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Exploring effects of introducing a ban on handheld phone use for cyclists – Pre-post results from the Netherlands and Denmark

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ABSTRACT

Cyclists' phone use can cause distractions and impose risks 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. Comparing survey results from the Netherlands before ($N = 553$) and after ($N = 484$) the ban, using Denmark (before $N = 568$, after $N = 519$) as comparison group, this study explores whether introducing a ban is associated with changes in phone use, traffic rule beliefs, perceived risk, sense of guilt, and perceived annoyance.

Comparison of phone function use before and after the Dutch ban revealed a significant decrease in the proportion using HH phone for conversation, while there was no change for other functions. In Denmark, proportions remained stable for all functions. Changes in the Netherlands possibly correspond to specific phone functions characteristics, e.g., how effortless one can pause and resume the function. The results additionally identified an increase in correct traffic rule identification, sense of guilt for HH phone use, and perceived annoyance, 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 correct rule identification, but only to limited changes in HH phone use. Banning HH phone use might have greater effects in changing behaviours over time as a result of social mechanisms related to changes in sense of guilt and perceived annoyance.

1. Introduction

The development of portable information and communication technologies enables the performance of a wide range of activities while on the go (Aguiléra, 2018). These technologies affect transport behaviours in several ways: they facilitate (new) transport services (Aguiléra and Boutueil, 2018), contribute to a pleasant ride (De Waard et al., 2011; Jungnickel and 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 they impose a risk in terms of safety (De Angelis et al., 2020; Goldenbeld et al., 2012). Further, the change from push-button phones to smartphones possibly introduced larger negative effects on cycling performance (De Waard et al., 2015, 2014). To prevent possible distractions from phones, the Netherlands (NL) in 2019 introduced a ban on handheld (HH) use of electronic devices while cycling (Henley, 2018; Ministerie van Infrastructuur en Waterstaat, 2019). We used this as a case to study possible changes in HH phone use, rule beliefs, and related psychological measures. We compare survey data from the 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 and to allocate liability in case of crashes (Yagil, 2005). 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 is underexplored in the literature (Huemer et al., 2019; Mwakalonge et al.,

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2014; Useche et al., 2018). 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 and Piquero, 1998). This is supported by studies identifying the effects from automated enforcement systems (Castillo-Manzano et al., 2019), which can be used for visible offences (Åberg, 1998). Yet the literature is inconclusive about whether, for example, increases in fines change traffic behaviours (Goldenbeld, 2017), and estimated detection risk has been found to not predict cyclists' HH phone use, although this may be related to actual low detection risk (van der Kint and Mons, 2021). Research drawing on social science has suggested that rules work from altering perceptions of moral and risk (Bilz and Nadler, 2014; Rose et al., 2006, Sunstein, 1997) and social norms (Nadler, 2017). This relates to previous research connecting risk perception and risk-taking behaviours among cyclists (e.g., Kummeneje and Rundmo, 2020). For rules to affect behaviours directly, it is a precondition that recipients are aware of their existence (Huemer and Eckhardt-Lieberam, 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 the NL

In July 2019, the NL introduced a ban on the use of HH electronic devices for cyclists with a sanction of €95 (Ministerie van Infrastructuur en Waterstaat, 2019). The Dutch ban covers HH use of electronic devices while cycling, e.g., engaging in any activity with the phone held by hand (s). Hands-free (HF) phone use, including using the phone while mounted, is not restricted per se, but a general rule prohibits all hazardous behaviours (Stelling-Kończak, 2018). The new ban in the NL corresponds to the Danish rules for cyclists' phone use, which is sanctioned with a DKK1000 fine (approximately €135). 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.). A reoccurring Dutch questionnaire study found that HH use among cyclists has decreased in recent years, when comparing statistics from 2017 (before the ban) to those of 2019 and 2021 (after the ban): reported HH use in 2017, 2019, and 2021 was 33.3 % 27.7 %, and 29.6 %, respectively. However, reported HF use increased over this period: from 16.8 % in 2017 to 20.9 % in 2019 and 24.3 % in 2021 (Christoph et al., 2017; van der Kint and Mons, 2019, van der Kint and Mons, 2021).

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 beliefs, perceived risk of HH and HF phone use, sense of guilt, and perceived annoyance before and after the introduction of the ban in the NL. We use a corresponding group of Danish respondents as a comparison group. Identifying a relevant comparison group in the NL was not possible because the new legislation was implemented nationally. Instead we chose Denmark as a comparison group because the legislation was already in use in Denmark and Denmark shares a range of relevant characteristics that are similar to those in the NL. For example, the countries are Europe's top-two cycling countries, which probably relates to the pro-cycling policies and developed infrastructure for cyclists (Haustein et al., 2020; Pucher and Buehler, 2008). With this study, 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. 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 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 cycle, who did not own a mobile phone, or who were younger than 18 years were filtered out. We received 2161 complete responses. We excluded respondents choosing the same option for all items within one block, as this would indicate incongruent answers, as items were phrased in different directions to catch straight-liners. The remaining sample consists of 2124 respondents. Table 1 presents an overview of sample characteristics.

3.2. Measures

3.2.1. Behavioural measures

Cycling frequency was measured with one item, using the options <1 day/month, 1–3 days/month, 1–2 days/week, 3–4/days week, and >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 browsing, and social media posting*. Answers were indicated on a Likert scale from 1 (*never)* to 5 (*very often*). Sound reception was measured among those respondents who reported 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, built-in speakers HF,* or *built-in speakers HH. HH phone conversation (primarily)* was coded as 1 if the sound was primarily received from built-in speakers in a HH phone. All other phone functions were coded according to how frequently respondents used the function, with 0 for "never" and 1 for all other options. Although using headphones does not prevent the cyclists from holding the phone by hand, we find this behaviour less likely, as an advantage of using headphones is the ability to use the phone HF.

3.2.2. Psychological and rule beliefs measures

Perceived risk HH and *perceived risk HF* were each measured with two items, calculated into mean scales: [*HH/HF*] *phone use while riding a bike is dangerous* and *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. These statements were the following: *Other road users become annoyed when I use my phone HH*; *Other road users become annoyed when I use my phone HF; I feel guilty when using a phone HH*; and *I feel guilty when using a phone HF*. All psychological measures were rated from 1 (totally disagree) to 5 (totally agree). *Rule beliefs* was measured as respondents' beliefs about the rules for phone use while cycling, with four response options: *There are no rules regarding cyclists' phone use; It is legal to use a phone HF and illegal to use it HH*; *It is legal to use*

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	.066[a]	.644[a]
	Male	44.9	49.1	47.7	46.3		
	Other	–	0.6	–	–		
***Mean age* (SD)**		46.2 (15.9)	44.8 (15.3)	46.0 (14.9)	45.8 (14.5)	.146[b]	.866[b]
Cycling frequency %	>5 days per week	29.8	31.0	33.7	39.6	.986[a]	.040[a]
	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		
	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	.760[a]	.001[a]
	Long	51.5	52.6	68	57.7		

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

a phone HH and illegal to use it HF; and *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 reported HH phone use before and after the Dutch ban were calculated from the measure "Phone use". We then calculated the percentage of respondents reporting the use of each HH function separately, as well as all HH phone use combined. The latter thus includes all respondents who reported using one or more HH functions (see Fig. 1). To further assess the decrease in the proportion of cyclists who primarily have conversations HH in the NL, we calculated a logistic regression model for *primarily using handheld phone use for conversation,* with *wave, education (long/short), cycling frequency, age,* and *gender* as explanatory variables (Table 3). 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 beliefs: To assess changes in rule beliefs, we calculated the relative frequencies for countries before and after the 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.

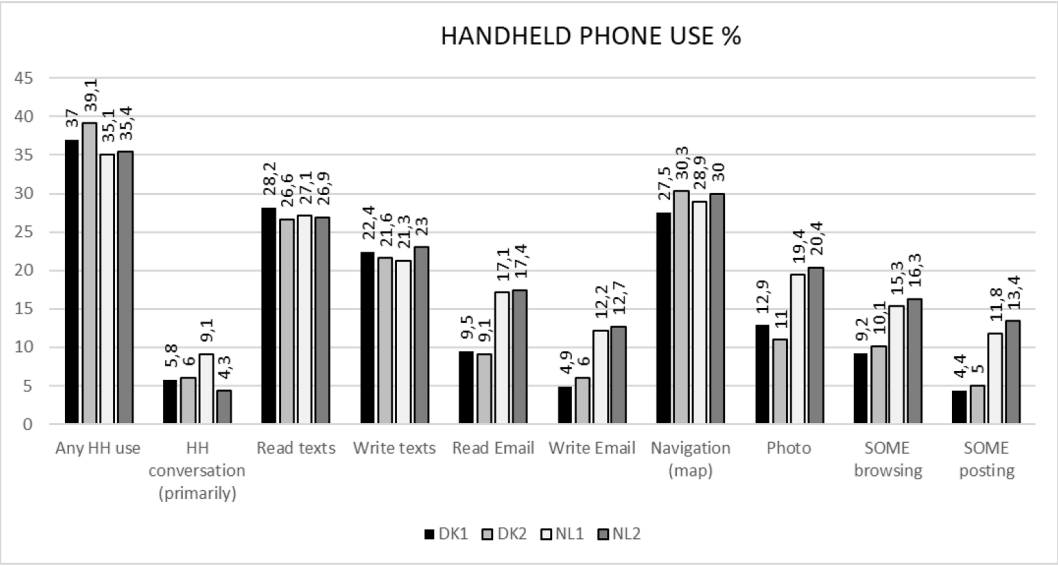

Fig. 1. Visual overview of percentages of self-reports on HH phone use by function from Table 2.

4. Results

4.1. Reported phone use

When comparing phone use before and after the ban, we identified a significant change in the proportion of Dutch respondents reporting to primarily engage HH in conversations, χ^2 (1, $N = 1037$) = 0.01, p =.909, which decreased from 9.1 % to 4.3 %. This was despite no significant change in the proportion of Dutch respondents generally reporting phone use for conversations (disregarding a distinction between HH or HF), χ^2 (1, $N = 1037$) = 0.62, p =.431. No significant change in reported 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, χ^2 (1, N = 1087) = 0.08, p =.782 (Table 2). How Dutch respondents mainly received sound when having conversations changed significantly, χ^2 (5, N = 309) = 15.2, p =.010. The proportion of respondents who reported primarily using the built-in speaker HH when having conversations while cycling decreased from 29.3 % to 15.9 %, while the proportion who reported using mostly in-ear headphones in both ears increased from 28.7 % to 42.1 %. There was no significant change in Danish respondents' reports of sound reception, χ^2 (5, N = 385) = 4.7, p =.455 (Fig. 2). The proportion who reported using a phone for photo, social media, and email-related activities was lower in DK than in the NL. The parameter estimates for reporting primary use of the built-in speaker HH when having conversations identifies a significant decreased probability in wave 2 compared to wave 1 among the Dutch respondents, while wave was not significant among the Danish respondents (Table 3).

4.2. Rule beliefs

Table 4 presents the distribution of respondents' rule beliefs separated by country and wave across the four response options, with the correct answer indicated in bold. There is an increase in correct rule beliefs in Demark of 9.6 percentage points, while the increase in the NL is 20 percentage points. In the 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 the 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. Changes in the answering patterns are significantly different between waves in both Denmark, χ^2 (3, N = 1087) = 10.70, p =.013 and the Netherlands, χ^2 (3, N = 1037) = 91.70, p <.001.

Table 2
Percentage of respondents' reporting to use specific phone functions, separated by country and wave.

Denmark (N = 1087)					
Phone function	**Wave 1 %**	**Wave 2 %**	**χ2**	**df**	***p***
Any phone use	44.4	45.3	0.09	1	0.762
Any HH use	37.0	39.1	0.53	1	0.468
Any conversation	35.0	35.8	0.77	1	0.782
HH conversation (primarily)	5.8	6.0	0.01	1	0.909
Read texts	28.2	26.6	0.34	1	0.560
Write texts	22.4	21.6	0.10	1	0.757
Read email	9.5	9.1	0.07	1	0.798
Write email	4.9	6.0	0.58	1	0.451
Navigation (map)	27.5	30.3	1.03	1	0.312
Photo	12.9	11.0	0.90	1	0.342
Social media browsing	9.2	10.1	1.22	1	0.270
Social media posting	4.4	5.0	0.22	1	0.636
The Netherlands (N = 1037)					
Phone function	**Wave 1 %**	**Wave 2 %**	**χ2**	**df**	***p***
Any phone use	38.2	41.4	1.09	1	0.296
Any HH use	35.1	35.4	0.01	1	0.915
Any conversation	31.1	28.8	0.62	1	0.431
HH conversation (primarily)	9.1	4.3	9.51	1	0.002
Read texts	27.1	26.9	0	1	0.965
Write texts	21.3	23.0	0.42	1	0.514
Read email	17.1	17.4	0.01	1	0.929
Write email	12.2	12.7	0.05	1	0.820
Navigation (map)	28.9	30.0	0.15	1	0.701
Photo	19.4	20.4	0.17	1	0.684
Social media browsing	15.3	16.3	0.19	1	0.664
Social media posting	11.8	13.4	0.60	1	0.438

4.3. Psychological measures

T-tests comparing before and after the ban identified no significant change for perceived risk of HH in neither Denmark [wave 1: M = 4.20, SD = 0.7; wave 2: M = 4.14, SD = 0.7), t(1085) = 1.4, p =.153] nor the Netherlands [wave 1: M = 4.14, SD = 0.8; wave 2: M = 4.13, SD = 0.8), t (1035) = 0.2, p =.842]. Similarly, there was no significant change for HF phone use in either Denmark [wave 1: M = 3.42, SD = 1.0; wave 2: M = 3.36, SD = 0.9), t(1085) = 1.0, p =.329] or the Netherlands [wave 1: M = 3.74, SD = 0.9; wave 2: M = 3.69, SD = 1.0), t(1035) = 0.8, p =.452]. The mean score for Dutch respondents increased significantly for the items about sense of guilt for HH phone use [wave 1: M = 2.94, SD = 1.1; wave 2: M = 3.40, SD = 1.1), t(412) = -4.2, p <.001] and perceived annoyance for HH use [wave 1: M = 3.18, SD = 1.1; wave 2: M = 3.46, SD = 1.1), t(412) = −2.5, p =.012], while not changing significantly for HF phone use. There was no significant change in DK for either the HH or the HF items (Table 5).

5. Discussion

The aim of the study was to explore changes in rule beliefs, 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 the NL.

5.1. Behaviour change and phone functions

The results identified a significant decrease in primarily use of HH sound sources for conversation in the NL after the ban, when controlling for demographic factors. Still, all relative user frequencies for other functions remained at the same level. No significant change for HH conversation or any of the other functions was identified in DK. That introducing rules does not automatically change behaviours is not new (Åberg, 1998), and the effectiveness of information about a rule likely depends on how effortless it is to comply with it (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 we found in user frequencies for these after the ban in the NL. Further, these remaining HH functions have the common characteristic that they can easily be paused and resumed, which enables cyclists to hide the use 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 most 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 to abstain from phone use in situations with high perceived risk (Manton et al., 2016). If cyclists only associate (safety or detection) risk with HH conversation and not with other types of HH use, this likely explains why decreased reports were only found in use of this particular function. In this case, the abstention from having HH conversations could express

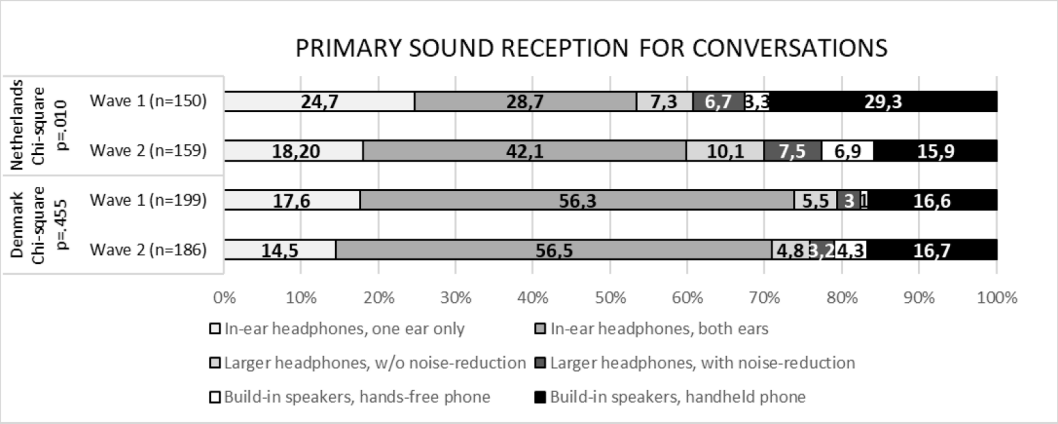

Fig. 2. "How do you mainly receive the sound when having phone conversations while cycling?" Distribution among respondents using phone for conversation while cycling.

Table 3
Parameter estimates for logistic regression models for Danish and Dutch respondents with handheld sound reception as the outcome variable.

Parameter estimates for HH speaker as primary sound source for conversation
Denmark

	B	*p*	Exp(B)
Wave = 2 (ref.: wave 1)	−0.041	0.875	0.959
Education = high	−0.294	0.27	0.745
Cycling frequency	0.266	0.005	1.305
Age	−0.001	0.876	0.999
Male		0.04	
Female	−0.693	0.011	0.5
Other	−18.968	0.999	0
Constant	−3.423	0	0.033

The Netherlands

	B	*p*	Exp(B)
Wave 2 (ref.: wave 1)	−0.793	0.003	0.452
Education = high	0.483	0.101	1.621
Cycling frequency	0.127	0.211	1.136
Age	−0.012	0.187	0.988
Female (ref.: male)	−0.593	0.022	0.553
Constant	−2.426	0	0.088

subjective rational compliance based on increased perceived risk (Elvik, 2016). The results on phone use behaviour therefore do not necessarily support the idea of changing behaviours based on deterrent mechanisms like fines and enforcement, as the results could also indicate subjective compliance based on 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) make it attractive to abstain from HH conversation. Additionally, a ban can encourage the development and uptake of other technological solutions, like voice commands and phone mounts. A ban therefore not only restricts HH phone use but also supports promotion and development of equipment that can facilitate HF phone use.

5.2. *Against better knowledge?*

We found that Dutch respondents' correct rule beliefs were almost three times higher after the introduction of the ban (59.5 %) compared to before (21.9 %), whereas these were 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 the proportion of 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 one group of respondents was well oriented regarding rules both before and after the

Table 4
Distribution of rule beliefs across four response options, and mean score for certainty in response with confidence levels. Correct answer for each wave and country indicated in bold and with black borders.

Rule beliefs 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]

Table 5
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	0.452
	2 ($N = 553$)	4.13				2 ($N = 553$)	3.69		
DK	1 ($N = 568$)	4.20	−0.06	0.153	DK	1 ($N = 568$)	3.42	−0.06	0.329
	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		

ban, while another 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). The campaign did not distinguish between HH and HF phone use, nor did it specify that only HH phone use was banned. This could cause respondents who believed that both HH and HF use were forbidden to think they were right when confronted with the message. In the second wave, 30 % of Dutch respondents and 17.7 % of Danish respondents believed that both HH and HF phone use were banned. This increases the total proportion of respondents who believed that HH phone was banned (either only HH being illegal or HH and HF being illegal) to 89.5 % in the NL and 85.3 % in DK. As the proportion of respondents using HH phones for any function was 35.4 % in the 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 as reasons for non-compliance with phone bans, and it 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 use their subjective assessment to adapt their phone use (Buhler et al., 2021) rather than following generic rules. This may apply particularly 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 sensible. That some believe both HH and HF phone use is banned offers additional nuance to the idea of rule knowledge as a prerequisite for compliance. Some cyclists believe the rules are stricter than the actual rules, and compliance also occurs out of an interest in 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 either DK or the NL. A possible 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 a HH phone while cycling. A previous study on changes following a Norwegian campaign focusing on crash risk perception found a significant change in perceived risk after the campaign (Rundmo and Iversen, 2004). The specific campaigning strategy probably affects related psychological measures (Hoekstra and Wegman, 2011; Lanzendorf and Busch-Geertsema, 2014). However, comparing the other psychological measures before and after the ban did reveal significant higher mean scores in sense of guilt and perceived annoyance for HH phone use in the 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 up the possibility that HH phone use among cyclists will change more over time, as HH phone use is visible to others, and thus it is likely to be impacted by social norms (Fraboni et al., 2016; Iversen and Rundmo, 2011; Nadler, 2017). This is supported by the fact that the use of social media, taking photos, and email-related phone use are all lower in DK compared to the NL. Perhaps except for taking photos, these functions are less likely to require immediate action from the cyclist, and are thus the easiest to postpone. Social norms possibly discourage taking photos while cycling on a general level, as it has been shown that social norms predict cyclists' HH phone use (Brandt et al., 2022). 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 morally correct (King and Bruner, 2000). As the proportion of cyclists using HH phones for most functions was similar between waves in the NL, this indicates that reporting of HH phone use was not altered (only) after the ban. However, it is still possible that reported behaviours are incorrect due to incorrect memory 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 of 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. However, future research could 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 found only in the NL but not in Denmark, where milder forms of road anger have actually been found to be 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 the same proportion of respondents continued to use HH phones for other functions. The results do not point to unawareness of the ban as a main reason for non-compliance, as the vast majority believed that HH phone use was banned. While correct rule beliefs among Dutch respondents increased significantly after the ban, response patterns raise the question of whether this is due to campaigning. The increase in respondents choosing the correct answers in wave 2 (wave 1 = 39.5 %, wave 2 = 59.5 %) corresponds to the decrease in the selected options that were correct answers in wave 1 (wave 1 = 21.9 %, wave 2 = 3.8 %). It is therefore possible that a group of cyclists who knew the rules noticed when the rules changed between waves. Perceived guilt and annoyance both increased, which could affect compliance rates in the longer term, and this points to the relevance of including psychological measures in the evaluation of traffic rules.

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CRediT authorship contribution statement

R.K. Brandt: Writing – original draft, Conceptualization, Methodology, Formal analysis, Investigation. **S. Haustein:** Writing – review & editing, Conceptualization, Methodology, Supervision. **M. Hagenzieker:** Methodology, Supervision. **M. 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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