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AN EXPLORATION OF CYCLISTS' MOBILE PHONE USE:

INDIVIDUAL, SOCIAL, AND CONTEXTUAL FACTORS AND THEIR INTERACTION

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PHD THESIS

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DTU Management
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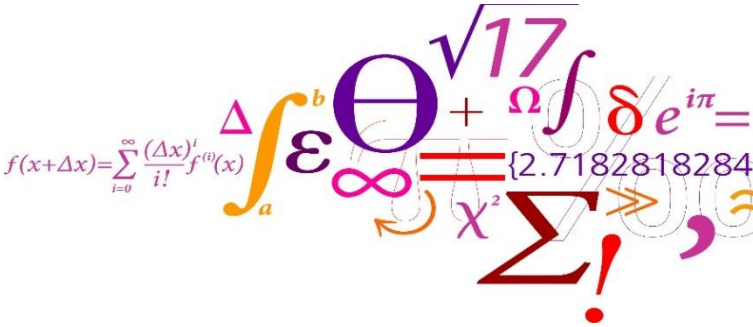

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SUMMARY

The available literature on cyclists' phone use is limited and has not been sufficiently updated along with technological developments, such as the switch from push-button phones to smartphones. Through three complimentary sub-studies this Ph.D.-project examines how individual, social, and contextual factors affect cyclists' phone use. The foundation of the sub-studies are in-depth qualitative interviews, as well as questionnaire data collected before and after July 2019, when a ban was introduced against use of handheld electronic devices whilst cycling in the Netherlands.

Through qualitative interviews with nine Danish and ten Dutch cyclists, the first sub-study examines how material characteristics of the environment along with the cyclists' own belongings are associated with phone use. One finding is that these characteristics influence whether the cyclists use the phone or not. Additionally, the cyclists use strategies to both facilitate and prevent phone use. For instance, some cyclists placed their phones to make it more easily accessible during the trip or disabled notifications and ring tones to avoid distractions. Because the cyclists both plan to use the phone and feel a need to avoid habitual use, it is suggested that phone use can be divided into reflective and impulsive use. Banning handheld phone use for cyclists seeks to regulate the behaviour through deterring the reflective decision. The influence of a ban on impulsive phone use will therefore only be indirect through encouraging the use of strategies to prevent phone use. It is possible that further indirect effects of a ban can occur through higher perceived risk or by creating a market for the development of technologies that enable legal phone use.

The second sub-study explores whether selected demographic, social, and psychological factors can predict cyclists' handheld phone use in the Netherlands and Denmark. Additionally, the cyclists' beliefs about traffic rules are included as an explanatory variable. At the time of the data collection, handheld phone use while cycling was banned in Denmark whilst it was still legal in the Netherlands. In both Denmark and the Netherlands the probability of handheld phone use increases with low age, high frequency of cycling, low self-identity as a safe cyclist, supporting subjective norms, and high perceived control of phone use while cycling. In Denmark, we furthermore identify an effect from believing handheld phone use is forbidden, whilst this is not associated with handheld phone use in the Netherlands. This points to a ban on handheld phone use not being obeyed solely because of its existence. The ban needs to be implemented through either changes in moral, enforcement of the law, or a combination of both in order to reduce the use of handheld phones among cyclists.

The third sub-study compares questionnaire data from before and after the Dutch ban on handheld phone use. In the Netherlands, we see a reduction in the proportion who use handheld phone for conversations while cycling while there are no changes for other functions (e.g. texts, e-mail, SOME). At the same time, we did not identify changes for any of the functions in Denmark. We do however find an increase in the use of headphones for conversations in the Netherlands after the ban. Furthermore, there is an increase in sense of guilt and in believing one's phone use annoys others for handheld phone use while this is unchanged for hands-free use. The results suggest that legislation can have an effect on cyclists' use of handheld phones by providing an incentive to use technological solutions. In the short term, the

overall reduction of phone use appears very limited. In the long term, it is possible that the ban will influence social norms through changes in moral, which may increase effectiveness. Psychological aspects like moral and perception of risk should therefore be included in the evaluation of a ban. Similarly, attention should be given to non-intended consequences like cyclists' possible uptake of strategies to avoid apprehension that can also affect cyclists' safety.

RESUMÉ (DANISH)

Forskning i cyklisters telefonbrug er stærkt begrænset og ikke blevet opdateret tilstrækkeligt i takt med den teknologiske udvikling, der eksempelvis har medført et skift fra knap-telefoner til smartphones. Dette ph.d.-projekt undersøger gennem tre komplementære delstudier, hvordan individuelle, sociale og kontekstuelle faktorer påvirker cyklisters telefonbrug. Delstudierne baserer sig på dybdegående kvalitative interviews samt spørgeskemadata indsamlet før og efter et forbud mod at anvende håndholdt elektronisk udstyr under cykling trådte i kraft i Nederlandene juli 2019.

Det første delstudie undersøger gennem kvalitative interviews med ni danske og ti nederlandske cyklister, hvordan materielle karakteristika ved fx omgivelserne og cyklisternes egne ejendele er associeret med telefonbrug. Delstudiet finder bl.a., at telefonens placering kan knyttes til egenskaber ved fx tøj, tasker og cykel, og at dette påvirker om cyklisterne bruger telefon eller ej. Derudover anvender cyklisterne strategier til både at muliggøre og forhindre telefonbrug. Eksempelvis placeres telefonen inden for rækkevidde for at kunne nå den under turen, eller notifikationer og ringetoner slås fra for ikke at blive forstyrret. Idet cyklisterne både planlægger telefonbrug og har behov for at forhindre vanebaseret brug, udledes det, at telefonbrug kan inddeles i refleksiv og impulsiv brug. Et forbud mod håndholdt telefonbrug for cyklister regulerer adfærd gennem at afskrække den refleksive beslutning. Derfor vil et forbud kun kunne reducere impulsiv telefonbrug indirekte, ved at tilskynde anvendelse af præventive strategier der forhindrer telefonbrug. Indirekte effekter af et forbud kan muligvis også ske gennem øget risikoopfattelse eller ved at skabe et marked for udvikling af teknologi, der muliggør at cyklister kan benytte mobiltelefon på lovlig vis.

Delstudie nummer to undersøger, om udvalgte demografiske, sociale og psykologiske faktorer kan forudsige om cyklister i hhv. Danmark og Nederlandene anvender håndholdt mobiltelefon. Herudover inddrages cyklisternes antagelser om lovgivningen som forklarende variabel. Danmark havde på dataindsamlingstidspunktet forbudt håndholdt mobiltelefon under cykling, imens dette endnu var lovligt i Nederlandene. I både Danmark og Nederlandene øges sandsynligheden for anvendelse af håndholdt mobiltelefon med lav alder, øget cykelfrekvens, lav selvidentitet som sikker cyklist, understøttende subjektive normer og høj følelse af kontrol over telefonbrug på cykel. Ydermere er der i Danmark en effekt af at tro, at håndholdt telefon er forbudt, imens denne ikke er signifikant i Nederlandene. Sidstnævnte tyder på, at loven ikke bliver efterlevet alene fordi den eksisterer, men at den skal forankres gennem enten ændringer af moral, håndhævelse af loven eller en kombination af begge dele, for at føre til reduktion i anvendelsen af hånholdt mobiltelefon på cykel.

Det tredje delstudie sammenligner spørgeskemabesvarelser før og efter det Nederlandske forbud mod håndholdt mobiltelefon. Der ses i Nederlandene en reduktion i andelen, der anvender håndholdt telefon til samtale, imens der ikke er ændringer for andre funktioner (sms, e-mail, SOME mm.). Samtidigt er der ikke ændringer for brugen af nogen af funktionerne i Danmark. I Nederlandene ses derimod øget brug af hovedtelefoner til telefonsamtaler efter forbuddet. Yderligere er der i Nederlandene øget skyldfølelse og øget fornemmelse af at irritere andre forbundet med håndholdt telefonbrug, imens disse ikke er ændret for håndfri telefon. Resultaterne peger på, at lovgivningen kan have en effekt på cyklisters håndholdte telefonbrug ved at øge inci-

tamentet til at anvende teknologiske løsninger. Den samlede reduktion i telefonbrug ser derimod stærkt begrænset ud på kort sigt. Det er imidlertid muligt, at loven over tid vil have indvirkning på sociale normer gennem ændringer af moral, hvorved effekten muligvis kan øges. Psykologiske effekter, som moral og risikoopfattelse, bør derfor inddrages i evalueringen af et forbud. Samtidig bør der rettes opmærksomhed mod mulige ikke-intenderede følgevirkninger, som eksempelvis strategier til at undgå pågribelse, som også kan påvirke cyklisters sikkerhed.

PREFACE

The Ph.D. project was funded by the Department of Management at the Technical University of Denmark, where the study was conducted under supervision of Senior Researcher, Mette Møller, and Senior Researcher, Sonja Haustein. As part of the project, Rebecca visited Professor Marjan Hagenzieker at the Technical University of Delft. The thesis consists of the present summary report and the three papers presented below, which are included as appendices.

Brandt, R.K., Haustein, S., M., Møller, M. Cyclists' phone use in relation to proximate environmental characteristics – A qualitative study. *Journal of Transport & Health*, 23, 101283 https://doi.org/10.1016/J.JTH.2021.101283

Paper submitted to *Transportations Research Part F: Traffic Psychology and Behaviour* (under revision):

Brandt, R.K., Haustein, S., Hagenzieker, M., Møller, M., (under revision). Cyclists' phone use and traffic rule knowledge.

Paper submitted to *Travel Behaviour and Society* (under review):

Brandt, R.K., Haustein, S., Hagenzieker, M., Møller, M., Exploring effects of introducing a ban on handheld phone use - pre-post results from the Netherlands and Denmark.

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I also want to thank all the cyclists who have contributed with time, knowledgeable insights, and interesting perspectives in the interviews for this project.

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Finally, I owe everything to my family; Jonas, Levi, Troels, Ulla and Ludvig. Finishing my PhD during a pandemic with several lockdowns has been challenging and demanding, but it was possible thanks to your love and support. I am lucky to have you.

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1 INTRODUCTION

The use of handheld electronic devices has increased over the past years (Aguiléra and Boutueil, 2018) and engagement in secondary tasks while driving is now recognized as a key risk factor (e.g. Dingus et al., 2016). When it comes to cycling, however, relatively few studies address the use and safety impact of mobile electronic devices. The technological development from push-button to smartphones establishes a need for more contemporary research. For example, smartphones require different fine motor skills than push-button phones, and have been associated with habitual use (Lapointe et al., 2013), which possibly also transfers to phone use in traffic. This research project investigates cyclists' use of phones through three sub-studies utilizing data from Denmark and the Netherlands. The present introductory chapter frames the background of the research project and presents its motivation in three sections. The first section establishes the relevance of cyclists' phones use as a research topic. The second section introduces the motivation from a psychological angle, while the third section identifies current approaches to mitigate the safety risks from cyclists' phone use. Altogether, the three sections create the foundation for presentation of the Ph.D. project in Chapter 2.

1.1 CYCLISTS' PHONE USE AND TRAFFIC SAFETY

Phone use can cause distractions and increase the crash risk among cyclists (De Angelis, Fraboni, Puchades, Prati, & Pietrantoni, 2020; Goldenbeld, Houtenbos, Ehlers, & De Waard, 2012; Useche et al., 2018). The use of phones in traffic can lead to distraction in various ways that relate to sensory systems and cognitive processing (Ministerie van Verkeer en Waterstaat,

2006; SWOV, 2017). This section outlines distractions from phone use in relation to visual, cognitive, motoric, and auditive distractions.

Cyclists' distribution of visual attention between phones and traffic is achieved from shifting glance or head orientation (Ahlstrom et al., 2016; Stelling-konczak et al., 2014; Vlakveld et al., 2021). The technological development from push-button phones to touch-screen interfaces of modern smartphones increase the need to look at the phone when writing text messages or using other functions that require manipulation of the interface (De Waard et al., 2011, 2015). This is likely the reason why the use of touch screen phones affects visual detection and cycling performance more negatively than push-button phones (De Waard et al., 2014). The processing of visual inputs from the traffic environment is furthermore reduced from cognitive workload, from, for example, conversations (De Waard et al., 2010). Cognitive distraction may additionally occur from increased workload when carrying out demanding handheld or hands-free tasks (De Waard et al., 2011) such as changing appointments on the go (Hjorthol, 2008). Moreover, sound notifications can attract cognitive attention, even if the cyclist chooses not to operate the phone and does not engage in hands-free calls or voice messages. The fine motor skills needed to operate the phone implies that the hand(s) is used to interact with buttons or interface, which may possibly delay responses in hand-breaking, bell ringing, and steering, as the hands are not readily in position for those actions (De Waard et al., 2011). The use of voice commands and - messages can work around some visual and motor distractions but still add to the cognitive workload. In addition to the visual, cognitive, and motor effects, phone use can also cause auditive distractions,

either from system-initiated sound notifications or self-initiated use like listening to music/radio or engaging in conversations (Nygårdhs et al., 2018). This type of distraction relates to the fact that cyclists, unlike car drivers, are not protected from the vehicle's constructive properties (Jones, 2006; Reynolds et al., 2009; Stelling and Hagenzieker, 2012). Cyclists therefore make use of, and may rely on, auditory cues to detect approaching vehicles (De Waard et al., 2010; Wolfe et al., 2016). The literature is not consistent in answering, whether the use of audio functions affects cyclists' safety (Stelling-Konczak et al., 2018). While cyclists were found to infringe on red lights and miss audio cues more often when listening to music (De Waard et al., 2011), it does not affect lateral position and is not considered risky by majority of cyclists (De Waard et al., 2010). Auditory attention can be directed, which likely explains why using only one earpiece had no effect on detection of auditory cues (De Waard et al., 2011). Additionally, the usage of audio devices has a possible positive impact on cyclists' safety as it increases calmness and alertness (Jungnickel and Aldred, 2014).

The above subsection outlined different types of distractions from phone use and how these possibly may affect cyclists' safety. The body of research point to handheld phone use being a particular risk towards safety, as it affects perceptions and motor responses at the same time. This is reflected in traffic rules in some countries (Mwakalonge et al., 2014). Engaging in secondary tasks have additionally been found to negatively affect safety-critical behaviours at intersections (Terzano, 2013). Although phone use might be particularly prevalent in high-cycling countries (Young et al., 2020), where "safety in numbers" (Jacobsen, 2003) possibly protect cyclists on a general

level, inattention is established as a contributing factor to cyclists' crash risk (Møller et al., 2021; Reynolds et al., 2009; Useche et al., 2018). All the above factors of cyclists' phone use and the shift from push-button phones to smartphones (De Waard et al., 2015) establish the need for further research on this topic.

1.2 Self-enforced distractions: a human-centered perspective

Unlike other distractions in traffic, phone use is initiated by the cyclists themselves. Though it can be requested by others, e.g., from incoming phone calls (Ahlstrom et al., 2016) and notifications, the activity is not an inherent part of cycling. This means the cyclist has various options to handle incoming requests in ways that reduce its impact on traffic safety. The cyclist can, for example, ignore the request, make a hands-free acceptance, though both may still increase the cognitive workload. Another possibility is to stop cycling to engage in the activity. Nonetheless, handheld phone use is still prevalent among cyclists in high-cycling countries (van der Kint and Mons, 2019). This presents an apparent curiosity as to why one would enforce distractions from handheld phone use on oneself. Further, it makes it relevant to explore the factors contributing to phone use to improve the understanding of cyclists' engagement in potentially dangerous activities. One probable explanation is that some cyclists consider the risk from handheld phone use towards (their own and/or others) safety insignificant. This is possibly connected to overconfidence bias (Puchades et al., 2018); those using their phone while cycling believe they can manage the risk by using, for example, compensatory behaviours. Another possibility is that some cyclists use the phone despite

believing it imposes a risk. They might choose this because of phone use's positive qualities, like enabling the fixing of practical arrangements on the go (Hjorthol, 2008) or contributing to a pleasant trip and flow (Jungnickel and Aldred, 2014). Finally, the prompting features of some phone applications (Lapointe et al., 2013) possibly drive habitual and addictive phone use in traffic (De Angelis et al., 2020; Jiang et al., 2019; Oviedo-Trespalacios et al., 2019).

1.3 Mitigating safety risks from phone use

A review of countermeasures targeting phone use in traffic divided these into people-focused and technical measures (SWOV, 2020). The review, however, only focused on measures initiated by authorities, and neglected individual cyclists' use of compensatory behaviours to mitigate negative effects from phone use. This section presents countermeasures targeting phone use, divided into two levels to separate self-initiated measures from those encouraged by authorities, and hereby include compensatory behaviours. First, it presents bottom-up initiatives picked up voluntarily by individual cyclists, and secondly, top-down interventions initiated by governments or organizations.

1.3.1 Bottom-up initiatives

A range of compensatory behaviours and the use of technological solutions have been identified among cyclists to mitigate distractions from phone use. In a semi-controlled naturalistic study where cyclists received text messages, some chose to stop cycling or postponed the reading to a more suitable place (Ahlstrom et al., 2016; Nygårdhs et al., 2018). Cyclists have also been found

to compensate for looking at the phone screen by adapting glance distribution (Ahlstrom et al., 2016; Stelling-Konczak et al., 2018), positioning themselves further from the curb (De Waard et al., 2015), and reduce speed (Adell et al., 2014; Kircher et al., 2015). In addition to the behavioural strategies, some cyclists use technological solutions developed to prevent phone use. For example, a bicycle lock manufacturer has developed a lock that blocks the phone signal when unlocked (e.g. Cluskey, 2017; Oviedo-Trespalacios et al., 2019). Other technological solutions work by facilitating phone use in ways that interfere less with the cyclists' manoeuvrability and sensory systems. For example, special headphones have been developed to allow the reception of audio input from traffic (Mwakalonge et al., 2014), and phone mounts enable use of the phone for navigation without holding it by hand.

Behavioural adaptions and technological solutions are both voluntary measures and hence depend on the individual cyclist's motivation to use them. The use, therefore, varies from cyclist to cyclist and is likely connected to individual risk tolerance levels (Nygårdhs et al., 2018). As the perceived risk does not necessarily correspond to the actual risk, individual initiatives might be insufficient in mitigating the risk from phone use. The next subsection presents top-down measures targeting cyclists' phone use in traffic.

1.3.2 TOP-DOWN INTERVENTIONS

Government-initiated interventions to promote specific behaviours can according to the intervention ladder (see Figure 1) be sorted into steps corresponding to how intrusive they are on individual, industrial, or population level (Krebs et al., 2007).

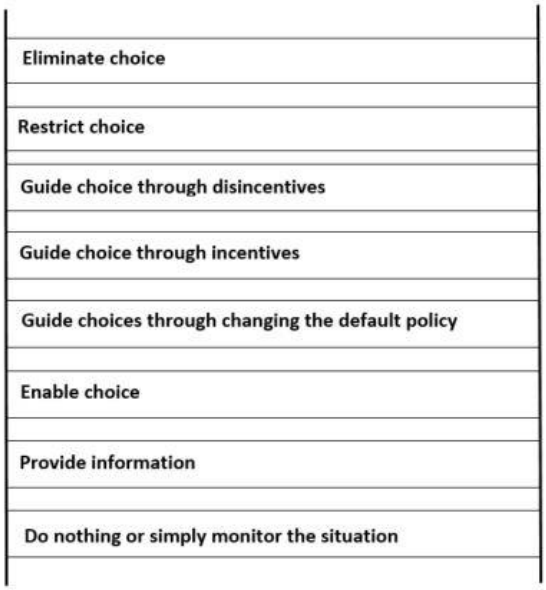

***Figure 1**:* A simplified version of The Intervention Ladder developed by Nuffield Council on Bioethics (Krebs et al., 2007), ranging from least intrusive intervention at the bottom to the most intrusive at the top.

Top-down interventions targeting cyclists' phone use span from the lowest to the highest step. Among the least intrusive interventions is the use of risk awareness campaigning to inform cyclists about the risk related to phone use. This corresponds to the step *provide information.* Risk awareness programs provide information about how phone imposes distractions in traffic. The programs sometimes also refer to other interventions, like encouraging

uptake of technology or informing about traffic rules (Mwakalonge et al., 2014). One example of an intervention in the middle of the intervention ladder is a phone application that the Ministry of Infrastructure and Environment and collaborative partners introduced in the Netherlands in 2014. The application used the principle of *discouraging phone use through incentives*, as trips without phone use were rewarded with points for use in competitions (SWOV, 2017). The most intrusive step *eliminate choice*, is, however, also widely used, with handheld and hands-free phone use being banned in different constellations in various countries (Mwakalonge et al., 2014). A ban introduces a new risk, a fine, which has a higher probability (Åberg, 1998). The certainty of the sanction, however, depends on enforcement of the ban. How effective the different measures are in reducing the safety risk from cyclists' phone use is under-researched (Mwakalonge et al., 2014; SWOV, 2017; van der Kint and Mons, 2019). It is likely that the effectiveness of the measures is connected to the underlying psychological motivations described in Section 1.2. A ban could, for example, target phone use motivated by overconfidence, if the cyclist, for example, complies out of moral obligation. A ban which is likely to be less effective in reducing impulsive phone use, as this behaviour is not a reflective decision (Brandt et al., 2021). The risk of apprehension and possibility of receiving a fine are therefore not actively considered before using phone impulsively.

2 THE PH.D. PROJECT

The Ph.D. project explores cyclists' phone use with a focus on factors affecting the behaviour from a psychological perspective. The project consists of three sub-studies each with different methodological and theoretical approaches. To express the foundation of the project this chapter first defines the overall research question and presents selected theoretical concepts. It then outlines the specific context for the data collection, before describing the three sub-studies and their individual contribution to the overall project.

2.1 PROBLEM DEFINITION

The Introduction (Chapter 1) presented a need for more contemporary research on cyclists' phone use and outlined the relevance of studying this behaviour and the related preventive measures. This Ph.D. project explores these topics using psychological theory, and hereby provides novel perspectives on factors affecting cyclists' phone use. It does so in three sub-studies that each contribute with different aspects to the answering of the overall research question:

> *How do individual, social, and contextual factors affect cyclists' phone use?*

The term individual factors can be used to refer to psychological constructs, like personality and attitudes, or demographic characteristics. This research project, however, extends this term to include individual belongings such as characteristics of the bicycle and phone. It does so from the conviction that human behaviours are related to the setting in which they unfold. This is a common assumption for all theoretical concepts used in

this research project. Similarly, contextual factors are defined more broadly than the physical environment. In this project, contextual factors therefore both include infrastructure characteristics (e.g. traffic lights) and traffic laws, to study how they affect cyclists' phone use.

Before presenting the three sub-studies that constitute the research project (Section *2.3.2 The sub-studies*), the following sub-sections introduce the overall approach and selected theoretical concepts used to answer the overall research question. It is possible to explore the research question from different scientific fields. This research project uses selected theoretical approaches that stem from the field of psychology, as this field consider the individual, social, and contextual levels, as well as their interaction. Psychological theories span from theories mainly focused on inner psychological notions (e.g., motivations, and personality as a stable core) to outer oriented concepts (e.g., governmentality, and discourses). Therefore, I wish to explicate the chosen approaches and how they complement each other. For this, I use Ken Wilber's quadrant model (Figure 2), which offers four primary perspectives in approaching a field of research: the subjective (singular, inner), the objective (singular, outer), the intersubjective (inner plural), and the inter objective (outer, plural) (Sonne-Ragans, 2012). This project takes on an eclectic approach to exploring cyclists' phone use and draws on theories belonging to all four quadrants (see 2.2 Theoretical approach). The research project hereby focus on behaviour and motivations as concepts related to context. The model will be

used as a reference in the following section that introduces the theoretical concepts; affordances, self-identity, and traffic rules.

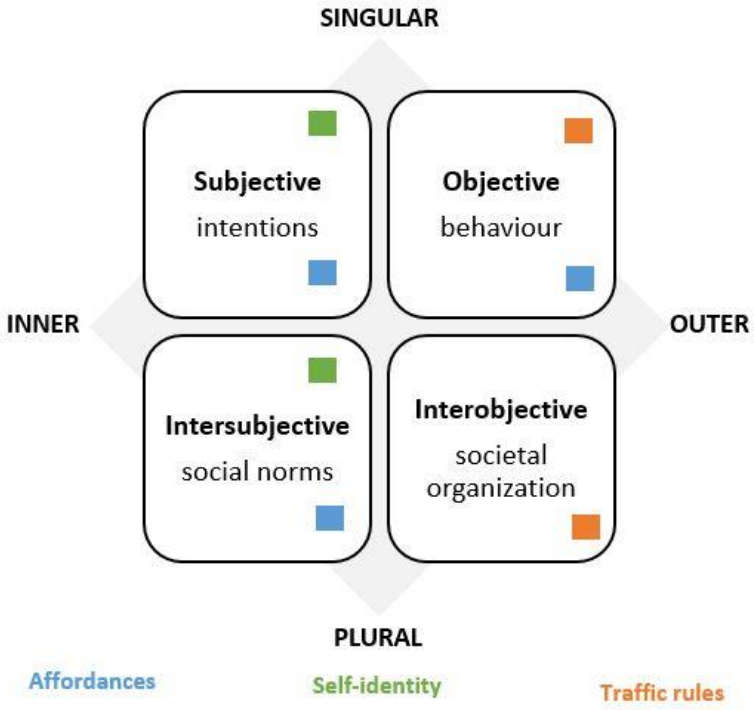

***Figure 2**:* A simplified version of Ken Wilber's quadrant model after Sonne-Ragans (2012). The coloured markings illustrate how central concepts of the research project belong to different quadrants, and thus complement each other.

2.2 Theoretical approach

This section describes the most prevalent theoretical concepts of the PhD-project in three sub-sections. It first introduces the concept of affordances and self-identity, and then presents deterrence theory and social psychological perspectives on traffic rules as means for behavioural change.

2.2.1 Affordances

The first sub-study explores cyclists' phone use in relation to proximate environmental characteristics. To do so, it draws on the concept of affordances, originally developed by the perceptual psychologist James Gibson (1977). With the concept of affordances, Gibson refers to perceptual characteristics offering different actions to different persons, as affordances relate to the specific context, embodiment and former experiences of the recipient. The concept of affordances hereby explains that intentions, physical capabilities, and culture mediated perceptions of material characteristics, which thus define what actions can be performed in a given context (Norman, 2013; Pedersen and Bang, 2016). This, for example, connects to cyclists' phone-using strategies (e.g. Jungnickel and Aldred, 2014; Kircher et al., 2015) and compensatory behaviours, as these can be explained as adaptions to specific environmental conditions (Ihlström et al., 2021). Affordance theory thereby acknowledges material and environmental characteristics as influencing behaviours rather than perceiving the environment as neutral. This implicates that cyclists' phone use is not solely a matter of expressing inner motivations and attitudes. The behaviour is therefore understood in relation to the proximate environmental characteristics that afford, moderate or constrain specific actions.

To study affordances in relation to cyclists' phone use, it is therefore necessary to capture both inner and outer perspectives as they appear to the individual cyclist and its embodied characteristics. Similarly, it is central to collect data across time and contextual settings. As a theoretical concept, affordances relate to both the subjective, the objective, and the intersubjective quadrant (Figure 2) and thus expand the idea of motivations and attitudes as the primary factors explaining cyclists' phone use.

2.2.2 Self-identity in transport research

The second sub-study includes the psychological concepts; subjective norm, perceived behavioural difficulty, and self-identify as variables to predict cyclists handheld phone use. While the first two concepts are well known and widely applied in transport psychology research as part of the theory of planned behaviour (Ajzen, 1991; Jiang et al., 2019), exploring traffic behaviours through self-identity is rather novel (Füssl and Haupt, 2017).

Self-identity refers to both the individual inner representation, and the individual's relation to, or positioning from, other people. In transport research self-identity has been connected to mode choice and how one interacts with other road users (Füssl and Haupt, 2017). Unlike some theories that describe personality as development of inherent characteristics (Roberts et al., 2005), self-identity is dynamic and relates to situational characteristics and how one wants to appear to others. Self-identity has previously shown useful in extending the measures from theory of planned behaviour in predicting phone use among university students (Walsh and White, 2007). In this research project self-identity is linked to moral, as to whether or not cyclists think of themselves as considerate and rule-compliant. It does so to explore the role

of moral self-identity in relation to handheld phone use when handheld phone use is forbidden and when it is legal. Self-identity mainly belongs to the subjective and intersubjective quadrant (Figure 2) but also connects to how inner perspectives affect behaviours (the objective quadrant).

2.2.3 Theories related to traffic rules and behavioural change

Sub-study two and three both touch upon traffic rules as means for changing cyclists' behaviours. Though some theories state that traffic rules mainly serve the purpose of allocating blame and liability in insurance cases (Yagil, 1998), traffic rules are often introduced with the aim of changing behaviours and increasing traffic safety (Åberg, 1998). Either from standardizing interactions between different road users, or between the road user and the environment (Goldenbeld, 2017). Two major distinct approaches explain rules as means for behavioural change from either deterrence mechanisms or change of moral (Haven and Tyler, 1990).

A central theory behind traffic rules as means for behaviour change is deterrence theory (Taxman and Piquero, 1998). It builds on an instrumental approach and proposes that people comply with traffic rules to avoid possible sanctions. As the name indicates, deterrence theory focuses on how traffic rules (de)motivates engagement in specific behaviours from presenting punishments with a higher probability (Åberg, 1998), which should ideally be both certain and severe (Taxman and Piquero, 1998). This follows a tradition in transport research and engineering, which assumes the individual makes rational choices to pursue its own interests (Schwanen, 2020). In order for traffic rules to have an effect, the punishment should therefore be as severe,

swift, and certain as possible (Castillo-Manzano et al., 2019; Huemer, 2018; Taxman and Piquero, 1998). Traffic rules are believed to be most effective in deterring visible offences, as detection is a prerequisite for enforcement of rules (Åberg, 1998). The deterrent mechanisms does, however, not necessarily derive from the punishment, but have also been suggested to come from, or being moderated by, facing authorities (Pogarsky and Piquero, 2004) and social disapproval of the behaviour (Wenzel, 2004).

Theories within the normative approach refer to social mechanisms and moral obligations as motivations for behavioural change from rules (Bilz and Nadler, 2014; Haven and Tyler, 1990; Sunstein, mecanisms1997). The normative theories present (traffic) rules as part of the societal structures that influence, for example, moral and culture (Greenberg, 2014). Rules are therefore believed to affect behaviours indirectly, from internalized obligations, social norms and moral guidance (Rose et al., 2006; Wenzel, 2004). Like deterrence theory, normative motivations may imply sanction-like consequences (e.g., disapproval from one's peers) but these are not certain nor under direct control by authorities and may thus vary between different subgroups. As rules belong to societal structures and have an influence on moral, banning a behaviour is believed to affect how that behaviour is generally perceived, including approval among peers and perceived risk (Bilz and Nadler, 2009).

The instrumental and normative theories about traffic rules mainly connect to the objective and the interobjective quadrant (Figure 2), but are explored in relation to how changes in traffic rules possibly affect aspects of the subjective and intersubjective domains.

2.3 RESEARCH OUTLINE

The previous section briefly introduced that the research project consists of three sub-studies that each contributes with different perspectives on the exploration of how individual, social and contextual factors contribute to cyclists' phone use. The data for all three sub-studies were collected in Denmark and the Netherlands (see Figure 3). Sub-study one and two compare the two countries, which at the time of data collection had different rules about cyclists' phone use. At that time, only Denmark forbade phone use while cycling, but a similar ban was introduced in the Netherlands in July 2019. The third sub-study compares survey data before and after the Dutch ban and uses data from Denmark as a reference. This section first describes the contextual framing of the data collection, before describing the three studies and their individual contribution more detailed.

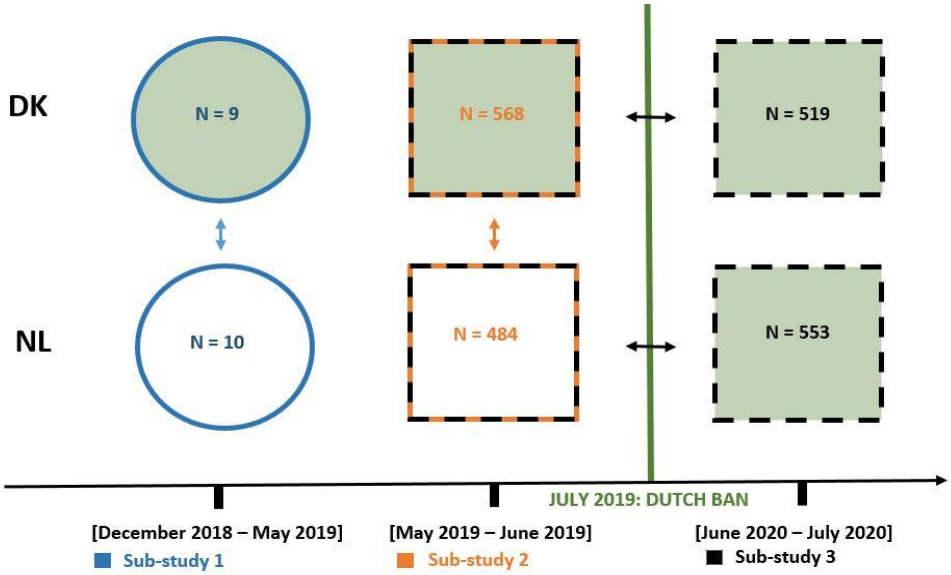

***Figure 3**:* Data collection timeline for the PhD-project. Circles indicate interview data and squares indicate survey data. Study 1 is marked with blue, study 2; with orange, and study 3; with black dashes. Arrows indicate what data sources each study compares, and green shading marks handheld phone use being illegal.

2.3.1 Contextual framing

Using data from different countries entails awareness of how the different contextual settings possibly affect these, but also contains a potential for studying differences and similarities in naturalistic settings (Haustein and Nielsen, 2016). Both Denmark and the Netherlands are recognised as particularly cycling-friendly (Haustein et al., 2020; Pucher and Buehler, 2008), and have Europe's highest cycling-levels, measured as the mode share of all trips (Haustein and Nielsen, 2016) with 23% of all trips being made by bike in the Netherlands; and 18 % in Denmark (Buehler and Pucher, 2012). Dutch cyclists, however, cycle more often and on average do longer trips than the Danish cyclists (Buehler and Pucher, 2012; Nielsen et al., 2015). Denmark and the Netherlands further share a wide range of characteristics that promote cycling, including a mostly flat topography, supportive infrastructure, and pro-cycling policies (Haustein et al., 2020; Pucher and Buehler, 2008). When it comes to cyclists' risk of death by exposure, it is in both countries calculated as 0.9 per 100 million kilometers (Buehler and Pucher, 2020) despite helmet use being much more prevalent in the Danish capital area (19.9%) than in Amsterdam (1.1%) (Markus et al., 2019).

While the Dutch government in 2006 recognised the risk from using a phone while cycling, they were reluctant in introducing a ban on phone use, because the number of known related accidents was relatively small and a ban was not believed to be effective (Ministerie van Verkeer en Waterstaat, 2006). Later changes in phone use from unlimited mobile data, and e-bikes and other electric micro motilities' contribution to increased speed levels on cycle paths, however, ultimately resulted in a ban on the use of handheld electronic

devices in July 2019 (Henley, 2018; Ministerie van Infrastructuur en Waterstaat, 2019).

2.3.2 THE SUB-STUDIES

The research project undertakes an eclectic approach, combining qualitative and quantitative methods in the three sub-studies. Qualitative research is often applied to uncover inner concepts, like motivations and attitudes (Brinkmann and Kvale, 2015), belonging to the subjective and intersubjective quadrant (Figure 2). This project, however, uses qualitative interviews as a tool to explore cyclists' behaviours in relation to the proximate environment, with a focus on affordances as mediators. To complement the first study, sub-study two and three therefore explore changes after introduction of a ban, and factors contributing to cyclists' phone use, in larger demographically representative samples.

Sub-study 1

The first study explores cyclists' phone use in relation to environmental characteristics through qualitative interviews in Denmark and the Netherlands as the two countries had different traffic rules regarding cyclists' phone use at the time of data collection. A key contribution of this study is the identification of how specific characteristics of the environment and personal belongings are associated with phone use while cycling. In addition to supporting the literature on cyclists' use of compensatory strategies, the results indicate that strategies not only vary between cyclists but that the same cyclist uses different strategies. For example, avoiding phone use when doing sports cycling or riding in groups, but using it for shorter trips in the city. The cyclists

explained this variation in reference to the proximate environmental characteristics like bike type, clothing, social environment, infrastructure design, and purpose of the ride. The discussion draws on cognitive dual-process theory to distinguish between reflective and impulsive phone use, which implies that traffic rules might be insufficient as a measure to reduce impulsive phone use.

Sub-study 2

Like the first study, the second study also uses a cross-country approach comparing Danish and Dutch cyclists. This study uses online surveys to identify demographic and psychological factors contributing to cyclists' phone use. Unlike previously published studies, it includes beliefs about traffic rules as predictive measures, and compares traffic rule knowledge-levels in different legal contexts. Central to the main research question is that the study, among other factors, identifies social norms and perceived behavioural difficulty as relevant targets for effective preventive measures. Additionally it finds that believing handheld phone use is forbidden significantly decreases the likelihood of using handheld phones, but only when it actually is forbidden. This could suggest that traffic rules working through changes in perceive risk, moral norms, deterrent mechanisms from enforcement, or a combination of all three.

Sub-study 3

This study compares survey data collected in Denmark and the Netherlands before and after the introduction of a ban on handheld phone use in the Netherlands in July 2019. Through these data, it assesses possible changes in phone use, behaviours, and psychological measures in relation to the ban.

Though traffic rule knowledge is almost three times higher in the Netherlands after introduction of the ban, the only reduction in handheld phone use is for conversations, whilst rates for other functions (e.g. texting) remain at the same levels as before the ban. Further, the levels of perceived risk of handheld phone use remain unchanged in both countries. Both sense of guilt and perceived annoyance do, however, change significantly in the Netherlands while staying the same in Denmark. This points to bans on handheld phone use having wider influences than in reducing levels of handheld phone use. The risk of enforcement and increased sense of guilt possibly motivates the use of strategies to avoid apprehension. Such effects should be included when evaluating or if considering the introduction of bans on handheld phone use for cyclists.

3 FINDINGS AND DISCUSSION

The overall research question defined the aim of the research project as to study how individual, social, and contextual factors affect cyclists' phone use. This was explored in three sub-studies with different theoretical approaches. Sub-study one explored how affordances from the proximate environment contribute to cyclists' phone use. Sub-study two identified demographic, psychological, and contextual factors predicting handheld phone use in Denmark and the Netherlands. Finally, sub-study three compared before-after ban measures of phone use, traffic rule knowledge, and the psychological measures: risk perception, perceived annoyance, and sense of guilt. This chapter summarises and discusses the main results and links findings across the three sub-studies.

3.1 CYCLISTS' PHONE USE STRATEGIES

The first sub-study (Brandt et al., 2021, p. 49) used affordance theory as a framework to analyse qualitative interviews with Dutch and Danish cyclists about phone use while cycling. The concept of affordances directed the focus towards how characteristics of everyday objects and the environment afford, moderate, or constrain cyclists' phone use from, for example, allowing proximate storage of the phone. Through thematic analysis of the interviews (Braun and Clarke, 2006), the study identified connections between cyclists' phone use and individual, social, and contextual factors. Cyclists with multiple bicycles of various types reported to change whether, how and for which purpose they used their phone due to both material properties and connections with social and contextual factors This points to cyclists adapting their risk-taking behaviours to the specific situation, as also suggested by Ihlström

et al. (2021) and Jungnickel and Aldred (2014). For instance, one cyclist avoided phone use when riding his racing bike, because of the lower positioning and high speed, but sometimes used the phone when riding his stable and slow three-wheeled cargo bike. Additionally, the different bicycle types were used in different social and physical contexts as they were used for different purposes. Previous research has linked contextual variations with changes in perceived risk (Kummeneje et al., 2019), and this variation possibly contributes to the behavioural variation. Further, clothing properties, bags, and baskets facilitated proximity of the phone, which made it easier to use the phone while cycling. Enabling reachability was an integrated part of some interviewees 'pre-trip strategies to use their phone while cycling. Planning for phone use while cycling is likely particularly prevalent among experienced and confident cyclists due to high perceived behavioural control (Adell et al., 2014), and in high-cycling countries due to designated infrastructure (Young et al., 2019). While previous research has identified strategies used to compensate for phone-related distractions during the trip (e.g. Adell et al., 2014; Ahlstrom et al., 2016; Jungnickel and Aldred, 2014; Kircher et al., 2015) the findings of the first sub-study extend these to include actions before the trip. The interviewees used pre-trip strategies to both enable and prevent phone use while cycling. To enable phone use some cyclists, for example, placed the phone in pockets or baskets within reach. Pre-trip strategies to prevent phone use included turning off notifications and sounds and starting music before the trip. The pre-trip strategies provide insights relevant to traffic safety on both an applied and a theoretical level. On an applied level, the specific behavioural strategies to prevent phone use while cycling contain a potential for reducing phone related crashes, if more cyclists actively make

use of them. On a theoretical level, cyclists' strategies to support or prevent phone use indicate that phone use can be planned or habitual. This corresponds with reflective and impulsive decision-making processes (e.g. Strack and Deutsch, 2004). Impulsive phone use possibly represents a higher risk towards cyclists' safety, as reflective use allows the cyclist to actively make use of the compensatory and adaption strategies that are crucial for traffic safety (Nygårdhs et al., 2020). Further, impulsive phone use is likely connected to the prompting features of smartphones (Lapointe et al., 2013) and use of social media (George et al., 2018). Habitual phone use while cycling has additionally been connected to persons of a younger age (van der Kint and Mons, 2019), which corresponds with the results of sub-study two (p. 91). Bans on phone use are founded on the idea that deterrent mechanisms affect the reflective decision to perform the behaviour (Åberg, 1998; Taxman and Piquero, 1998). Because impulsive phone use does not rely on reflective decision-making processing, this type pf phone use possibly imposes a threat towards the effectiveness of bans on handheld phone use. Forbidding handheld phone use could, however, motivate the uptake of strategies that prevent handheld phone use, including shifting to hands-free use by using headphone or phone mounts. This idea is supported by the findings of sub-study three (p. 127). The questionnaire study explored changes in handheld phone before and after the introduction of a ban on handheld phone use in the Netherlands, utilising a Danish sample for comparison. The results identified a significant decrease in use of handheld phone for conversations among Dutch respondents from 9.1% to 4.4%. The drop is likely explained from reduction in the proportion of cyclists using the phone's build-in speaker handheld, as receiving sound from this source reduced from 29.3% to 15.9%.

No reduction was detected for other phone functions, whilst Danish respondents did not significantly reduce use of any phone function. These results indicate that traffic rules rather motivate the uptake of strategies for how to use phone and avoid apprehension than reduce cyclists' phone use.

3.2 Factors predicting cyclists' phone use

Sub-study two (p. 91) compared how selected individual, social and contextual factors predict handheld phone use among Danish and Dutch cyclists. At the time of data collection, handheld phone use was only forbidden in Denmark. In the models for both countries, the likelihood of using handheld phone whilst cycling decreased as age increased, high self-identity as a safe and considerate cyclist, and high perceived behavioural difficulty of handheld phone use. Furthermore, the probability of handheld phone use increased with cycling frequency and high subjective norm. Factors related to education, population size of residential area and perceived risk did neither predict handheld phone use in Denmark nor in the Netherlands. Gender and ban belief each predicted handheld phone use in one of the two countries: Being male significantly increased the likelihood of using a handheld phone whilst cycling in the Netherlands. Believing handheld phone use was forbidden was associated with reduced likelihood of using handheld phone while cycling in Denmark. Most of these results support previous findings, such as identifying associations between handheld phone use and factors related to social norms (Jiang et al., 2019), cycling frequency, and lower age (Huemer et al., 2019; Young et al., 2020). The significant effect of being male in the Dutch model, however, contradicts previous research which do not find a gender

effect (Goldenbeld et al., 2012) and was unexpected as cycling in both Denmark and the Netherlands is not associated with gender, in contrast to many low-cycling countries, where men cycle more (Koglin et al., 2021). The gender effect could be connected to different design of “mens” and “women's” bicycles, but this does not explain why it is only found in the Netherlands, and the effect should be studied in future research.

Traffic rule beliefs have, to our knowledge, not previously been included as an explanatory variable for phone use among cyclists or other groups of road users. The belief that handheld phone use is forbidden is only connected to a reduced likelihood of handheld phone use in Denmark and provides nuances to the debate about traffic rule mechanisms. To support the idea that (traffic) rules can change behaviours indirectly by changing attitudes and/or moral norm (e.g. Bilz and Nadler, 2014; Greenberg, 2014), we would expect ban beliefs to reduce the likelihood of handheld phone use, disregarding the official legal status. There is no effect of ban belief in the Netherlands whilst there is in Denmark, which could point to traffic rules gaining effects from experiencing enforcement and related change in moral norms over time. The negative association with self-identity as a safe and considerate cyclist could however indicate an effect from moral norm. This is however likely not linked to traffic rules, as the model corrects for traffic rule beliefs. It is however also possible that cyclists align their self-identify to their actual phone use behaviours to avoid cognitive dissonance like suggested for car drivers (Gauld et al., 2021). This could for example mean that cyclists who use handheld phone while cycling lower their moral self-identify. That subjective norm is the strongest contributing factor in both Denmark and the Netherlands (OR:

DK=1.98, NL=2.19), suggests that addressing behaviours in social groups is relevant in order to reduce handheld phone use among cyclists. Previous research of non-compliance with other traffic rules have suggested to target pluralistic ignorance of how widespread the behaviour is (Das, 2020; Møller and Haustein, 2014), which could also be relevant for cyclists' handheld phone use.

3.3 Changes after forbidding handheld phone use

A widely used measure to prevent the risk from phone use among cyclists, is to ban handheld and/or hands-free phone use (Mwakalonge et al., 2014). The third sub-study explored effects of banning handheld phone use for cyclists in the Netherlands, comparing results to Danish cyclists, who already experienced a similar ban. The results identified changes in traffic rule knowledge, phone use behaviours, and the psychological measures: sense of guilt and perceived annoyance before and after introduction of the ban.

An analysis of the proportion of respondents using a phone for various purposes whilst cycling revealed national similarities and differences. In both the Netherlands and Denmark, the second and third most used functions (after navigation), were reading and writing text messages. The proportion of respondents using these functions whilst cycling were strikingly similar across both countries and across before-after ban measures, ranging from 26.6% to 28.2% for text reading, and 21.3% to 23% for text writing. Yet for other functions (writing and reading e-mails, taking photos, and browsing and posting on social media), there are clear national differences with more use in the Netherlands than in Denmark, and no change between data collection

waves. A common trait for these functions is that they do not need prompt responses, like text messages sometimes do. This difference makes it easier to postpone phone use for these functions until the trip is over. It is possible that Danish cyclists to a lesser extent use a handheld phone for these “unnecessary” functions, as a consequence of handheld phone being illegal before smartphones became the dominant phone type (Rigsadvokaten, 1998). Changes in cultural norms could either have an effect on its own (Bilz and Nadler, 2014) or boost the deterrence mechanisms of a ban (Wenzel, 2004). That sense of guilt and perceived annoyance (the degree to which one believes their phone use annoys others) both increased for handheld phone use in the Netherlands, and remained stable for hands-free phone use, could indicate that the ban has the potential to change cultural norms over time, including phone use behaviours. It is, however, probable that a ban on handheld phone use does not eliminate the behaviour, but rather changes *how* and *where* cyclists use phones, as expressed by Danish cyclists in the interview study.

Overall, the changes between pre- and post-ban measures are likely connected to the introduction of the ban, as they were only significant in the Netherlands and for the psychological measures connected to handheld phone use. This indicates that the introduction of traffic rules affects individual and social factors, and possibly changes behaviours through these mechanisms. It is therefore vital that evaluations of bans on handheld phone take the psychological changes into account and acknowledge that changes may take time before they manifest. Finally, deliberations about banning handheld phone use should also consider potential rebound effects, as some cyclists

will pick up strategies to avoid apprehension, which could impose distractions and risk towards cyclists' safety.

4 STRENGTHS AND LIMITATIONS

The findings of the research project were identified in three sub-studies that used a mixed-methods approach including qualitative interview data and quantitative questionnaire data. Mixing qualitative and quantitative methods strengthens the research project, as the different approaches identify different aspects and complement different weaknesses. The choice of using qualitative interviews for sub-study one, was made due to their ability to capture in-depth descriptions of both behaviours and reasoning (Brinkmann and Kvale, 2015) from the same cyclists in different individual, social, and contextual settings. On the contrary, using web-based questionnaires in sub-study two and three, allowed for data collection in much greater demographically representative samples, with standardised phrasing of questions. This made it possible to perform statistical analysis and compare results across countries and before-after the Dutch ban.

The interview and questionnaire studies both made use of self-reported data. A methodological concern, when using self-report measures, or when there is an interaction between the study-participants and the data administrator, is that participants might change responses or behaviours to appear more socially desirable. Social desirability is likely more prevalent in-person interviews, where there is a direct interaction between interviewer and interviewee (Johnson and Van De Vijver, 2003). Therefore the interviewer may take on a curious interview style, to appear open-minded and less threatening (Brinkmann and Kvale, 2015). Danish interviewees did nevertheless willingly describe their use of handheld phone, despite the self-incrimination aspect. It is not possible to know if interviewed cyclists suppressed descriptions

of more hazardous or frequent use but the interviewees did not seem to find the topic controversial.

Social desirability is also a concern in questionnaire studies. A study exploring whether social desirability affect reports of transport behaviours in questionnaires could neither confirm nor eliminate such an effect completely (Sullman and Taylor, 2010). The results from the questionnaire studies of this research project, nevertheless, indicate that there was no alteration of responses, or that these were neutralized on an aggregate level. For example, proportions in use of handheld phone functions (except for conversation) did not change in the Netherlands after the ban, despite an increased proportion believing handheld phone use was forbidden. As part of ethical and general data protection regulation-compliant data collection, participants were guaranteed pseudonymity, which probably reduced the pressure to appear socially desirable.

Another methodological concern of questionnaires is their ability to account for varying behaviours. A finding from the interview study was that cyclists' phone use behaviours vary in relation to the environment, and previous research suggested that the risk perception varies similarly (Blitz, 2021). Measuring behaviours and risk perception with questionnaire items does hardly allow us to capture such influences from detailed contextual characteristics. Some questionnaire studies have used scenarios (e.g. pictures) to identify contextual variations (Huemer et al., 2016; Oviedo-Trespalacios et al., 2018), but this still restricts the variation to a given number of fixed examples. To overcome part of this problem, we asked respondents to fill out the questionnaire for trips on their most used bike, as bike type was associated with

phone use in the interview study. This however still neglects the specific environmental contexts and the results of sub-study two and three should therefore be interpreted as indicating overall trends, which relations can be explored in-depth in qualitative studies. Further, the questionnaire studies included measures on both risk perception and other established psychological concepts that have previously been defined and measured in various ways (Sjöberg et al., 2004). All items for the questionnaires of this research project were newly developed, particularly to investigate cyclists' phone use, which strengthens their relevance in identifying results on this topic. However, it also means that the results are not directly comparable to other studies that used the same concepts, but measured them differently. Another limitation that relates to the comparability and transferability of the results is that all data were collected in Denmark and the Netherlands, which are both high-cycling countries with pro-cycling policies (Pucher and Buehler, 2008). The risk from cyclists' phone use might be different in countries with lower cycling rates both because phone use is more or less prevalent among cyclists and because the infrastructure for cyclists is less developed to forgive error, and cyclists therefore behave more cautiously (Dumbaugh and Li, 2010). As more countries aim for more cycling and create more cyclist-safe infrastructure, there is a risk of increase in phone use among cyclists (Young et al., 2020). This makes the results relevant for these countries as well.

5 CONCLUSIONS AND IMPLICATIONS

The three sub-studies complement each other and the existing body of literature in advancing our knowledge about cyclists' phone use. The discussion focused on cyclists 'phone use strategies, factors predicting handheld phone use, and the effects of banning handheld phone use. This conclusive chapter summarises the findings in relation to the overall aim of answering how individual, social, and contextual factors affect cyclists' phone use, and points to how the findings provide perspectives on bans as measures to mitigate the related risk.

The introduction established that cyclists' phone use imposes a risk towards safety from possible visual, auditive, motoric, and cognitive distractions (SWOV, 2017). Previous studies have connected phone use while cycling to risk-compensatory strategies but also to the performance of safety-critical behaviours (e.g. De Waard et al., 2014; Oviedo-Trespalacios et al., 2016; Terzano, 2013). The research project identified how selected individual, social, and contextual factors affect cyclists' phone use: from specific material characteristics of everyday objects, over psychological constructs, to legal interventions. These can be summarised in the following four key results:

1 Some cyclists use **pre-trip strategies** to allow and prevent phone use during the trip. This points to some phone use being reflective, and some being impulsive. As traffic rules can only directly affect reflective use, pre-trip strategies offer a possible solution for mitigating impulsive phone use during cycling.

2 Phone use while cycling was connected to **social factors** in two ways. Riding in groups was associated with abstaining from phone use, while supportive subjective norm was a strong predictor of handheld phone use.

3 Cyclists' phone use varies in relation to **specific contextual affordances**. For example, phone use is facilitated by proximity, if the phone is stored in reachable pockets or baskets. The immediate affordances connect to infrastructure as, for instance, waiting for a red light allow the cyclists to use their phones in ways that appear less of a risk.

4 A ban on handheld phone use likely contributes to a decrease in handheld phone use for conversation while cycling and encourages the uptake of pre-trip strategies and technological solutions (e.g. use of headphones). This points to a willingness for compliance when phone use can be facilitated though non-handheld sources. A ban probably also increase perceived annoyance and guilt related to handheld phone use and could have greater effect over time.

The association between phone use and proximate environmental characteristics is on one hand assuring, because it implies that the behaviour is (mostly) performed with consideration to the specific context. On the other hand, it points to some cyclists' believing they can control the risk, which is sensitive to both overconfidence bias, risk detection abilities, and actual behavioural control. The use of strategies related to context also indicates that phone use behaviour varies between the individual cyclists, and that it is not only performed incautiously by particularly bad mannered cyclists. If cyclists

can abstain from reflective phone use in some contextual setting, it implies a potential for reducing this in other situations as well, for example from deterrence mechanisms of a ban. Particular visible and continuous types of use (like conversation) is probably more sensitive to deterrence mechanisms of facing authority and risking a fine, than shorter handheld interactions. Additionally, phone use utilised for conversation can easily be changed to hands-free use by use of technology. For impulsive phone use, a ban on handheld phone use probably encourage wider use of pre-trip strategies and technological solutions to prevent handheld phone use. The results do however not show whether or not the uptake is motivated by deterrence mechanisms, change in moral, or a combination of both. It is a relevant topic for future research to investigate the mechanisms behind traffic rules on phone use. An unintended consequence of banning handheld phone use could, nevertheless, be that cyclists start using strategies to avoid apprehension. If cyclists use cognitive and visual resources to avoid apprehension, a ban's total effect on cyclists' safety is likely reduced. Evaluations of bans on handheld phone use should consider such rebound effects and other unintended changes, as these likely also affect cyclists' safety. Additionally, a ban on handheld phone use probably affects psychological factors: The pre-post ban results in the Netherland identified higher sense of guilt and higher perceived annoyance of handheld phone use after the ban. These concerns are not arguments against banning handheld phone use, but a recommendation of acknowledging the wider impacts traffic rules can have on individual, social, and contextual levels. Finally, the strong connection between handheld phone use and supportive subjective norms and low self-identity as a safe cyclist further indicate a potential for future research. If characteristics of sub-

groups with high peer-pressure and plural misconceptions related to phone use can be identified, it will be possible to target these variables with more specific interventions.

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THE PAPERS

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

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CYCLISTS' PHONE USE IN RELATION TO PROXIMATE ENVIRONMENTAL CHARACTERISTICS - A QUALITATIVE STUDY

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.

Keywords: cyclist safety, distractions, phone use, traffic behaviour, affordance theory

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 preripheral 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 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. Chataway et al. (2014) suggested cyclists' phone use might be more prevalent in high-cycling countries with designated cyclist infrastructure designed from the principle 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 & 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 proxmiate 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 minutes. The language was either Danish or English. All interviews were audio recorded and transcribed verbatim by the first author.

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

Name*	Country	Gender	Age	Primary bicycle type	Primary 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[a]	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

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

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 Figure 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.

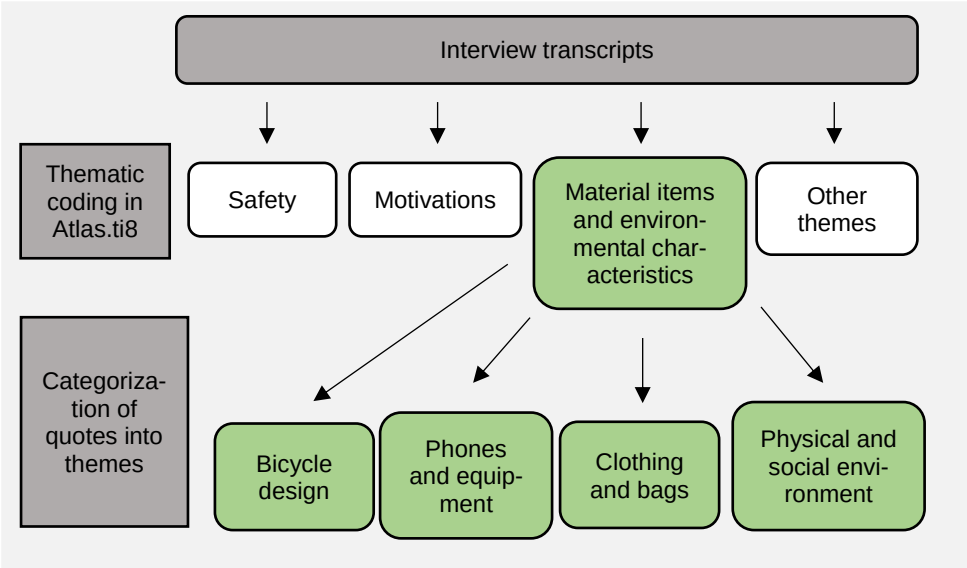

Figure 1: Analytical process of extraction of the data subset material items and environmental characteristics and further categorization into thematic categories.

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 & 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 & 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 & 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 kilometers in both countries (Buehler and Pucher, 2020).

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, Figure 2 shows categories identified in the analysis arranged according to how easily cyclists can influence them. All categories from Figure 1 are described under the relevant headings.

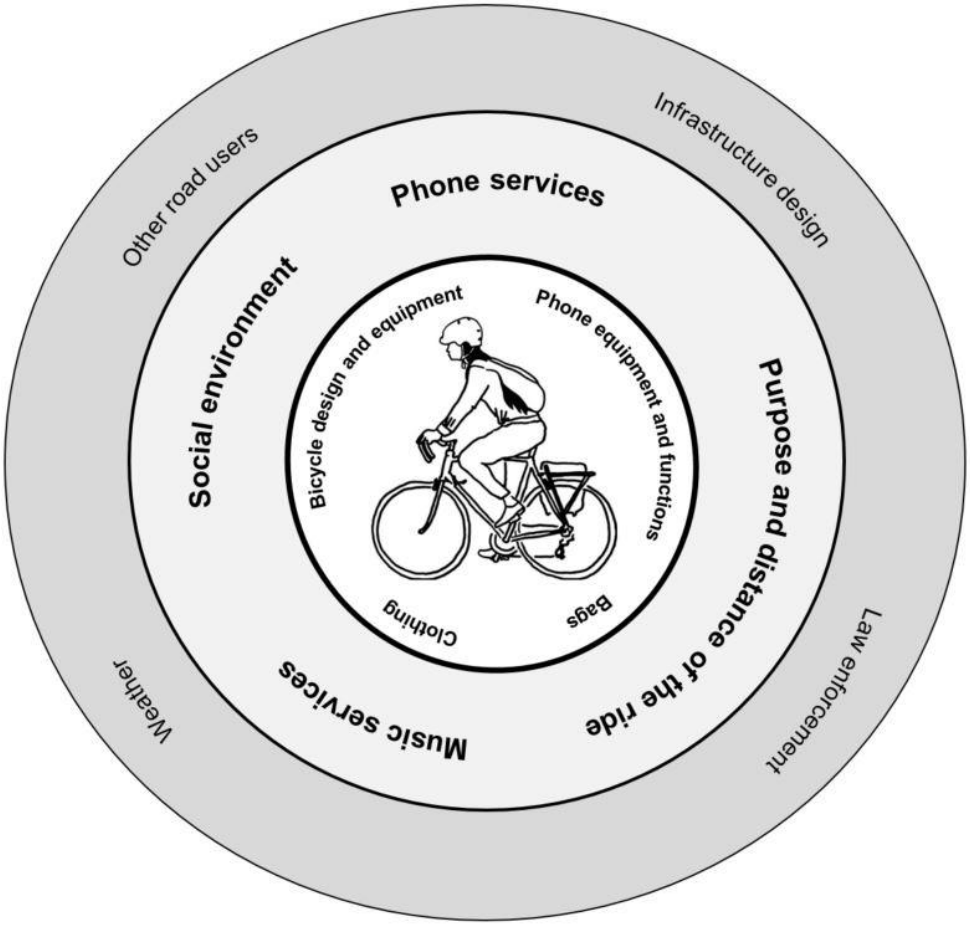

Figure 2: Overview of the identified categories of proximate environmental characteristics associated with cyclists' phone use in traffic. The circles represent how easily cyclists can affect the characteristics related to phone use, with highest possible direct impact on items in the inner circle and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

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).

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 maneuvers:

> *[…] 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 & 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 revealed 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.

Preventive measures are often designed to targeting different sub groups, but it is possible that the combination of, for example, traffic rules and technological measures strengthen the overall aim of changing and regulating behaviours to improve traffic safety.

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PAPER 2

Under revision in Transportations Research Part F: Traffic Psychology and Behaviour

Cyclists' handheld phone use and traffic rule knowledge

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CYCLISTS' HANDHELD PHONE USE AND TRAFFIC RULE KNOWLEDGE

ABSTRACT

Phone use is likely to distract cyclists and possibly increase crash risk. Therefore, handheld phone use among cyclists is forbidden by law in some countries, even though cyclists use compensatory strategies to attempt to mitigate distractions and related effects. Both demographic, environmental, and psychological factors have been associated with cyclists' phone use. This study extends the existing literature by including traffic rule beliefs as an explanatory measure in predicting cyclists' handheld phone use and additionally explores how well cyclists know these rules in different legislative contexts. Online questionnaire responses were collected in 2019 among 1055 cyclists living in Denmark (*N*=568), where handheld phone use for cyclists was forbidden, and in the Netherlands (*N*=487), where it was legal. Responses on phone use, traffic rule knowledge, cycling behaviour, demographic, and psychological measures were used to identify factors contributing to the likelihood of handheld phone use in three regression models; one for all respondents and one for each country. In the combined model, believing there are no rules on handheld phone use increased the likelihood of handheld phone use while cycling. Other significant factors were subjective norm, perceived behavioural difficulty, self-identity as a safe cyclist as well as demographic factors. The country-specific models found that male

gender was only associated with more handheld phone use in the Netherlands, while believing there was no ban was only connected to an increase in the likelihood of using handheld phone in Denmark. Correct traffic rule knowledge was almost three times higher in Denmark, where handheld phone use was forbidden. The results identify subjective norms, potential overconfidence, and traffic rule awareness (when there is a ban) as relevant factors in reducing the likelihood of cyclists' handheld phone use. Findings from country-specific models possibly point to a connection between culture and traffic rules. Future research should focus on underlying mechanisms and awareness of traffic rules.

Keywords: Cyclist safety, phone use, distractions, traffic rule knowledge

1 INTRODUCTION

The increased use of electronic devices has affected traffic behaviours by, for example, providing effective route choice services (Aguiléra & Boutueil, 2018) and enabling music reception (Jungnickel and Aldred, 2014), conversation, and texting. This also applies to cyclists, who use phones for various purposes both handheld and hands-free (De Angelis et al., 2020; De Waard et al., 2011, 2010; Terzano, 2013). Phone use is likely to distract road users (SWOV, 2018) and increase crash risk among cyclists (De Angelis, Fraboni, Puchades, Prati, & Pietrantoni, 2020; Goldenbeld, Houtenbos, Ehlers, & De Waard, 2012). The increasing prevalence of smartphones has likely contributed to the observed shift over time towards more handheld screen operation (e.g., De Waard, Westerhuis, & Lewis-Evans, 2015). This is critical as smartphone use appears to be more dangerous than the use of push-button phones (De Waard et al., 2014). A range of factors has been connected to cyclists' phone use. Phone use was identified to increase with cycling frequency and decrease with age (e.g., Huemer, Gercek, & Vollrath, 2019; Young, Stephens, O'Hern, & Koppel, 2020). The psychological factors social norm, sensation seeking, and perceived behavioural control were associated with an increased likelihood of phone use, while a high level of perceived risk was connected to a lower prevalence of phone use among cyclists (Christoph, Kint, & Wesseling, 2017; Jiang et al., 2019; Young et al., 2020). Cyclists' phone use was further connected to external conditions, such as sunny weather (Huemer, Gercek, & Vollrath, 2019), proximate environmental conditions (Brandt et al., 2021), and waiting at a red light (Nygårdhs, Ahlström, Ihlström, & Kircher, 2018).

To compensate for phone-related distractions, some cyclists use strategies such as increased glance behaviour (Ahlstrom, Kircher, Thorslund, & Adell, 2016; Jungnickel & Aldred, 2014; Stelling-Konczak et al., 2018) and positioning further from the curb (De Waard, Edlinger, & Brookhuis, 2011). Though cyclists use strategies to mitigate crash risk, these are sometime insufficient (Stelling-Konczak et al., 2018), and cyclists' handheld phone use is categorized as a safety risk and forbidden by law in some countries (Mwakalonge, White, & Siuhi, 2014). The literature has not yet clarified the effectiveness of bans on handheld or hands-free phone use in improving cyclist safety. Forbidding handheld phone use for car drivers points to a potential decrease in the prevalence of handheld phone use (Olsson, Pütz, Reitzug, & Humphreys, 2020), while bans on phone use for cyclists are under-researched (Mwakalonge et al., 2014).

This paper investigates psychological, legislative, and demographic factors contributing to cyclists' handheld phone use in Denmark and the Netherlands that had different traffic rules for cyclists' phone use at the time of the study (see Section 1.2). As novel contributions, the study compares two high-cycling countries with diferent legislation, and includes traffic rule beliefs as an explanatory measure to explore whether believing handheld phone use is forbidding decreases the likelihood of engaging in this practice.

1.1 Background

According to Åberg (1998) and Taxman and Piquero (1998), traffic rules influence behaviour by imposing a risk more certain than the risk from the

undesired behaviour itself. In addition to the probability of detection, compliance is believed to depend on the swiftness and severity of the punishment (Prati, 2018). The wish to avoid sanctions thus becomes a new motivation to behave safely. The effect of increasing traffic fines is nevertheless unconfirmed (Goldenbeld, 2017), and it is necessary for the target group to be aware of the traffic rules for them to have a direct effect (Huemer, Eckhardt-Lieberam, & Rules, 2016). It has, however, also been suggested that laws impact behaviours through social norms and other psychological factors, which then shape individual values (Nadler, 2017). In this study, we use selected factors that connect to cyclists' behaviours to predict cyclists' handheld phone use in a country with and without a ban. In addition to demographic and behavioural factors as well as traffic rule knowledge, we include a range of psychological constructs, which we describe in the following.

Subjective Norm (SN) refers to the normative beliefs about a specific behaviour, including the social pressure to act similar to others (Ajzen, 1991). As SN is possibly affected by laws (Nadler, 2017), different legal contexts possibly provide divergent social pressure for compliance. SN has previously been identified to explain phone use among car drivers (Walsh et al., 2008).

Perceived Behavioural Difficulty (PBD) is a measure we adapt from the construct perceived behavioural control (PBC) from the Theory of Planned Behaviour (Ajzen, 1991). PBC focus on both the actual control and the perceived easiness or difficulty of performing the behaviour and has previously been connected to cyclists' phone use (Jiang et al., 2019). PBD focuses

specifically on the latter and identifies the perceived difficulty of using handheld phone while cycling, including whether the cyclists think it affects their attention.

Self-Identity (SI) is a dynamic concept that covers self-portrayal as well as behavioural strategies in social settings, for example, identifying with cyclists as a group (Füssl & Haupt, 2017; Walsh & White, 2007). Perceived correctness of a behaviour further strengthens the likelihood of translating intentions into behaviour (Godin, Conner, & Sheeran, 2005), while group identity provides motivations for compliance (Nadler, 2017). Therefore, we focus specifically on moral dimensions of self-identity, such as thinking of oneself as a safe and considerate cyclist (see Table 2).

Perceived risk (PR) refers to the individual evaluation of a specific risk as a psychological attribution from the individual rather than an assessment of the actual risk (Rickard, 2014). Previous research found an association between perceived (crash and police-detection) risk and phone use among motorcyclists and car drivers (Nguyen-Phuoc, Oviedo-Trespalacios, Su, De Gruyter, & Nguyen, 2020).

1.2 THE PRESENT STUDY

At the time of this study, Denmark and the Netherlands had different rules for cyclists' phone use. In Denmark, handheld use of phones and other electronic devices was forbidden by law and fined 1000 DKK (approx. 130 EUR) (Transport-, Bygnings- og Boligministeriet, 2018). In the Netherlands, authorities acknowledged phone use as a safety issue for cyclists and addressed it through awareness campaigns (GVB, 2018) but without any rules

specifically forbidding the behaviour[1] (Minister van Verkeer en Waterstaat, 2010).

While the rules were different, the two countries shared a range of other characteristics that are relevant when comparing phone use among cyclists. Both countries are known for their high cycling levels, flat topography, pro-cycling policies and infrastructure (Haustein, Kroesen, & Mulalic, 2020; Pucher & Buehler, 2007, 2008), though this applies particularly to larger cities in Denmark, while being more commer all over the Netherlands (Koglin et al., 2021). Further, the countries have high digital adoption rates, and the number of mobile phone service subscriptions, for example, exceeds the number of inhabitants (ITU, 2021).

In this study, we explore demographic, psychological, and legislative factors contributing to cyclists' handheld phone use, including traffic rule beliefs. In line with previous studies, we expect phone use to decrease with age, high PBD, high SI, and high PR, and increase with riding frequency, and SN. The study extends the existing literature on cyclists' phone use from three novel contributions. Firstly, the study compares two high-cycling countries with different legislation. Secondly, it includes traffic rule beliefs as an explanatory measure in predicting cyclists' handheld phone use along with the psychological measures SN, PBD, SI and PR. Thirdly, the study explores how well cyclists know these rules in different legislative contexts. We expect more respondents to believe handheld phone use is forbidden

[1] The rules were changed in the Netherlands by 1st of July 2019, and now includes a ban on the use of handheld electronic devices, with a penalty of 95 euros (Ministerie van Infrastructuur en Waterstaat, 2019).

when it actually is and expect handheld phone use to be less common among respondents believing the behaviour is forbidden. The paper discusses possible implications of the results related to the prevention of phone use among cyclists.

1.2.1 Ethical approval

We contacted the scientific ethics committee in the capital region of Denmark, who informed us that the project did not need ethical approval. All data collection and storage was completed in accordance with the European General Data Protection Regulation.

2 METHOD

2.1 PROCEDURE AND PARTICIPANTS

We collected data with a questionnaire distributed to online panels in Denmark and the Netherlands from May 9th to July 17th 2019, by the market research institutes Epinion and Norstat. A sample representative regarding age and gender received invitations via email, and complete responses were compensated according to standard agreements at each institute. Respondents were minimum 18 years old, owned a mobile phone, and used a bicycle more than “never” (see Section 2.2.2). Before beginning the survey, respondents received general information like purpose of the questionnaire, and data storage information. In total, 1126 respondents completed the survey. After excluding suspicious responses, for example, respondents with the same choice for all attitudinal items in one block, the total sample consisted of 1055 cyclists: 568 people living in DK with a mean age of 46.18 (SD = 15.84), and 487 living in the Netherlands with a mean age

of 45.93 (SD = 14.88). For an overview of sample characteristics, see Table 1.

Table 1: Overview of sample characteristics separated by country.

Sample characteristics						
		Denmark (DK) (*N*=568)		**The Netherlands (NL) (*N*=486)**		**DK vs. NL**
Demographic variable	*Group*	*N*	*Percentage*	*N*	*Percentage*	*p*
Gender	Female	310	55.1	254	52.2	.348[b]
	Male	253	44.9	232	47.8	
Education[a]	Short	272	48.5	155	32.0	.000[b]
	Long	289	51.5	329	68.0	
Cycling frequency	>5 days per week	169	29.8	163	33.6	.000[c]
	3-4 days per week	86	15.1	102	20.8	
	1-2 days per week	102	18.0	112	23.1	
	1-3 days per month	98	17.3	53	10.9	
	<1day per month	113	19.9	56	11.5	
Handheld phone use within group	Female	116	37.4	76	29.6	.652[b]
	Male	91	36.0	96	41.4	
	Male + female	207	36.8	172	35.4	.608[b]

Note: Subgroups may not sum up to the total participant number due to missing responses for some variables. a Short = Compulsory education + max. 2 years, Long= Compulsory education + min. 2 years. b Fishers exact Chi2-test. c U-test.

Comparing countries, there were no significant differences in age, gender, and use of handheld phones, while differences in education and cycling frequency were significant ($p < 0.001$) with more frequent cycling and a higher share of respondents with long education among Dutch respondents.

2.2 Measures

2.2.1 Demographic measures

Demographic measures included age, gender, level of education, and population size. *Education* was measured with one item asking to report the highest completed education with six options, derived from local education levels, plus *other*.

Population size of responsents residential city was covered with one item with seven response options (<5000, 5000-9.999, 10.000-19.999, 20.000-49.999, 50.000-99.999, 100.000-500.000, and >500.000).

2.2.2 Phone use, cycling frequency, and traffic rule knowledge

Phone use was measured by asking respondents if they had ever used their phone while cycling for music, texting, or other purposes. If they chose the option *yes*, they were asked how often they used specific functions while cycling (camera, navigation, audio reception, text functions, and more). Those using the phone for auditory reception (e.g., calls and music) were asked how they received the sound (headphones, speaker: handheld or hands-free, etc.) for each auditory function.

Cycling frequency was measured with five response options (>5 days per week, 3-4 days per week, 1-2 days per week, 1-3 days per month, and <1 day per month).

Traffic rule knowledge was measured by asking respondents to identify traffic rules for cyclists from the options: 1) There are no rules regarding cyclists' phone use. 2) It is legal to use a phone hands-free and illegal to use it handheld. 3) It is legal to use a phone handheld and illegal to use it hands-

free. 4) It is illegal to use a phone hands-free and handheld in traffic. The item on traffic rule knowledge was placed at the end of the survey to avoid interference with items on phone use and psychological measures.

2.2.3 Psychological measures

An overview of included psychological items is available in Table 2.

Self-identity was measured by three items (SI1-SI3): SI1 measures respondents self-concept of being a safe cyclist. SI2 measures respondents' believed compliance with traffic rules. SI3 measures respondents' consideration of their behaviours affecting other road users.

Perceived risk was measured by two items: PR1 measures the general perceived risk of handheld phone use while cycling, while PR2 measures the perceived risk of handheld phone use causing a crash.

Subjective Norm was measured by three items presented as statements (SN1-3). The first two items refer to injunctive (SN1) and descriptive (SN2) subjective norms related to important others (friends), while SN3 covers social norms more generally.

Perceived Behavioural Difficulty was measured by three items with slightly different phrasing for respondents who did/did not use their phone while cycling (PBD1-3). PBD1 and PBD2 cover the ability to perform the task, while PBD3 measures how respondents believe performing the task affects their attention.

2.3 Analysis

Using all responses from both countries, we first calculated a logistic regression model using multiple predictors with *handheld phone use* as the dependent variable (Table 3) and *country* as an explanatory variable. We then calculated a similar model for each country (Table 4 and 5) to assess national differences. Differences in traffic rule knowledge were assessed from frequency distributions.

2.3.1 Recodings

The variables education, traffic rule knowledge, and phone use were recoded before including them in the final models. Education was recoded into the categories “short” (less than two years of education in addition to compulsory education) and “long” (minimum two years of education in addition to compulsory school). Traffic rule knowledge was recoded into the variable *ban belief*, separating responses according to whether they believed handheld phone use was forbidden for cyclists or not. Phone use was recoded into the variable *handheld phone use* that summarizes the items covering all types of phone use and related equipment into two categories: those who had used a handheld phone for any activity (coded as 1) and those reporting not to have used a handheld phone while cycling (coded as 0).

2.3.2 Allocation of psychological items to factors

Before including the measures in the regression models, we analysed how items of the constructs SI, PR, SN and PBD were allocated to factors in a principal component analysis. An Eigenvalue approximation above 1 extracted a 3-factor solution, explaining 61.8% of the variance (see Table 2).

As expected, items belonging to the same theoretic construct loaded together: All items belonging to the construct SI loaded on one factor, and all items of the construct SN loaded on another factor. All items belonging to the constructs PR and PBD nevertheless loaded on the same factor, and we thus assessed whether we could keep PR and PBD as separate constructs. A correlation table indicated a correlation with a coefficient of 0.5, and a collinearity test identified VIF values of maximum 2.03 (perceived risk). From this, we decided to keep PR and PBD as separate constructs in accordance with the theoretical approach. Cronbach's alpha values from 0.68 to 0.79 revealed acceptable internal consistencies of SI, PR, SN, and PBD. Mean scales for each theoretical construct were calculated and included in the regression models.

***Table 2**:* A principal component analysis with Varimax rotation showing factor loadings and internal consistency of items belonging to the psychological constructs. All items were measured on a 5-point Likert scale (1=strongly disagree; 5=strongly agree).

Rotated Component Matrix				
	PR + PBD	**SI**	**SN**	**Cronbach's alpha**
SI1: *I am a safe cyclist*	0.013	**0.779**	-0.108	0.709
SI2: *I generally comply with traffic rules*	0.222	**0.768**	-0.076	
SI3: *I think about how my behaviours in traffic affect others*	0.228	**0.700**	-0.011	
PR1: *Handheld phone use while riding a bike is dangerous*	**0.658**	0.424	-0.154	0.716
PR2: *Using a phone handheld while riding a bike is likely to cause an accident*	**0.670**	0.238	-0.197	
SN1: *My friends think it is fine to use one's phone while riding a bike*	-0.116	-0.071	**0.814**	0.679
SN2: *My friends use their phone handheld while riding their bike*	-0.078	-0.063	**0.848**	
SN3: *It is normal to use one's phone while riding a bike*	-0.267	-0.074	**0.618**	
PBD1[a]: *I swerve more when using my phone handheld while cycling*	**0.799**	0.003	-0.087	0.788
PBD2[a] *I find it difficult to use my phone handheld while riding*	**0.787**	0.073	-0.164	
PBD3[a]: *Using a phone handheld while riding disturbs my attention towards traffic*	**0.761**	0.221	-0.114	

a Phrased as hypothetical statements for non-users.

3 RESULTS

This section first presents results on factors contributing to handheld phone use. Second, it presents results regarding differences in traffic rule knowledge and handheld phone use between Denmark and the Netherlands.

3.1 ASPECTS PREDICTING HANDHELD PHONE USE AMONG CYCLISTS

Table 3 presents the parameter estimates for the logistic regression model for the complete sample (both countries), with handheld phone use as the dependent variable, which explains 53% of the variance (Nagelkerke's Pseudo R^2). With the exception of gender and perceived risk, all explanatory variables are significant ($p < .05$). The strongest contributing factors to an increased likelihood of handheld phone are living in Denmark (OR = 1.47), believing there is no ban (OR = 1.72), cycling frequency (OR = 1.41), and SN (OR = 2.09). The variables with the strongest decreasing effect are SI (OR = 0.57) and PBD (OR = 0.42). Additionally, handheld phone use decreases with short education (OR = 0.69) and increasing age (OR = 0.94), though the effect is small. PR not reaching significance is the only parameter incongruent with expected results in the combined model.

Table 3: Parameter estimates for a logistic regression model for responses from both Denmark and the Netherlands with 'Handheld phone use' as the dependent variable.

Note: Ref.=reference group

DENMARK AND THE NETHERLANDS: Parameter estimates for handheld phone use						
	B	**S.E.**	**Sig.**	**OR**	**95% C.I. for OR**	
					Lower	**Upper**
Denmark *(ref.: the Netherlands)*	0.384	0.189	0.043	1.468	1.013	2.128
Male *(ref.: female)*	0.220	0.179	0.221	1.245	0.876	1.771
Education = short *(ref.: long)*	-0.379	0.184	0.039	0.685	0.477	0.982
Ban belief = no ban *(ref.: ban)*	0.542	0.208	0.009	1.719	1.143	2.585
Age	-0.061	0.007	0.000	0.941	0.929	0.953
Cycling frequency	0.344	0.064	0.000	1.411	1.244	1.599
Population size residential city	0.129	0.061	0.036	1.137	1.008	1.282
Self-identity (SI)	-0.557	0.166	0.001	0.573	0.414	0.794
Subjective Norm (SN)	0.739	0.128	0.000	2.094	1.629	2.692
Perceived Behavioural Difficulty (PBD)	-0.877	0.128	0.000	0.416	0.324	0.534
Perceived Risk (PR)	-0.063	0.149	0.672	0.939	0.701	1.258
Constant	3.590	0.897	0.000	36.248		

Table 4 includes the results for the Danish sub-sample. It includes the same dependent and explanatory variables as Table 3 apart from country. Similar to the combined model, the strongest contributing factors are believing there is no ban (OR = 1.92), cycling frequency (OR = 1.52), and SN (OR = 1.98). Moreover, age (OR = 0.94), SI (OR = 0.58), and PBD (OR = 0.42) are all significant ($p < .05$), while PR ($p = .80$) and gender ($p = .66$) is not, which also corresponds to the combined model. Dissimilar to the combined model, education and population size, are both insignificant.

***Table 4**:* Parameter estimates for a logistic regression model with 'Handheld phone use' as the dependent variable only using the responses from Denmark.

DENMARK: Parameter estimates for handheld phone use						
	B	**S.E.**	**Sig.**	**OR**	**95% C.I. for OR**	
					Lower	**Upper**
Male *(ref.: female)*	-0.110	0.250	0.659	0.895	0.548	1.463
Education = short *(ref.: long)*	-0.267	0.244	0.273	0.765	0.474	1.235
Ban belief = no ban *(ref.: ban)*	0.651	0.311	0.036	1.918	1.044	3.525
Age	-0.062	0.009	0.000	0.940	0.924	0.955
Cycling frequency	0.421	0.085	0.000	1.524	1.290	1.800
Population size residential city	0.163	0.088	0.065	1.177	0.990	1.399
Self-identity (SI)	-0.496	0.227	0.029	0.609	0.390	0.949
Subjective Norm (SN)	0,681	0.184	0.000	1.975	1.378	2.832
Perceived Behavioural Difficulty (PBD)	-0.860	0.181	0.000	0.423	0.297	0.604
Perceived Risk (PR)	-0.052	0.203	0.799	0.950	0.638	1.413
Constant	3.393	1.365	0.013	29.743		

Note: Ref.=reference group

Table 5 includes the results of the Dutch responses. In this model, the strongest significant factors ($p < .05$) are SN (OR = 2.19) and being male (OR = 1.88). Like in both the combined and the Danish model age (OR = 0.95), cycling frequency (OR = 1.25), SI (OR = 0.53), and PBD (OR = 0.40) are significant ($p < .05$), while PR is not ($p > .10$). Education and population size were not significant, which is similar to the Danish model and in contrast to the combined model. Believing there is no ban was, unlike in the combined and the Danish model, not significant ($p > .10$).

***Table 5**:* Parameter estimates for a logistic regression model with 'Handheld phone use' as the dependent variable only using the responses from the Netherlands.

THE NETHERLANDS: Parameter estimates for handheld phone use						
	B	**S.E.**	**Sig.**	**OR**	**95% C.I. for OR**	
					Lower	**Upper**
Male *(ref.: female)*	0.629	0.268	0.019	1.875	1.110	3.169
Education = short *(ref.: long)*	-0.440	0.296	0.136	0.644	0.361	1.149
Ban belief = no ban *(ref.: ban)*	0.417	0.289	0.149	1.517	0.861	2.672
Age	-0.055	0.011	0.000	0.946	0.926	0.966
Cycling frequency	0.226	0.101	0.025	1.253	1.029	1.526
Population size residential city	0.083	0.086	0.339	1.086	0.917	1.287
Self-identity (SI)	-0.632	0.255	0.013	0.532	0.323	0.877
Subjective Norm (SN)	0.785	0.185	0.000	2.192	1.525	3.149
Perceived Behavioural Difficulty (PBD)	-0.907	0.186	0.000	0.404	0.280	0.582
Perceived Risk (PR)	-0.117	0.237	0.622	0.890	0.559	1.415
Constant	4.441	1.280	0.001	84.870		

Note: Ref.=reference group

3.2 Traffic rule knowledge in Denmark and the Netherlands

The distribution of responses across the four options regarding traffic rule knowledge is significantly different (Chi-square, p<.001) in Denmark and the Netherlands. The share of correct responses is significantly higher (t-test, p < .001) among Danish (58%) than Dutch (22%) respondents. Despite different legislation in DK and NL, the distribution of responses follows a similar pattern. In both countries, the highest share of respondents choose option 2 (*It is legal to use a phone hands-free and illegal to use it handheld*), followed by option 4 (*It is illegal to use a phone hands-free and handheld in*

traffic), 1 (*There are no rules regarding cyclists' phone use*), and 3 (*It is legal to use a phone handheld and illegal to use it hands-free*). When separating Danish participants according to traffic rule knowledge, there is no variation in how many that use handheld phone while cycling (Chi-square test, p = .92). On the contrary, phone use frequency diverges significantly between Dutch groups with different traffic rule knowledge (Chi-square test, p = <.05) with the highest frequency of handheld phone use (52%) among those believing handheld phone use is legal while hands-free is forbidden. On an over-all level (Table 1), there is no significant difference (Chi-square test, p = .65) in frequencies of handheld phone use between Denmark (36.8%) and the Netherlands (35.4%).

Table 6: Traffic rule knowledge separated by country. Grey shading highlights the correct answer for each country. Percentage of respondents using handheld phone in each category indicated in brackets.

	Traffic rule knowledge			
	1 **No traffic rules**	**2** **Hands-free = legal** **Handheld = illegal**	**3** **Hands-free = illegal** **Handheld = legal**	**4** **All phone use banned**
DK	**16.9%** (39.6%)	**58.0%** (36.8%)	**2.1%** (33.3%)	**22.9%** (35.4%)
NL	**22,0%** (39.3%)	**39.5%** (40.3%)	**5.1%** (52.0%)	**33.3%** (24.1%)

4 Discussion

The study aimed to investigate demographic, legislative, and psychological aspects contributing to cyclists' handheld phone use and to assess traffic

rule knowledge in different legislative contexts. From the literature, we assumed the probability of using a handheld phone would decrease with age, perceived behavioural difficulty, high self-identity, high perceived risk, and increase with riding frequency, and subjective norm. With the exception of a decrease of reported handheld phone use with perceived risk (insignificant in all models), the results were in line with the assumptions. Additionally, we found that believing the behaviour is legal increases the likelihood of handheld phone use in the combined and the Danish model. In the Dutch model, being male and having a long education was associated with an increased probability of handheld phone use. Finally, the percentage of correct traffic rule responses was much higher in Denmark, where there was a ban. The following discussion first addresses findings from the combined and the country-specific models before moving on to results regarding traffic rule knowledge.

4.1 Factors contributing to cyclists' handheld phone use

Though the effect is very small, the prevalence of handheld phone use decreases with age in all models, which corresponds with the findings in a Dutch report identifying phone use to peak among 18-24-year-olds and then decline (Christoph et al., 2017). This is likely explained by younger people simply sending more text messages compared to older age groups (Forgays, Hyman, & Schreiber, 2014). The likelihood of using handheld phone while cycling significantly increases when believing the behaviour is legal in the combined (OR = 1.7) and the Danish model (OR = 1.9). This is the second strongest effect among the variables and indicates a connection between believing there is a ban on handheld phone use and an actual

reduction in the behaviour, when the remaining variables are fixed. The effect of believing there is no ban is nonetheless insignificant in the Dutch model, which possibly suggest that this factors is supported by other country-specific aspects, like general norms and culture. Though the effect of believing there is no ban is insignificant in the Dutch model, it is associated with more phone use, and thus follow the tendency of the other models. When introducing traffic rules, it is, therefore, important to increase awareness of the rules for them to have an effect (Huemer et al., 2016). Correct law identification was nonetheless much higher in Denmark (58%) than in the Netherlands (22%), which points to higher traffic rule knowledge when there is a ban, though it is possible that some Dutch respondents mistakenly believed the upcoming ban on handheld phone use was already in effect. In the country-specific models, the effect of believing there is a ban is only significant among Danish respondents, who actually experienced a ban. This national difference could be connected to detection risk, as Dutch respondents could not have experienced police encounters for a non-existent ban. The effect from believing there is a ban in Denmark could nevertheless also be associated with different culture (Koglin et al., 2021; Nielsen et al., 2015), as a ban possibly changes norms over time (Nadler, 2017). In the combined model the variable *country* connects living in Denmark with a higher likelihood of phone use, which similarly might express national differences not included in the model; like the cultural aspects (Haustein et al., 2020), infrastructure design (Colville-Andersen, 2018; Koglin et al., 2021), or distribution of bicycle types. Such aspects could also connect to the increase in the likelihood of handheld phone use with a higher popula-

tion size in the residential area, as urban areas typically have better infrastructure for cyclists compared to suburban areas. In an experimental study, some cyclists found waiting at a red light to be a suitable place for texting (Nygårdhs et al., 2018). The higher prevalence of traffic lights in urban areas creates more forced stops, which could trigger phone use among boredom prone cyclists, as identified among male car drivers (Oxtoby, Schroeter, Johnson, & Kaye, 2019).

Population size is not significant in the country-specific models, but fairly close in Denmark ($p = 0.065$), which may relate to the capital-area being particular cycling friendly in Danish standards, while the Netherlands have numerous cycling friendly cities (Koglin et al., 2021). All models further identified an increasing likelihood of phone use with higher cycling frequency. This could simply be explained by more cycling time expanding the window of opportunity for phone use and more experienced cyclists having more confidence in their riding and multi-tasking skills (Young et al., 2020). All models identify high perceived behavioural difficulty to decrease the likelihood of handheld phone use and still finds the likelihood of handheld phone use to increase with higher cycling frequency; it supports both the ‘window of opportunity’ and experience explanation.

The association between high self-identity and lower likelihood of handheld phone use could indicate that cyclists with more considerate and safe attitudes act accordingly. Subjective norm, the strongest effect in all models, increases the likelihood of handheld phone use, which may connect to either pluralistic ignorance; believing a behaviour is more common and/or more highly approved than it actually is (Das, 2020), or actual experiences of phone use among peers. While pluralistic ignorance could possibly be

corrected from campaigning, experiences of actual phone use would require a change in the peers' behaviours.

Perceived risk did not reach significance in any of the models, which conflicts with a finding in an earlier study (Christoph et al., 2017). We suggest the inclusion of perceived risk in future studies about cyclists' phone use for further exploration, as other studies indicate that underestimation of risk may discourage sufficient use of behavioural caution among cyclists (Møller & Hels, 2008).

4.2 Traffic rule knowledge and types of non-compliance

As highlighted in the previous section, correct traffic rule identification is much higher in Denmark (58%) than in the Netherlands (22%). In addition to cyclists possibly being more aware of a ban than the absence of one, people living in countries with a ban have the chance of gaining awareness of it from informative campaigning, word of mouth, and experiences of enforcement. If these mechanisms contribute to increasing traffic rule knowledge, it provides another aspect of how traffic rules work than the deterrent effects from sanctions, as suggested by, for example, Åberg (1998) and Taxman and Piquero (1998). Literature built on social science (e.g., Sunstein, 1997; Tyler, 1990) has challenged the behaviouristic idea of compliance from deterrence. They have suggested that (traffic) rules also affect attitudes (Bilz & Nadler, 2014) and that compliance can be motivated by democratic and moral obligations (Yagil, 1998). The effect from moral obligations corresponds to the identified decrease in the likelihood of

handheld phone use with high self-identity. While this study does not focus on motivations for compliance, the results do reveal an interesting finding on cyclists' traffic rule knowledge. In both Denmark and the Netherlands, responses about traffic rule knowledge on phone use are distributed in a similar pattern across response options, with most (DK: 58%, NL: 40%) believing handheld phone use is forbidden, while hands-free is allowed. In addition to this being correct in Denmark, it is equivalent to the rules for car drivers in both countries. It is thus probable that some respondents reasoned the rules for cyclists to be similar to those for car drivers. Another explanation for why many Dutch respondents chose this option is that the suggestion to forbid handheld phone use for cyclists was publicly debated in the years prior to the data collection. Some respondents may have had the impression that the upcoming ban on handheld phone use was already in effect. Contrary, the debate could have made some aware of the absence of rules regarding phone use. Future rule awareness campaigns could likely benefit from further research about how and from where cyclists obtain traffic rule knowledge.

Increasing safety and reducing physical effort have been highlighted as motivations behind cyclists' disobedience of traffic rules (Ihlström, Henriksson, & Kircher, 2021; Marshall, Piatkowski, & Johnson, 2017). While phone use is not a direct measure to achieve either of these, it may be motivated by other positive features, like offering flexibility in arranging daily tasks (Hjorthol, 2008) and contributing to a pleasant riding experience (Jungnickel & Aldred, 2014). Whether cyclists find it pleasant to use handheld phone is probably related to perceived behavioural difficulty. The lower likelihood of handheld phone use with perceived behavioural difficulty

indicates that higher confidence in own skills is associated with more handheld phone use. This connects to a study by Puchades et al. (2018) that identified an association between high perceived behavioural control and cyclists' overconfidence in their own skills. Overestimation of how well one cycles and distributes attention while using handheld phone could be an underlying explanation for the decreasing likelihood of handheld phone use with perceived behavioural difficulty. Further, the technological development of mobile phones probably adds to an underestimation of perceived behavioural difficulty, as the constant stream of (possible) messages and notifications is connected to habitual use (Oxtoby et al., 2019; Soror, Hammer, Steelman, Davis, & Limayem, 2015). If the behaviour is not under complete voluntary control (Brandt et al., 2021), it imposes a risk towards the effectiveness of a ban. While a ban possibly can have an indirect effect (Bilz & Nadler, 2009) from, for example, moral stigmatization or change in attitudes with the introduction of rules, traffic rules and sanctions cannot minimize habitual phone use directly. Yet another aspect to consider in relation to the introduction and effectiveness of legal measures towards cyclists' phone use is the possible misconception of the term 'handheld'. A report from the Dutch institute for road safety research (Christoph et al., 2017) noted that remarkably fewer respondents reported using their phone in traffic when asking with one general item, compared to calculating phone use frequency from multiple items on specific types of use, as we also chose to do in this study. Though traffic rules are formulated in a flexible and vague wording to include arbitrary cases (Endicott, 2001; Yagil, 1998), traffic rule awareness campaigning could benefit from exemplifying the term *handheld*.

5 LIMITATIONS

The study includes two West European, high-cycling countries, which limit the generalizability of the results to countries where cycling is limited to specific demographic groups and the infrastructure is less developed. Identification of psychological factors, like the connection between subjective norm and likelihood of handheld phone use, could nevertheless be generally relevant for the improvement of cyclist safety. Another limitation is that self-reported data can be sensitive to (intentional or unintentional) incorrect reports. For example, answers could be altered due to social desirability; respondents believing handheld phone use is forbidden could be less inclined to admit this behaviour. In a survey study on driving behaviours, social desirability was not identified to affect car drivers' responses (Sullman & Taylor, 2010). We would expect this to be similar for cyclists and furthermore designed the survey to minimize possible influences on social desirability by presenting items with revealing information about traffic rules at the end of the survey. Another important limitation is that regression models do not allow causal conclusions. The association between low perceived behavioural difficulty and increased likelihood of handheld phone use could relate to both; positive experiences of phone use while cycling decreasing perceived behavioural difficulty and low perceived behavioural difficulty as a prerequisite for pleasant experiences of phone use. As a final note, the study mainly focuses on factors related to individual cyclists, and we would therefore like to emphasize the importance of safe infrastructure and measures targeting, for example, car speed levels in creating safe environments for cyclists (Ralph & Girardeau, 2020).

6 CONCLUSIONS

This study identified both demographic and psychological factors contributing to the likelihood of handheld phone use while cycling. The relation with psychological factors points to the relevance of targeting potential overconfidence and (pluralistic ignorance related to) subjective norms. In addition, awareness of traffic rules should be increased. Believing that handheld phone use is forbidden was only associated with a decreased likelihood of handheld phone use when there actually was a ban, which can connect to both detection risk and cultural norms. We encourage more research on the implications and mechanisms behind traffic rules to create a better foundation for improving measures to reduce the distractions related to phone use among cyclists.

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PAPER 3

Under review in Travel Behaviour and Society

Exploring effects of introducing a ban on handheld phone use - pre-post results from the Netherlands and Denmark

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EXPLORING EFFECTS OF INTRODUCING A BAN ON HANDHELD PHONE USE FOR CYCLISTS - PRE-POST RESULTS FROM THE NETHERLANDS AND DENMARK

ABSTRACT

Cyclists' phone use can cause distractions and impose a risk towards traffic safety. To prevent phone related distractions, the Netherlands introduced a ban on handheld (HH) phone use for cyclists in July 2019. The effects of traffic rules on phone use and their underlying mechanisms are however uncertain. This study explores whether introducing a ban is associated with changes in phone use, traffic rule knowledge, perceived risk, sense of guilt, and perceived annoyance. We compare survey results from the Netherlands before (N=553) and after (N=484) the ban, using Denmark (before N= 568, after N=519) as a comparison group.

Comparing user rates for different phone functions before and after the ban, revealed a significant decrease in the proportion using HH phone for conversation in the Netherlands, while there was no change for other functions. In Denmark, rates remained similar for all functions. Changes in NL possibly correspond to characteristics of the functions; e.g. how effortless the function can be pause and resumed. The results additionally identified increase in traffic rule knowledge, sense of guilt for HH phone, and

perceived annoyance of others, while there was no significant change in perceived risk of HH phone use.

The study found that banning HH phone use was associated with increase in rule knowledge, but only to a limited extend to changes in HH phone use. A ban on HH phone use might have greater effects in changing behaviours over time from social mechanisms related to changes in the sense of guilt and perceived annoyance.

Keywords: Cyclists' phone use, preventive measures, cyclist safety, safety legislation, traffic laws

1 INTRODUCTION

The development of portable information and communication technologies enables the performance of a wide range of activities while on the go (Aguilera, 2018). These technologies affect transport behaviours in several ways; they facilitate (new) transport services (Aguilera and Boutueil, 2018), contribute to a pleasant ride (De Waard, Edlinger, & Brookhuis, 2011; Jungnickel & Aldred, 2014), and are valuable time optimizers in the arrangement of everyday tasks during transportation (Hjorthol, 2008). Phone use in traffic can, however, also distract the visual, auditive, cognitive, and motoric senses (SWOV, 2017), and therefore impose a risk towards safety (De Angelis, Fraboni, Puchades, Prati, & Pietrantoni, 2020; Goldenbeld, Houtenbos, Ehlers, & De Waard, 2012). To prevent possible distractions from phones, the Netherlands (NL) introduced a ban on handheld (HH) use of electronic devices while cycling in 2019 (Henley, 2018; Ministerie van Infrastructuur en Waterstaat, 2019). We used this as a case to study possible changes in HH phone use, rule knowledge, and related psychological measures. We compare survey data from NL before and after the ban and use Denmark (DK) as a comparison group. With the study, we aim to improve knowledge about the effects of banning HH phone use for cyclists from a perspective that considers both compliance and related psychological effects.

2 BACKGROUND

2.1 TRAFFIC RULES AS MEANS FOR BEHAVIOUR CHANGE

Traffic rules are widely used to organize and adjust behaviours in traffic. It is nevertheless not clear whether rules prohibiting phone use in traffic are effective as a tool for changing behaviours. Among car drivers, bans on phone use have presumably limited effects in reducing phone use (Olsson et al., 2020), while the effect of bans on phone use for cyclists are under-explored in the literature (Mwakalonge et al., 2014). The introduction of rules often builds on the notion that people comply with the law to avoid the instrumental risks of law enforcement and related sanctions (Castillo-Manzano et al., 2015; Haven, 1990), as assumed in, for example, rational choice theory and deterrence theory (e.g., Åberg, 1998; Taxman & Piquero, 1998). Yet the literature is inconclusive about whether, for example, increases in fines change traffic behaviours (Goldenbeld, 2017), and research drawing on social science has suggested that rules work from altering perceptions of moral and risk (Bilz & Nadler, 2014; Rose, O'malley, & Valverde, 2006) and social norms (Nadler, 2017). For rules to affect behaviours directly, it is a precondition that recipients are aware of their existence (Huemer et al., 2016). Previous research has nevertheless found rule knowledge among cyclists to be limited on a general level (Briant et al., 2020; Huemer, 2018), and though compliance may occur naturally to maintain self-preservation (Yagil, 2005), this presupposes risk awareness of the specific behaviour from the individual cyclist.

2.2 Introduction of a ban in NL

In July 2019, the NL introduced a ban on the use of HH electronic devices for cyclists with a sanction of 95 euros (Ministerie van Infrastructuur en Waterstaat, 2019). The Dutch ban only covers HH use of electronic devices, whereas hands-free (HF) distractions are covered by a general rule prohibiting hazardous behaviours (Stelling-konczak, 2018). The new ban in the NL corresponds to the Danish rules for cyclists' phone use, which is sanctioned with a 1000 DKK fine (approx. 135 euro). The new Dutch rules were communicated as part of a nationwide public campaign on traffic distractions with a branch aiming to inform cyclists about the new rules and the related sanction ('MONO-zakelijk: Nederland veilig en vitaal - MONO Zakelijk', n.d.).

2.3 The present study

The purpose of this study is to assess changes related to the introduction of the ban, from a perspective that not only identifies possible behavioural effects, but also looks at related psychological mechanisms. We explore changes in phone use behaviours, rule knowledge, perceived risk of HH and HF phone use, sense of guilt, and perceived annoyance before and after the introduction of the ban in NL. We use a corresponding group of Danish respondents as a comparison group. With this, we aim to explore the effects of introducing a ban on HH phone use for cyclists as well as contribute to a better understanding of psychological effects in relation to traffic rules.

3 METHODS

3.1 PROCEDURE AND PARTICIPANTS

We collected data before and after the introduction of the Dutch ban with an online questionnaire inspired by the literature on cyclists' phone use. The market research institutes Epinion and Norstat distributed a Dutch and a Danish version of the questionnaire to an online panel in the respective country. Respondents were compensated by standard agreements from the market research institutes. The questionnaire was distributed from May 13th to June 7th 2019, prior to the introduction of the Dutch ban, and again when the ban was in effect, from June 19th June to July 2nd 2020. We aimed for data collection at the same time of year to avoid skewness from seasonal variation (Kummeneje et al., 2019). Respondents, who never cycled, who did not own a mobile phone, or were younger than 18 years, were filtered out. We received 2161 complete responses. After the exclusion of respondents choosing the same option for all items in one block, we had 2124 respondents left. Table 1 presents an overview of sample characteristics.

Table 1: Basic sample characteristics separated by country and data collection wave.

Sample characteristics							
		DK (N=1087)		**NL** (N=1037)		**Wave 1 vs. 2**	
	Categories	**Wave 1** (N=568)	**Wave 2** (N=519)	**Wave 1** (N=484)	**Wave 2** (N=553)	**DK**	**NL**
Gender%	Female	55.1	50.3	52.3	53.7		
	Male	44.9	49.1	47.7	46.3	0.066[a]	0.644[a]
	Non-binary	-	0.6	-	-		
***Mean age* (SD)**		46.2 (15.9)	44.8 (15.3)	46.0 (14.9)	45.8 (14.5)	0.146b	0.866b
Cycling frequency%	>5 days per week	29.8	31.0	33.7	39.6		
	3-4 days per week	15.1	14.6	20.9	21.3		
	1-2 days per week	18.0	18.3	23.1	23.5	0.986[a]	0.040[a]
	1-3 days per month	17.3	17.1	11.0	8.9		
	<1 day per month	19.9	18.9	11.4	6.7		
Education%	Short	48.5	47.4	32.0	42.3	0.760[a]	0.001[a]
	Long	51.5	52.6	68	57.7		
Proportion using HH phone%		37.9	39.1	35.1	35.4	0.492[a]	0.948[a]

[a]p-value chi-square test, [b]p-value independent samples t-test

3.2 MEASURES

3.2.1 Behavioural measures

Cycling frequency was measured with one item, and the options <1 day/month. 1-3 days/month, 1-2 days/week, 3-4/days week, >5 days/week. *Phone use* was measured with the item "*Have you used your phone while cycling to listen to music/radio, texting, talking or other?*". Respondents choosing ''yes'' were then asked how frequently they used the phone while

cycling for *conversations, reading text messages, writing text messages*, *reading emails, writing emails*, *navigation (map/visual), photographing, social media (SOME) browsing, and SOME posting*. Answers were indicated on a Likert scale from (1 *never* to 5 *very often*). Each HH phone function was recoded according to how frequently respondents used it with 0 for 'never' and 1 for all other options *Sound reception* was measured among those using a phone for conversations. They were asked if they received the sound from *in-ear headphones (one ear only), in ear-headphones (both ears), larger headphones w/o noise reduction, larger headphones with noise reduction, build-in speakers HF,* or *build-in speakers HH. HH phone conversation* was 1 if the sound was received from build-in speakers in a HH phone.

3.2.2 Psychological and rule knowledge measures

Perceived risk HH and *Perceived risk HF* were each measured with two items, calculated into mean scales 1) [*HH*/*HF*] *phone use while riding a bike is dangerous*. 2) *Using phone* [*HH*/*HF*] *while riding a bike is likely to cause an accident*. Mean scales were calculated separately for items belonging to *Perceived risk HH* (Cronbach's alpha: 0.716) and *Perceived risk HF* (Cronbach's alpha: 0.778). Additionally, four statements concerning beliefs about whether one's phone use annoys other road users (*perceived annoyance*) and *perceived guilt* were included as single items to phone-using respondents only: 1) *Other road users become annoyed, when I use my phone HH*. 2) *Other road users become annoyed when I use my phone HF.* 1) *I feel guilty when using a phone HH.* 2) *I feel guilty when using a phone HF*. All psychological measures were rated from 1 (totally disagree) to 5 (totally agree). *Rule knowledge* was measured as respondents' beliefs

about the rules for phone use while cycling, with four response options: 1) *There are no rules regarding cyclists' phone use.* 2) *It is legal to use a phone HF and illegal to use it HH*. 3) *It is legal to use a phone HH and illegal to use it HF*. 4) *It is illegal to use a phone HF and HH in traffic.* Respondents then indicated *certainty* in their answer from 1 (totally unconfident) to 5 (totally confident).

3.2.3 Demographic measures

We measured *age* from year of birth and *gender* with the options male, female, and other. *Education* was measured with one item on highest completed education with six options, plus 'other'. Responses were recoded into the categories *short* (less than two years in addition to compulsory education) and *long* (more than two years in addition to compulsory education).

3.3 Analysis

Phone use behaviour: Changes in HH phone use before and after the Dutch ban were calculated from the measure 'Phone use'. We then calculated the percentage using each HH function as well as all HH phone use combined (see Figure 1). To assess whether a possible decrease in HH conversation in NL resulted from a general decrease in phone conversations, we calculated the percentage using both HH and HF phone for conversation and chi-square values for changes between waves. To check for changes in sound sources for HH conversations we calculated the relative distribution for all options as well as chi-square values for change between before and after the ban.

Rule knowledge: To assess changes in rule knowledge, we calculated relative frequencies for countries before and after ban-introduction, separated on the four response options (see *Measures*). We also calculated mean scales for respondents' 'certainty' in their answer and corresponding confidence levels.

Psychological measures: To assess changes before and after the ban in Perceived risk for HH and HF phone use, and the four separate statements concerning guilt and perceived annoyance, we used independent samples t-tests.

4 RESULTS

4.1 PHONE USE

When comparing phone use before and after the ban we identified significant change in the proportion of Dutch respondents using HH conversation (t-test, $p = 0.002$), which decreased from 9.1% to 4.3% (Figure 1). This was despite no significant change in the proportion of Dutch respondents generally using the phone for conversations (disregarded whether it is HH or HF) (chi-square, $p = 0.497$). No significant change for use of any phone function was identified among Danish respondents and there was no significant change in Danish respondents generally using the phone for conversations (chi-square, $p = 0.849$). How Dutch respondents mainly received sound when having conversations changed significantly (chi-square, $p = 0.010$). The proportion primarily using the build-in speaker HH when having conversations while cycling decreased from 29.3% to 15.9%, while the proportion using mostly in-ear headphones in both ears increased from 28.7% to 42.1%. There was no significant change among Danish respondents'

sound reception (chi-square, p = 0.455). The proportion using a phone for photo, SOME and email related activities were lower in DK than in the NL.

Figure 1: Frequencies of respondents using specific phone functions more than 'never'. P-values for t-tests comparing waves.

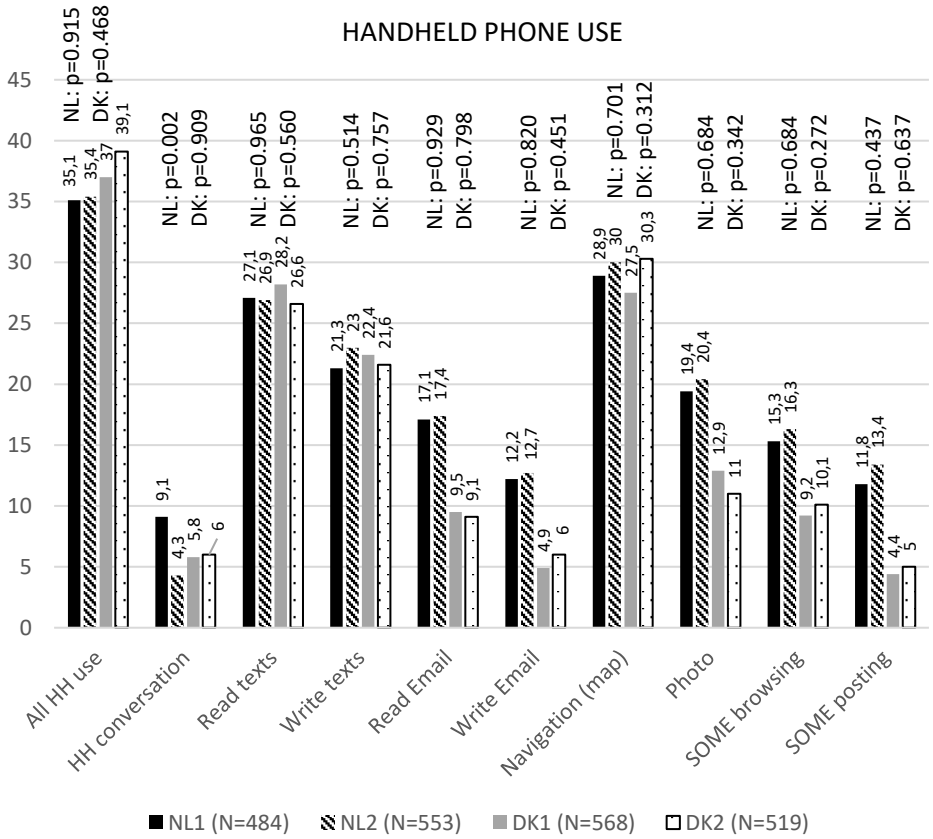
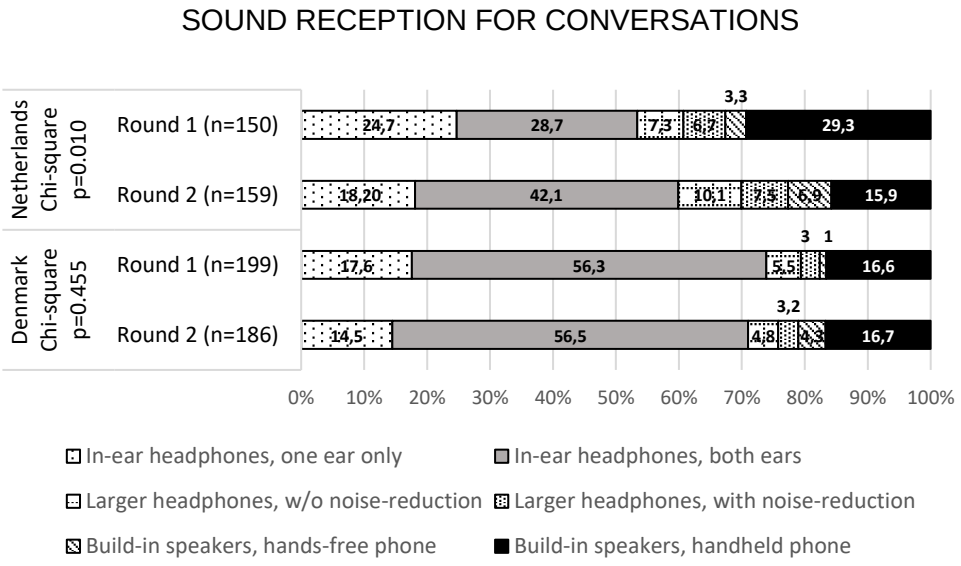


***Figure 2**:* 'How do you mainly receive the sound when having phone conversations while cycling?' Distribution among respondents using phone for calling while cycling.



4.2 Rule knowledge

Table 2 presents the distribution of respondents' rule knowledge separated by country and wave across the four response options with the correct answer indicated in bold. There is an increase in correct rule knowledge in Demark of 9.6 percentage points, while the increase in NL is 20 percentage points. In NL, the biggest reduction is in the percentage of respondents choosing the option *There are no rules regarding cyclists' phone use*, which decreased from 21.9% to 3.8%. The mean for respondents' confidence is highest for the correct answer in all waves except wave 1 in NL. Here the respondents choosing the option *It is illegal to use a phone HF and HH in traffic* are most confident regarding their response.

***Table 2**:* Distribution of rule knowledge and mean score for certainty in response with confidence levels. Results related to correct answer for each wave and country indicated in bold.

Rule knowledge and certainty								
	No rules on phone use		**HF = legal HH = illegal**		**HF= illegal HH=legal**		**HH + HF phone use = illegal**	
	Frequency	**Certainty [95%CL]**	**Frequency**	**Certainty [95%CL]**	**Frequency**	**Certainty [95%CL]**	**Frequency**	**Certainty [95%CL]**
NL1	**21.9%**	**3.58 [3.38;3.77]**	39.5%	3.46 [3.33;3.58]	5.2%	3.20 [2.86;3.54]	33.5%	3.64 [3.51;3.78]
NL2	3.8%	3.14 [2.73;3.56]	**59.5%**	**3.84 [3.75;3.93]**	6.7%	3.46 [3.17;3.75]	30.0%	3.82 [3.68;3.96]
DK1	16.9%	2.55 [2.37;2.74]	**58.0%**	**3.57 [3.45;3.68]**	2.1%	3.33 [2.46;4.20]	22.9%	3.40 [3.20;3.60]
DK2	12.9%	2.45 [2.21;2.69]	**67.6%**	**3.61 [3.50;3.72]**	1.7%	3.22 [2.67;4.00]	17.7%	3.46 [3.26;3.65]

4.3 Psychological measures

T-tests comparing before and after the ban identified no significant change for perceived risk of HH (NL: $p = 0.842$; DK: $p = 0.154$) nor HF phone use (NL: $p = 0.450$; DK: $p = 0.327$). The mean score for Dutch respondents on the items about sense of guilt for HH phone use ($p < 0.001$) and perceived annoyance ($p = 0.012$) increased significantly, while not changing significantly for HF phone use. There was no significant change in DK for the HH nor the HF items (Table 3).

Table 3: T-tests for changes in psychological measures comparing before and after the ban.

Perceived risk HH					**Perceived risk HF**				
	Wave	Mean	Mean difference	p		Wave	Mean	Mean difference	p
NL	1 (N=484)	4.14	-0.01	0.842	NL	1 (N=484)	3.74	-0.04	0.450
	2 (N=553)	4.13				2 (N=553)	3.69		
DK	1 (N=568)	4.20	-0.06	0.154	DK	1 (N=568)	3.42	-0.06	0.327
	2 (N=519)	4.14				2 (N=519)	3.36		
I feel guilty when using phone HH					**I feel guilty when using phone HF**				
	Wave	Mean	Mean difference	p		Wave	Mean	Mean difference	p
NL	1 (N=185)	2.94	0.46	<0.000	NL	1 (N=185)	2.62	0.21	0.071
	2 (N=229)	3.40				2 (N=229)	2.83		
DK	1 (N=252)	3.32	0.04	0.748	DK	1 (N=252)	2.57	0.07	0.519
	2 (N=235)	3.35				2 (N=235)	2.63		
Other road users become annoyed, when I use my phone HH					**Other road users become annoyed, when I use my phone HF**				
	Wave	Mean	Mean difference	p		Wave	Mean	Mean difference	p
NL	1 (N=185)	3.18	0.28	0.012	NL	1 (N=185)	2.86	0.07	0.535
	2 (N=229)	3.46				2 (N=229)	2.79		
DK	1 (N=252)	3.37	-0.16	0.126	DK	1 (N=252)	2.69	0.00	0.974
	2 (N=235)	3.21				2 (N=235)	2.70		

5 Discussion

The aim of the study was to explore changes in rule knowledge, phone use behaviours, perceived risk of HH and HF phone use, sense of guilt, and perceived annoyance before and after the introduction of a ban on the use of HH electronic devices in NL.

5.1 Behaviour change and phone functions

The results identified a significant change in HH conversation in NL after the ban, while relative user frequencies for other functions remained at the same level. No significant change for HH conversation or any of the other function was identified in DK. That introducing rules does not automatically change behaviours is not new (Åberg, 1998) and effectiveness of information likely depends on how effortless it is to comply (Service et al., 2014). This possibly explains why HH conversation was the only type of phone use that decreased significantly after introduction of the ban, as we also identified increased use of headphones for this activity. As HH conversations can be transferred to HF use by the use of headphones, it is possible for cyclists to continue to have phone conversations, while complying with the new rules. For the remaining functions, conversion from HH to HF requires more effort, which fits the insignificant changes in user frequencies for these after the ban in NL. These remaining HH functions, further have the common characteristic that they can easily be paused and resumed, which possibly enables cyclists' to hide them from law enforcement. This connects to the idea that traffic rules are more effective in reducing conspicuous offences as these are more easily enforced (Åberg, 1998). The fact that HH functions (except conversations) can be paused and resumed additionally allows the cyclists to adapt to external conditions (e.g. Aldred and Jungnickel, 2014; Brandt et al., 2021; De Waard et al., 2015), and for example abstain from using it in situations with high perceived risk (Manton et al., 2016). The fact that only HH conversation decreased in NL could therefore express subjective rational compliance (Elvik, 2016), if cyclists only associate risk (of safety or detecting) with this specific function. The results on phone use

behaviour does therefore not necessarily support the idea of changing behaviours from deterrent mechanisms like fines and enforcement, as the results could also indicate subjective compliance from concrete risk evaluations. Rather the results point to behavioural change being facilitated by multiple sources simultaneously, as both the law and the technological solution (headphones) makes it attractive to abstain from HH conversation.

5.2 Against better knowledge?

We found that Dutch respondents' correct rule knowledge was almost three times higher after the introduction of the ban (59.5%) compared to before (21.9%), whereas it was only slightly higher in DK. While this could be interpreted as an effect of successful campaigning, we would in that case expect the related decrease in responses to be evenly distributed among the incorrect options. Conversely, the decrease in Dutch respondents was mainly within *There are no rules regarding cyclists' phone use* that reduced from 21.9% to 3.8%, which was correct in wave one. It is thus plausible that a group of respondents were well-oriented regarding rules both before and after the ban, while the group who wrongly thought there was a ban, stuck with that option. Another possible explanation is that the central message of the campaign was to "keep your phone and 95 euro in your pocket" (Rijksoverheid, 2019). It did therefore not distinguishing between HH and HF phone nor specify that only HH phone use was banned, which could cause respondents believing both HH and HF use was forbidden, to think they were right. After the introduction of the Dutch ban, 30% of Dutch respondents, and 17.7% of Danish respondents believed both HH and HF phone use was banned. This brings the total proportion of respondents who believed HH phone was banned (either only HH being illegal or HH and HF

being illegal) up to 89.5% in NL and 85.3% in DK. As the proportion of respondents using HH phone for any function was 35.4% in NL and 39.1% in DK, some respondents in both countries used their phone HH despite believing it was illegal. While some traffic rules are sometimes infringed out of safety concerns (Chaloux and El-Geneidy, 2019; Ihlström et al., 2021), this is not likely for HH phone use. This points to the relevance of exploring other explanations than self-preservation and unawareness of traffic rules reasons for non-compliance to phone bans, and further questions the idea of compliance purely from moral obligations (Bilz and Nadler, 2014). It is a possibility that intentions to comply can be challenged by habitual phone use (Brandt et al., 2021; Jiang et al., 2019). It is however also possible that cyclists conceptualize different phone functions and the related risk differently, and rather use their subjective assessment to adapt their phone use (Buhler et al., 2021) than flowing generic rules. This may apply particular to rules on phone use, as these only address individual behaviours, while rules on interactions with other road users to a higher extent standardize behaviours to avoid conflicts (Briant et al., 2020). Infringing a ban on phone use will not directly result in a conflict with other road users, and thus some might only comply when they consider it rational. That some believe both HH and HF phone use is banned additionally nuances explanations from previous studies of rule knowledge as a prerequisite for compliance (Huemer, 2018; Huemer et al., 2016). Some cyclists believe the rules are more strict than the actual rules, and compliance also occurs out of the interest of staying safe (Yagil, 2005).

5.3 Wider changes from the ban on HH phone use

The assessment of changes in the psychological measures after the ban did not identify significant changes in perceived risk of HH or HF phone use in neither DK nor NL. A possibly reason for this is that the Dutch campaign emphasized the wanted behaviour and the risk of the fine (Rijksoverheid, 2019), rather than the safety risk of using HH phone while cycling. A previous study on changes form a Norwegian campaign focusing on accident risk perception found significant change in perceived risk after campaigning (Rundmo and Iversen, 2004). The specific campaigning strategy probably affects related psychological measures (Hoekstra and Wegman, 2011; Lanzendorf and Busch-Geertsema, 2014). Comparing the other psychological measures before and after the ban did, however, reveal significant higher mean scores in sense of guilt and perceived annoyance for HH phone use in NL, while there was no change for items for HF phone use and no change of any psychological measures in DK. These results might suggest that the effects of rules exceed their specific aim of changing behaviours. Such unintended effects will ideally support the intended change, but it is also possible that they can have adverse effects (Cohen and Einav, 2003). The changes in sense of guilt and perceived annoyance opens for the possibility that HH phone use among cyclists will change more over time, as HH phone use is visible to others, and thus likely to be impacted by social norms (Fraboni et al., 2016; Iversen and Rundmo, 2011; Nadler, 2017). This is supported by the use of photo, SOME and email related phone use being lower in DK compared to NL. The changes in psychological measures further point to the relevance of evaluating traffic rules on

other measures than behaviour only, to obtain a better understanding of the wider implications of traffic rules.

6 LIMITATIONS

A general limitation of survey studies is the inability to validate the self-reported data, which potentially could be altered from incorrect memories (Nenycz-Thiel et al., 2013), or the wish to appear more socially desirable or moral correct (King and Bruner, 2000). As the proportion using HH phone for most functions was similar between waves in NL indicates that reporting of HH phone use was not altered. It is, however, still possible that reported behaviours are incorrect due to wrong perceptions of how one behaves, and the behavioural reports should therefore not be interpreted as exact behavioural measures. Further the analyses would have been stronger, if we had the chance to use the same groups of respondents for both waves. As this was not possible, we aimed for groups with similar demographic characteristics, representative to the general population.

The survey does not include phone mounts as an option for HF phone use while cycling. We do not think this is crucial when it comes to using phones for conversation. Future research can however benefit from including phone mounts to explore their possible implications. Finally, the items on perceived annoyance were included to measure psychological changes, but it is possible that they rather reflect an actual increase in annoyance among other road users. As this increase is only found in the NL but not in Denmark, where milder forms if road anger have actually been

found increasing (Møller and Haustein, 2018), it is more likely to be interpreted as an effect of the ban.

7 CONCLUSIONS

Dutch cyclists reported significantly less use of HH phone for conversation after the ban. This is likely explained by a transfer to HF phone conversations, whereas same proportions of respondents continued to use HH phone for other functions. The results do not point to unawareness of the ban as a main reason for noncompliance, as the vast majority believed HH phone use was banned. While rule knowledge among Dutch respondents increased significantly after the ban, response patterns raises the question of whether this is due to campaigning or well-informed cyclists. Perceived guilt and annoyance both increased, which could affect compliance rates in the longer term and points to the relevance of including psychological measures in the evaluation of traffic rules.

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