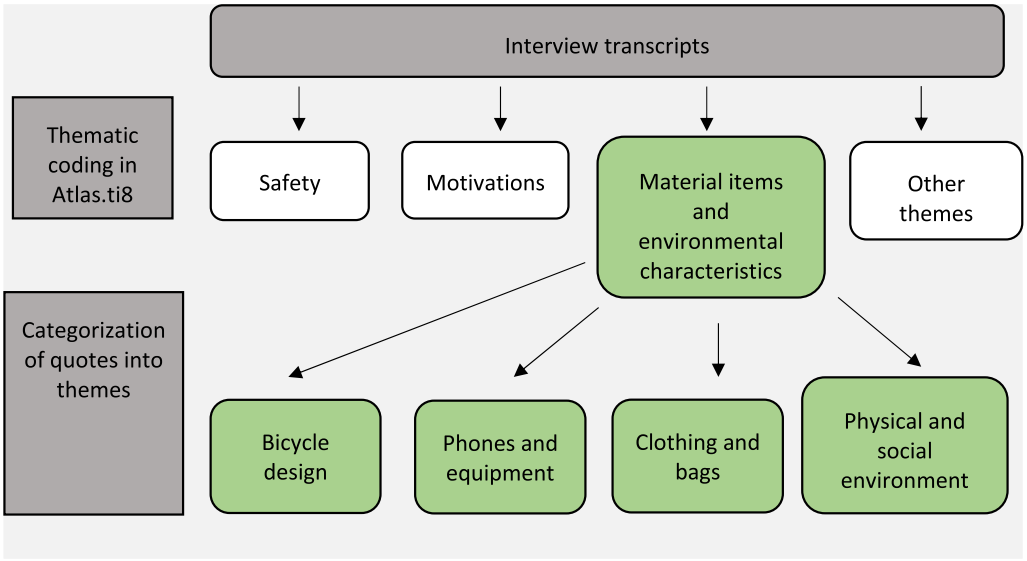

Fig. 1. Analytical process of extraction of the data subset *material items and environmental characteristics* and further categorization into thematic categories.

3. Results

The presentation of the results corresponds to the four themes generated in the analysis, but with more specific titles: *Bicycle design and equipment, Clothing and bags, Phones: equipment, functions, and related services,* and *Physical and social environment*. Under each theme, we identified characteristics connected to cyclists' phone use, supported by interview extracts to provide the reader with rich descriptions and an overview of how results derived from the analysis. Created with inspiration from Bronfenbrenner's (1979) ecological systems theory, Fig. 2 shows categories identified in the analysis arranged according to how easily cyclists can influence them. All categories from Fig. 1 are described under the relevant headings.

3.1. Bicycle design and equipment

Table 1 presents the interviewees and their type of bicycle. Some – mainly those using a bicycle as main transport mean,– owned or had access to multiple types of bicycles, often with different designs assigned for different purposes. Our analysis indicates that the cyclists associate bicycle design with different types and levels of crash risk, and regulate behaviours to mitigate this risk accordingly. This was prevalent concerning both phone use and other behaviours, and below we include examples of how the bicycle types affected helmet use to support the argument of a relation between bicycle characteristics and behaviours.

Among cyclists with multiple bicycles, some reported only using a helmet in specific situations and on specific bicycle types:

> *if you go to the grocery store, you don't put on a helmet. Come on. You are on your oma fiets* [grandma bicycle = step-through frame], *why should you wear a helmet? I mean it's perfectly logical if you go out on a mountain bike, or you go on a racing bike with a group or something, you put on a helmet, but for other cases; not necessary* (Julian, 49, the Netherlands).

And

> *Well it's* [riding a recumbent] *like being on your sofa, yes. And when I had that, I wore a helmet always. Because it was lower, and you are not as visible as on a normal, normal bike. But since I don't have that sofa-bike anymore, I don't wear a helmet anymore. When we* [Diederik and his wife] *are together, or alone on a racing bike then yes. Then I usually wear one* (Diederik, 61, the Netherlands).

This distinction was particularly prevalent among Dutch cyclists. None of them wore a helmet at all times, but some chose to use one when riding specific bicycle types. On the contrary, Danish interviewees had an overall positive attitude towards helmet use, including those not using one themselves.

The type of bicycle was also linked to phone use – both as a music device and for communication purposes, which often required handheld operation. The properties of the bicycle type create the foundations for how effortless the cyclist can perform different phone-related tasks while riding. For example, the lightweight and aerodynamic design of racing bicycles allows the rider to go fast, but the speed simultaneously entails constant awareness of surroundings. By contrast, a three-wheeled cargo bicycle lets the cyclist stay balanced without effort; it is highly visible, slow due to its weight, and the rider will often block the cycle path due to its wideness. An interviewee shifting between these two bicycle types described how such features affected his phone use:

> *if I am on the cargo bike then I am much more prone to do it* [operate the phone]. *If I am on the fixed-gear bike then never. […] Because it is a bit more complex to ride. It requires some more attention and hands on* (Kasper, 34, Denmark).

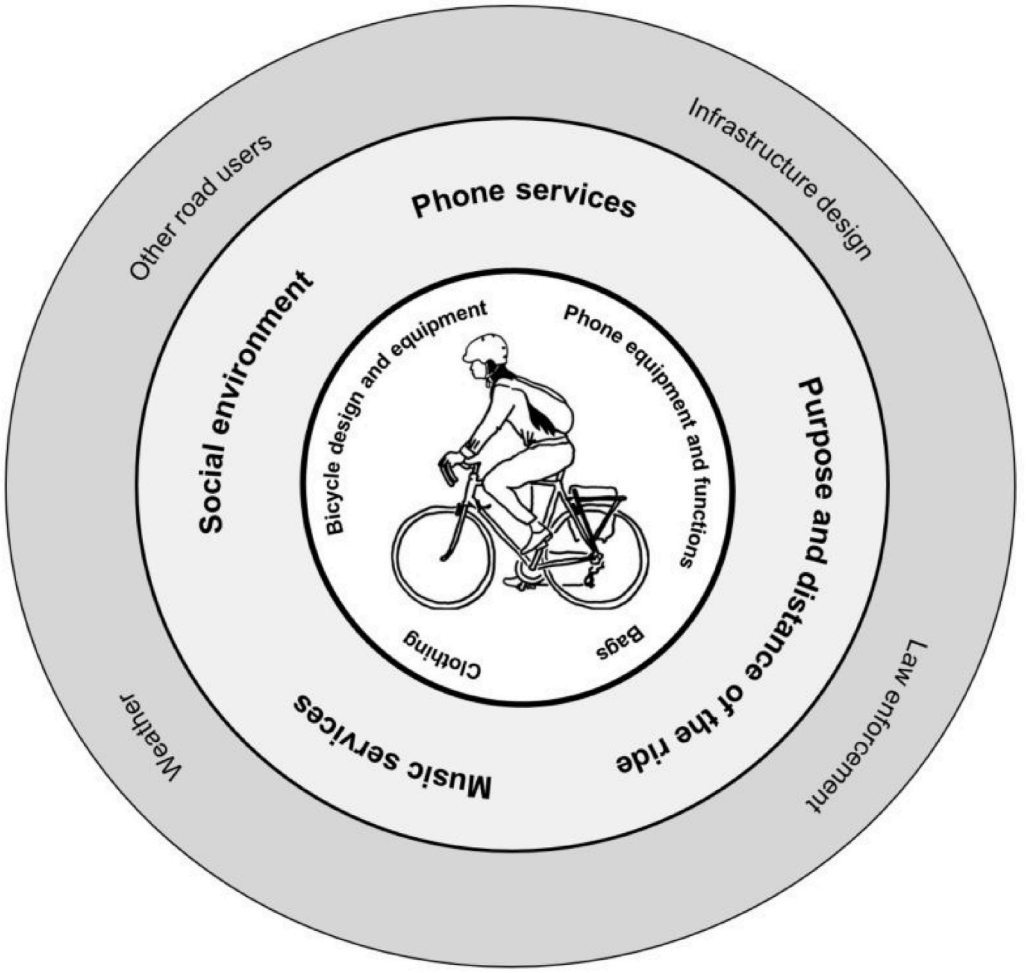

Fig. 2. Overview of the identified categories of proximate environmental characteristics associated with cyclists' phone use in traffic. The circles represent how easily cyclists can affect the characteristics related to phone use, with highest possible direct impact on items in the inner circle and lowest impact on categories in the outer circle.

Another cargo bicycle user also highlighted this distinction:

> *And sometimes I simply ride and text, eh, because I have a cargo bike, right? So it's a bit easier, you can- you can text and ride at the same time, contrary to a racing bike […]* (Ida, 32, Denmark).

The discrepancy was also present for other bicycle types and phone use that did not require handheld operation:

> *I never do it* [listen to music] *when I'm on the racing bike, because you don't participate in traffic, if you, if you ride with headphones on. […] on the city bike, yes. When I go to the, from my house to the cinema or something, or I meet up in the city, usually I go with headphones and music on* (Stijn, 42, the Netherlands).

The last quote indicates a relation between bicycle type, trip purpose, and type of location (i.e., city, countryside, forest), which is explored further in Section 3.4.

Among the central design characteristics that define a bicycle are the frame construction and handlebar. These determine the angle, position, and weight distribution of the rider, and thus affect how easily cyclists can access their pockets or text while riding:

> *I use my phone when riding my grandma bike, but not on my mountain bike […] I ride much faster on my mountain bike. And also my position. I sit like this* [she bends forward to illustrate the point]. *I don't want to text like that* (Sophie, 18, the Netherlands).

Other design properties also had a connection to cyclists' phone use. Non-compulsory equipment, like baskets and racks, provides a space for bags, groceries, and other belongings. Baskets fastened to the handlebar afford reachability of the content, and thus provide a space to keep the phone within a proximate distance that enables phone use more effortlessly. Direct positioning in front further affords the visible and/or audible salience (e.g. when the screen lights from a notification) and the option to use the phone:

> *if it* [the phone] *is right in front of you in the basket then you can just quickly check it while waiting for the traffic light* (Sarah, 28, Denmark).

In Sarah's example, the basket offers easy access to the phone, which the forced stop at the traffic light then actualizes. The environmental characteristics are thus also interrelated in how they may affect behaviours, and behaviours may also affect environmental characteristic. As an example of the latter, we identified a bidirectional relation between bicycle design and phone use, in the sense that phone use also change what equipment cyclists add to their bicycle. This was emphasized by a Dutch bicycle courier, who's colleagues had bought handlebar phone mounts to use their phones as a GPS while riding. Despite the need for navigation, he chose not to use this solution, because the proximity of the phone would tempt handheld interaction, which he perceived unsafe:

> *I'm one of the only guys that doesn't have it on his steer- I don't like that. I don't want to have it all the time in front of me, because then I'm going to touch it* (Ruben, 31, the Netherlands).

3.2. Clothing and bags

Clothing and bags also provide the ability to store the phone while riding. With this is mind, some cyclists consciously placed their phone either within or outside immediate reach:

> *It is kept so one can easily take it out, in case it rings then I can just grab it. […] It has to be within direct reach* (Susanne, 60, Denmark).

Other cyclists did not have a specific place for their phone, but found the most suitable solution from time to time. In such situations, clothes and phone characteristics limited possible storage options:

> *It depends on which jacket I wear […]. Sometimes, I've got it in my bag, because the pocket is not big enough for my phone. I have quite a big phone* (Sophie, 18, the Netherlands).

To follow up on implications of this, the interviewer asked whether keeping the phone in the bag affected how much it was used:

> *Yes, then I don't use it at all* (Sophie, 18, the Netherlands).

Several of the other cyclists also emphasized that clothing can facilitate proximity and plays a role in how much they would use their phone while riding:

> *It depends on my clothes, but if I am for instance wearing one of those thermo jumpsuits that has a small pocket right here* [she points to her chest] *then I can open it in case I receive a text, and then I open and check, right? Er, but if it is in my bag, then I don't think so much about it, you know? The closer it is to me, the more I check it* (Ida, 32, Denmark).

And

> *if it's in the bag on my back then the it's like, then there is not much to do, or like then you don't see it […]* (Sarah, 28, Denmark).

What type of clothes they wore related to external factors, like the weather, which forced some to have seasonal variation in their phone placement.

Some interviewees used phone communication while cycling as part of their job. A Dutch bicycle courier described riding with his phone in his left hand, despite being right-handed. At first, he did not have an explanation for his choice of hand, but then he went through the process in his mind; he mimicked reaching for his phone and then said:

> *I do it differently, because I always have the phone in my left jersey pocket* (Julian, 49, the Netherlands).

He then explained that he could reply with a *yes* or *no* using left hand only, but would have to stop to perform more complex tasks. Clothing characteristics, like placement and angle of pockets, thus both afford cyclists' phone use and *how* they use phones. Clothing characteristics were further related to the purpose of the trip as some cyclists (also) cycled for physical training and wore specific clothes.

3.3. Phones: equipment, functions, and related services

For a Danish cyclist, practical circumstances inhibited his choice of using his phone while cycling:

> *The last time I didn't listen to music, was because my headphones broke. And otherwise then I, eh, share my Spotify subscription with* [name of girlfriend], *and if she is listening, I sometimes don't* (Mads, 25, Denmark).

The last part of the quote points to an impact from external factors, as some music streaming providers have a limit on users simultaneously from the same subscription. Web-based music streaming additionally offers an almost unlimited amount of music available at all times, which a Danish cyclist described would cause her to change track whenever she felt like it:

> *I can listen to music on iTunes; on Soundcloud; Spotify. So if I'm listening- if I'm cycling and listening to a track then it might be 'well, I feel like listening to another track', and because it's available, I can choose another app. When we had iPods, it just played a playlist* (Ida, 32, Denmark).

Further, the number of available functions in smartphones has increased. Now cyclists have the option to perform a wide variety of tasks while riding:

> *Times have changed. The phone does everything now, right? It's where I get my emails, and messages, and like Facebook messages, and calendar, and […]. You've got everything on the phone now, right?* (Ida, 32, Denmark).

And

I change my music a lot when I'm riding my bicycle. And I use it when I get calls sometimes, [and] *to see where I have to go […]* (Max, 24, the Netherlands).

The bicycle courier who in Section 3.1 stated he preferred not to mount his phone to his handlebar, still used his phone for navigation. His reason for using his phone, and not a GPS device, was a combination of practical and financial interests:

I mean you could use this Garmin stuff or other navigation GPS stuff, but it's quite expensive and I have an iPhone, so I just use my iPhone for that (Ruben, 31, the Netherlands).

The fact that the phone constantly offers the possibility to do other tasks while cycling lead some to experiences of habitual phone use performed without a specific purpose:

Do you know, when you plan to do something? I consider [sending] *a text, which is more or less unimportant, and before I make the decision that it is unimportant, I have the phone in my hand and prepare to type something in. Because the body is sometimes a few steps ahead, right?* (Kasper, 34, Denmark).

The physical features of the phone and headphones also had a connection to whether and how the cyclists would use their phones. Headphones with buttons enable the cyclist to accept a call or change music without handheld operation of the phone:

I've just got new headphones, so now I can change everything close to my ear. Then I don't look at it [the phone] (Sarah, 28, Denmark).

And

It [the use of buttons on the headphones] *has been very cool when I've been listening to music. Er, because then you could, well you don't have the same need to operate the phone. And then sometimes, I put it away for a bit, I put it in my bag in my* [cargo] *bike* (Ida, 32, Denmark).

Others deliberately avoided music and headphones to enable detection of traffic sounds:

[…] sound is an essential part of your orientation, yeah, and before you can look if something is coming, you already hear something is coming. So if you have, if you have headphones, I think that's really crazy (Ruben, 31, the Netherlands).

Used only one earbud or keeping the volume at a low level allowed cyclists to detect audio inputs from the immediate traffic while receiving audio (calls, music, radio, or navigation) from the phone:

I've got it [the volume] *right in the middle, so I am able to hear the music but also what is happening in traffic* (Sophie, 18, the Netherlands).

Another cyclist used the built-in speaker on full volume to receive audio cues for navigation while keeping his phone in his pocket to enable reception of traffic sounds. Another strategy to minimize phone-induced audio distractions was to turn off notifications before starting the ride. This strategy was mainly used for longer trips because longer trip time increased the likelihood of disturbance:

Yes, especially if I'm going to work for about half an hour or so then I do it [turn off notifications], *because it is likely that something will happen within that time. If it is only a ten-minute ride then I might not do it* (Lisa, 29, Denmark).

3.4. Physical and social environment

Cyclists' descriptions often related to specific experiences with a main focus on proximate surroundings. Because of this, this section only briefly touches upon broader social and societal impact, but does include country specific national characteristics like legislation and (perceived) cultural differences. The cyclists described making adaptions to the physical environment when using their phone:

[…] if there are not a lot of cars around and there is a good … like … overview then I just check [the phone] *for a little bit, and then put it back, yeah* (Olivia, 24, the Netherlands).

As presented previously, some considered waiting for a red light a suitable place to have a brief look at their phone and used this to check if something required immediate action:

[…] if I stop by a traffic light then I am able to reach for the phone and check who is calling. I don't call back, but just to see whether it is something relevant (Louis, 30, Denmark).

And

[…] when you stop at a red light, then you can just open the bag and have a quick glance at who sent the headline and then back again (Sarah, 28, Denmark).

When using the phone to perform a motoric complex task, like writing a long message, some cyclists chose to stop on or along the pavement:

Along the pavement. Yeah I make myself like small [laughs]. *So as not to form an obstacle for other users, yeah* (Julian, 49, the Netherlands).

This strategy is twofold: one objective is to perform the task, but simultaneously he adjusts his behaviour out of concern for other road users. Changing behaviour because one might affect other was also found in the following quote from a Danish interviewee, who referred to a talk he had with one of his housemates:

[…] he would never do it [use the phone while cycling] *because it creates precedence* (Viggo, 24, Denmark).

Local knowledge connected to whether or not interviewees (needed to) use their phone for navigation and how alert they were

towards the proximate environment:

> *I always ride the same routes. So I know them by heart, and I know where I have to look out or not […]* (Max, 24, the Netherlands).

When riding as a leisure or sport activity, interviewees used the ride as a way to clear their head and, therefore, deliberately chose not to use the phone for communication and social media. For these trips they often rode outside larger cities, as there is more space to ride in groups. Being accompanied by others limited the interviewees' need for digital communication:

> *I've got my friends beside me, so I don't need to contact them with my phone* (Max, 24, the Netherlands).

According to the interviewees, distance and duration of the ride affected whether it was worth the trouble finding headphones and search for music before starting the ride. For longer trips or when in a hurry, music was used both for entertainment purposes and as a sensory strategy to support a rhythmic pedal flow:

> *[…] I think it is nice when I have to ride a long distance. Then I like to listen to music, because then I am more relaxed. I don't think about where or for how long I am going. I just ride then* (Ida, 32, Denmark).

Despite not always being present with their children, parents reported to guide their behaviours remotely. A Dutch cyclist, who is also a mother, instructed her kids to only listen to music if they could still hear traffic sounds:

> *[…] I wanted them to not listen to music, and- you know-, not having ear-earphones and earplugs in, eh. Because then, you know, you can listen to the sounds of the traffic […] then we had lot of fights about it, and then we had the, what do you say-, compromise, that they put in only one side* (Iris, 47, the Netherlands).

While physical national characteristics were linked to specific risks (e.g. having a wheel stuck in tram tracks is more common in the Netherlands), these were not connected to phone use among interviewees. Other national differences were however associated with both whether and how phones were used. As Danish law prohibits handheld phone for cyclists, police presence changed how a Danish cyclist used her phone:

> *I think I look around, like a brief scan 'is there anybody around: no', or then I grab it when I reach a small cycle path […]. Then I am able to check it there, while cycling at it, where there is no motorbike police* (Susanne, 60, Denmark).

The risk of receiving a fine made her limit her phone use to places with an estimated small likelihood of police detection, but did not cause her to refrain completely from using phone while cycling. Contrary, another Danish cyclist had the impression of enforcement being either random only present at specific points, where cyclists are known to do illegal manoeuvres:

> *[…] then I always think to myself 'well that's because they need to collect some money'* (Lisa, 29, Denmark).

Because Lisa had the impression that police detection was both limited and random, she did not make substantial changes in her behaviour to avoid police detection:

> *[…] it's not like I have the feeling that it* [the police] *is something that you have to look out for at all times* (Lisa, 29, Denmark).

Other national specific characteristics related to perceived cultural differences from experiences in both countries:

> *Last year me and [name], and a couple of friends of mine went to Copenhagen, and we were all, we were all like: "Wow, you ride your bikes so neat* (Stijn, 42, the Netherlands).

Similar descriptions were presented by other interviewees and point to cultural differences related to cycling, but not specifically to phone use.

In summary, the physical and social environment were often integrated parts of the interviewees' strategies for phone use. Road design and specific circumstances, like congestion and overview, were considered in order to minimize crash risk, but also to avoid police detection. Trip characteristics, like distance, duration, number of riders, and environment, were associated with whether they used the phone, for what purposes, and how they used it.

4. Discussion

The aim of the study was to investigate cyclists' phone use in traffic by identifying affordances, moderations and constrains from proximate environmental characteristics. We found characteristics of both personal items (e.g., bicycle type and clothing design) and factors under limited control of individual cyclists (e.g. road design and streaming services), to be associated with whether, how, and for what purpose interviewees used their phone while cycling. Descriptions of deliberate and habitual phone use corresponds to the cognitive distinction between reflective and impulsive behaviours (Strack and Deutsch, 2004), which we use as a framework for the discussion.

4.1. Affordances and strategies for reflective phone use

Consistent with findings in earlier studies (Adell et al., 2014; Jungnickel and Aldred, 2014; Kircher et al., 2015; Stelling-konczak et al., 2014) the interviewed cyclists reported consciously using compensatory strategies like slowing down, increasing visual orientation, and only using one earbud when listening to music if using their phone while cycling. Behavioural adaptions across different bicycle types (like helmet use) were reasoned from differences in (perceived) risk, which corresponds to identified relations between environmental conditions and perceived cycling safety (Blitz, 2021; Kummeneje et al., 2019). As previously found among both cyclists (Nygårdhs et al., 2018) and car drivers (Huth et al., 2015; White et al., 2010) some of the interviewed cyclists operated their phone while waiting at a red light. It was perceived as safer compared to when in motion. This conscious use of compensatory

strategies implies that, despite addictive features of (smart)phones (Lapointe et al., 2013), cyclists' phone use can be an active and reflective decision. This is crucial, as legal restrictions aim to target decisions and behaviours through deterrent mechanisms (Åberg, 1998; Taxman and Piquero, 1998). When phone use is reflective, the cyclist can make the choice to comply with legal restrictions. However, it might be more important to target impulsive phone use, as reflective phone may lead to fewer safety-critical situations compared to impulsive phone use, as it involves active consideration and adaption to environmental characteristics (Ihlström et al., 2021; Nygårdhs et al., 2020). Compensatory strategies were, however, not only used to increase safety, but also to minimize the risk of being apprehended. Multiple interviewees describe increase of visual scanning and changing route to lower the probability of police detection. Therefore, a ban, not only affects the prevalence of the target behaviour, it may also affect other behaviours and the way phones are used. Among motorists this has lead to the development of radar detection systems designed to avoid speed controls (Christoffel, 1987). Other studies have, however, only found small effects from deterrence factors (Huemer, 2018; Olsson et al., 2020), and yet others have suggested traffic rules (also) work through psychological mechanisms (e.g. Bilz and Nadler, 2014; Nadler, 2017; Sunstein, 1997). The mixed results in both literature and in this study supports the request for further research in the effects of traffic rules (Yagil, 2005).

4.2. Affordances and strategies for impulsive phone use

While traffic rules possibly have an effect in regulating reflective phone use, impulsive phone use is not likely to be reduced from deterrence mechanisms alone, as it is not under volitional control. Furthermore impulsive phone use is likely linked to experience as cyclists and perceived behavioural control, as less experienced cyclists find phone use while cycling more difficult (Adell et al., 2014). Impulsive phone use is, however, only possible when enabled by environmental circumstances, and the identified characteristics moderating and/or constraining impulsive phone use may work as strategies to improve cyclists' safety. To avoid phone use triggered by notification prompts (Fitz et al., 2019) some turned off notifications and/or placed to phone out of reach. Using headphones with buttons makes it possible to accept a call and engage in a conversation without operating the phone, while storing the phone out of immediate reach. These strategies do not eliminate phone use, but may convert handheld use into hands-free. Though earlier research identified both handheld and hands-free phone use as distracting (De Waard et al., 2011), a more recent publication found handheld operation to likely impose a greater risk (De Waard et al., 2015). In this light, strategies that convert handheld operation into hands-free phone use possibly increase cyclists' safety. Legal measures may encourage using such strategies and could thus have an indirect effect in reducing impulsive phone use.

4.3. Further implications for cyclists' safety

While the two previous subsections discuss findings specifically related to phone use, the interviews also interviews also reviled other results relevant to cyclists' safety worth mentioning. Identified national variations in helmet use corresponds to much lower observed helmet use in the Netherlands than in Denmark (Markus et al., 2019), and point to high-cycling being achievable in varying cultural environments. Aldred and Jungnickel (2014) described how high cycling levels allow cycling to be culturally invisible, as it becomes the norm and not a distinct choice of the individual. This likely also applies to helmet use, with high rates allowing helmets to be neutral artefacts (e.g. not associated will cycling skills), as normative beliefs were strongly associated with cyclists' helmet use (Ledesma et al., 2019). This was indicated as some Dutch interviewees expressed negative attitudes towards helmets in general, while this was not reported by Danish interviewees. Those expressing negative attitudes, however, still used helmets when riding specific bicycle types, which was explained by reference to bicycle characteristics, trip characteristics, and related behavioural adaptions. This corresponds to the link between high perceived risk and lower likelihood of phone use (Ichikawa and Nakahara, 2008), and supports risk homeostasis theory (Evans, 1986). Finally, the findings from this study identified behavioural variation between different cyclists as well as within the individual. Though segmentation of cyclists into types is a useful tool for policy makers (e.g. Damant-Sirois et al., 2014; Haustein et al., 2016) acknowledgment of variations within individual cyclists possibly offer more nuanced and accurate representations of cyclists in high-cycling countries.

4.4. Strengths and limitations

Although use of retrospective descriptions are sensitive to bias like distorted memory and selective reporting, they provide important insights about travel behaviours across timely settings (Müggenburg, 2021). The study provides a unique contribution by distinguishing practical bicycle characteristics on a detailed level (e.g., not only between e-bicycles and non-motorized bicycles) in relation to phone use by considering both environmental affordances and psychological theory about reflective and impulsive decision-making processes. The study thus offers an exploration of affordances of material socio-technical relations, but should not be interpreted as exhaustive assessment, as it neglects aesthetic and emblematic characteristics (Blitz and Lanzendorf, 2020) and psychologic factors like attitudes and motivations that might be linked to environmental characteristics (Blitz, 2021). Yet the study presents insights on the emergence of cyclists' phone use, which thus offers new perspectives on how to address the behaviour with the aim of increasing safety in traffic. Though the sample consists of interviewees from high-cycling countries the results are also relevant for emerging cycling cultures, as phone use might increase when the environment is developed enough to allow for some distraction-related behaviours (Young et al., 2020). More participants would have enabled wider and more robust conclusions related to, for example, demographic characteristics and transport behaviours, and the findings could thus benefit from further exploration following a quantitative approach.

5. ConclusionS

The results present examples of how specific characteristics of the bicycle, clothing, infrastructure and more is associated with *whether*, *how,* and *for what purpose* cyclists use their phone. The use of phone was conversely connected to the choice of equipment; like headphones with buttons for conversations and music, or phone mounts for the handlebar for navigation. Distinguishing between impulsive and reflective phone use, we propose these should be targeted with different measures due to different cognitive processes. We argue that legal measures only have the potential to restrict reflective phone use directly, while impulsive phone use could be targeted with action-based strategies (e.g. placing the phone out of reach). From the descriptions, we find that cyclists in high-cycling countries have varying phone and helmet use behaviours across bicycle types, and suggest taking these into account when dividing cyclists into segments. Further research on how specific material characteristics may relate to cyclists' varying behaviours and psychological factors may inform behavioural design solutions as a part of the work towards safe cycling environments.

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CRediT authorship contribution statement

Rebecca Karstens Brandt: Writing – original draft, Conceptualization, Methodology, Formal analysis, Investigation. **Sonja Haustein:** Writing – review & editing, Conceptualization, Methodology, Supervision. **Mette Møller:** Writing – review & editing, Conceptualization, Methodology, Supervision, Project administration.

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