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Cyclists' handheld phone use and traffic rule knowledge

Rebecca Karstens Brandt [a,*], Sonja Haustein [a], Marjan Hagenzieker [b,c], Mette Møller [a]

[a] Technical University of Denmark, Division of Transport, Bygningstorvet 116, 2800 Kgs. Lyngby, Denmark
[b] Technical University of Delft, Department of Transport and Planning, Stevinweg 1, 2628 CN Delft, the Netherlands
[c] Norwegian Centre for Transport Research (TØI), Gaustadalleen 21, 0349 Oslo, Norway

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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.

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 & Aldred, 2014), conversation, and texting. This also applies to cyclists, who use phones for various purposes both handheld and hands-free (De Angelis, Fraboni, Puchades, Prati, & Pietrantoni,

* Corresponding author at: Bygningstorvet, Building 116, 2800 Kgs. Lyngby, Denmark.
E-mail addresses: rebbr@dtu.dk (R.K. Brandt), sonh@dtu.dk (S. Haustein), m.p.hagenzieker@tudelft.nl (M. Hagenzieker), mette@dtu.dk (M. Møller).

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2020; De Waard, Edlinger, & Brookhuis, 2011; De Waard, Schepers, Ormel, & Brookhuis, 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, Lewis-Evans, Jelijs, Tucha, & Brookhuis, 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, Haustein, & Møller, 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, White, Hyde, & Watson, 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), which applies particularly to larger cities in Denmark, while being more common all over the Netherlands (Koglin, te Brömmelstroet, & van Wee, 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 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, 1,126 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 1,055 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.

Comparing countries, there were no significant differences in age, gender, and use of handheld phones, while differences in education and cycling frequency were significant ($p < .001$) with more frequent cycling and a higher share of respondents with long education among Dutch respondents.

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 Chi^2-test. [c] *U*-test.

[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).

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 (<5,000, 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 (Table 6).

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

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		

Note: Ref. = reference group

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
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

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%)

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%).

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 factor 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, Christensen, Haustein, & Koglin, 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 population 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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CRediT authorship contribution statement

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

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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