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E-scooter riders and pedestrians: Attitudes and interactions in five countries

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Abstract

Electric scooters (e-scooters) have become a popular phenomenon internationally; however, their use has raised concerns about pedestrian safety. This study describes the possible effects of the emergence of e-scooters on pedestrians. We focus on the interaction, conflicts, crashes, and attitudes between pedestrians and e-scooter riders and pedestrians' perceived safety in the presence of e-scooters. Data were collected from e-scooter riders and non-riders (n=3385) through an online survey in Australia, Belgium, the Czech Republic, Norway, and Sweden. Around 20–30% of e-scooter riders rode on sidewalks, whether it is allowed or not. Non-riders of e-scooters tended to report that riding an e-scooter is rather dangerous. Pedestrians, except Australian ones, perceived e-scooter riders (and e-scooter operation) as annoying. Half of the e-scooter riders had experienced a near miss at some point in the past and more than 50% of these near misses included another road user. Up to 10% of the e-scooter riders from all five countries reported having experienced a crash. On the basis of these findings, we believe that the most relevant suggestions for the implications in sustainable (urban) mobility involve separating e-scooter riders and pedestrians.

Previous

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Keywords

Traffic safety; Micromobility; E-scooters; Pedestrians; Traffic psychology

1. Introduction

Electric scooters (e-scooters) have become a new and popular phenomenon all around the world in the last five years as they seem to be a cheap, fast, convenient, and flexible means of transport in cities with frequent junctions [1]. Recent literature concludes that e-scooters are attractive among people aged between 26 and 35 years for short distances (1.7 km or 0.5–2 miles, usually representing the “first/last mile”) and they most often replace walking, public transport less so, and the car least often [[2], [3], [4], [5], [6], [7]]. Commuting to work/school and leisure activities are the most common purposes of e-scooter rides [4,6,8,9].

E-scooters are promoted and viewed as an environment-friendly means of transport [10], despite research findings to the contrary. Another study concluded that shared e-scooters are not yet environmentally beneficial as they can cause 202 g CO2-eq/passenger-mile. What is more, e-scooters mainly replace active modes of transportation, which is why their impact will always be harmful to the environment [11,12].

Despite their popularity, safety issues are discussed and studied as there is little regulation of e-scooter use. Some researchers have pronounced safety issues to be a major inconvenience of e-scooters [6,8]. There is an increasing number of studies which focus on types of e-scooter injuries and their prevalence, as well as healthcare costs resulting from e-scooter crashes. Aizpuru et al. found that the change in the incidence of e-scooter injuries in the USA was not significant between 2013 and 2017 [13]. Ioannides et al. estimated that 115 injuries per million e-scooter trips were treated in 180 clinics and two hospitals in Los Angeles in 2014–2020 [14]. On the other hand, recent studies noted that after the launch of shared e-scooters there was a dramatic increase in e-scooter injuries – a 625% increase in Salt Lake City when comparing a control period in 2017 (i.e., before shared e-scooter programs were launched) [15] with a test period in 2018 (i.e,. after shared e-scooter programs were launched); then an incidence of 248 injuries was found in summer 2019 in Berlin [16]. Similarly, there was a six-fold rise (from an average of 26.9 to an average of 152.6 injuries) in the monthly number of e-scooter injuries in the emergency department of a hospital in a major metropolitan area after the introduction of shared e-scooter services [17]. Numerous papers conclude that superficial soft tissue injuries and extremity and head injuries are the most common [13,[15], [16], [17], [18], [19], [20]]. Sikka et al. published a case study highlighting the health and financial impact for pedestrians involved in an e-scooter collision [21].

Another major issue identified by e-scooter research is the parking of dockless e-scooters. An improperly parked shared e-scooter (e.g., in the middle of a sidewalk) can block a sidewalk so that a pedestrian can stumble over the e-scooter or they might be made to use a road to bypass the blockage, which can endanger the pedestrian. Another study highlighted that e-scooters were parked on private property in San Jose [22]. On the other hand, a study examining parking in five U.S. cities concludes that improper parking is infrequent among e-scooters: only 1.1% of e-scooters violated parking regulations to such an extent that a sidewalk was badly passable or blocked a crossing or a pedestrian ramp. The data show that if a city provides parking infrastructure e-scooter riders use it [23]. In the light of these findings, Zakhem and Smith-Collin offer techniques for analyzing areas of high parking demand to promote micromobility in cities [24].

Concerning interactions between e-scooters and pedestrians, e-scooter riders are said to hamper pedestrian mobility. Maiti et al. analyzed specific spatio-temporal metrics on two university campuses in Texas and reported that there were more e-scooter encounters with pedestrians in certain locations (e.g., parking lots, recreation centers, etc.) and at specific times (Wednesdays around noon and Thursdays around midnight) [25]. They also observed that the majority of close encounters happened on narrow pedestrian paths. They recommend that municipalities improve the infrastructure (e.g., creating more bike lanes) and create clear regulations, which is consistent with other literature [26]. Another highlight of Maiti et al.'s study is that 58% of the pedestrians were interested in a mobile application alerting them about potential encounters with e-scooter riders.

Trivedi et al. emphasize the impact of e-scooter riding on pedestrian safety and pedestrians' comfort on the street. An Australian study observed that more than 90% of e-scooter riders rode on sidewalks and "about 40% were ridden with at least one pedestrian within 1 m" [20]. Despite this, the rates of conflicts were from 0 to 1.5% [27]. Fitt and Curl produced similar findings; over 90% of e-scooter users from New Zealand had ridden on a sidewalk for at least a part of their journey; however, most of them agreed that the sidewalk was not a suitable environment for e-scooter use [28]. Similarly, only 26% of non-riders think the sidewalk is appropriate for e-scooter use. Arellano and Fang noted that e-scooter users ride at lower speeds in spaces that are shared with pedestrians and so they can be less dangerous to pedestrians [29].

A recent study from Paris sheds light on how e-scooter users move and navigate through the city and how responsive to pedestrians they are. The authors conclude: 1) the traffic rules for e-scooters are not clear; 2) e-scooter riders bend the rules, and 3) there is a relative absence of common knowledge in perceiving and understanding e-scooter motion so that pedestrians become hesitant and react haphazardly [30]. Likewise, Siebert et al. found that 32% of 777 shared e-scooters' riders observed violated existing road rules (e.g., using prohibited infrastructure, simultaneous use of an e-scooter by two people) [31]. Next, a study from Rosslyn, Virginia, highlights that 56% of the respondents felt unsafe or very unsafe around dockless e-scooter riders compared to users of other modes of transportation. Interestingly, 76% of those respondents who had no experience with riding e-scooters reported that walking around e-scooter riders was unsafe or very unsafe [32]. These findings suggest that the perception that e-scooter riding is not safe can cause tensions between riders and pedestrians. Buehler et al. also examined the attitudes of riders and non-riders and point out that 43% of non-rider pedestrians reported feeling unsafe walking around e-scooters [33]. Both riders and non-riders would prefer more separate spaces, such as bike lanes, for e-scooters to use, which is consistent with a survey from Thessaloniki, Greece, where safety is a major concern for non-riders and a major reason why they are not attracted by this means of transport [26].

Another interesting qualitative study from New Zealand addresses how pedestrians and e-scooter riders experience sharing transport space. According to the participants, e-scooter riding shares more similarities with cycling and driving than with walking. Pedestrians' and e-scooter riders' encounters were described as uncertain and ambiguous. Also, "*pedestrians in this study raised concerns about the way that e-scooter riders travel in close proximity and blend in with pedestrians*" [34]. The same author points out that the power relations on the path are blurred, because pedestrians see e-scooter riders as threats to their safety, whilst e-scooter riders tend to adjust their behavior and use the path in a considerate manner [34]. Recently, a virtual reality experiment was conducted in Singapore in which the attitudes towards e-scooter operating speed during pedestrian-e-scooter interaction on shared sidewalks were determined. The researchers found out that e-scooter riders and pedestrians perceive the speed of 10 km/h as being safer than 15 and 20 km/h during an overtaking maneuver. However, in face-to-face interaction the pedestrians felt safer when an e-scooter rider went at 15 km/h than at 10 km/h, which suggests that speed may not be the only factor in the perception of risk assessment. In addition, four out of six near misses in this study were caused by misconduct on the part of e-scooter riders (e.g., approaching a pedestrian silently from behind or riding in a zigzag fashion). Altogether, pedestrians felt less safe in general in comparison with e-scooter riders. Finally, the authors studied anger levels and they revealed that most pedestrians were annoyed by an e-scooter approaching at 20 km/h; however, there was no difference in the anger levels between speeds of 10 km/h and 15 km/h [35].

The research on interactions or communication between road users is based on psychological principles and research methods. Interaction is a kind of action that occurs as two or more objects have an effect upon one another. The idea of a two-way effect is essential in the concept of interaction, as opposed to a one-way causal effect. Communication is the imparting or interchange of thoughts, opinions, or information by speech, writing, signs, or other means. Each encounter or interaction in traffic (or general) includes communication.

Road user behavior, more specifically road user interactions or communication, can be described by using various types of data, collected under different conditions, which can be categorized as follows: (i) controlled data collection: stated behavior data (surveys, questionnaires, interviews, focus groups), data collected from simulations using driving simulators or virtual reality; (ii) naturalistic data collection (behavior observation, traffic conflict observation, naturalistic driving – using instrumented vehicles to collect behavior data) [36].

On the basis of the previously presented state of the art we can conclude that the topic of e-scooters, mobility, and traffic safety has been solidly discussed in the literature in the last five years. The research focuses mainly on traffic safety (e.g., the occurrence of crashes), the share of public space (e.g., parking of dockless e-scooters), and shifts in modes of transportation (e.g., the replacement of car trips with e-scooters). Little attention is paid to interactions with other road users, especially vulnerable road users. This topic is not covered properly in the research, even though it is of high importance (e.g., in some cases e-scooters share the public space with pedestrians or cyclists). The research gap that we identified and on which we focus our research is the interaction between e-scooter users and pedestrians and their attitudes towards each other. According to a systematic review of 32 papers dealing with e-scooter riders' psychosocial risk features this topic "remains relatively understudied" [37].

The innovative feature of this work, based on a thorough literature review and identification of the research gap, can be defined by its complexity. In this research we focus on both pedestrians and e-scooter riders and present the results of their interaction process. The main focus is on the subjectively perceived safety (and comfort) of pedestrians when using the sidewalk and when an e-scooter is present. This point of view is very important as we see walking as a basic traffic mode, the importance of which grows with the vulnerability of road users (e.g., children or the elderly) or road users with all kinds of impairments. In our eyes, the sidewalk is a part of the urban space which is devoted to pedestrians (and walking) and any other device (especially one moving faster than walking speed) might be a very disturbing one, with unwished-for consequences (e.g., a decrease in the number of walking trips or an increase in the number of injuries). Moreover, in this work we present results from five different countries around the globe (most other studies are municipality-based, in a substantial number of cases from U.S. cities), which allows us to discuss the results in the light of different cultures and legal regulations (e.g., a ban on riding on the sidewalk).

2. Aims, methods, and research sample

2.1. Aims

The aim of this work is to describe the possible effects which the emergence of e-scooters has on pedestrians, or, more generally, walking as a mode of transportation in urban settings. Specifically, we will focus on: interaction, communication, and attitudes between pedestrians and e-scooter riders; pedestrians' perceived safety in the presence of e-scooters; conflicts and crashes involving e-scooters and pedestrians; and sharing the space devoted to pedestrians with e-scooters.

Furthermore, as this work is based on data collected from five countries (Australia, Belgium, the Czech Republic, Norway, and Sweden), we aim to provide an international comparison with regard to this topic.

On the basis of the aims, we formulated the following research questions.

1. Do e-scooter riders travel faster than at walking pace on sidewalks and under what circumstances?

2. What are the attitudes of pedestrians and e-scooter riders to one another, especially in terms of perceived subjective safety and comfort?

3. Do pedestrians perceive e-scooters as annoying? How is this affected by situational factors such as legal regulations or shared infrastructure?

4. What is the prevalence and what are the influencing factors of conflicts and crashes including pedestrians and e-scooters?

2.2. Methods and procedure

The results of an online survey (questionnaire) of e-scooter riders in five countries are presented in this study. The study was first suggested in Belgium and subsequently developed in conjunction with e-scooter researchers in other countries who were financed independently. Researchers from Australia (Queensland University of Technology (QUT), Brisbane), Belgium (the VIAS Institute), the Czech Republic (Palacky University Olomouc), Norway (Institute of Transport Economics (TØI)), and Sweden (Chalmers University of Technology) collaborated on the study. Because the data were collected anonymously, there was no need for institutional ethical approval in the Czech Republic, Belgium, and Sweden. Ethical approval was obtained in Australia and Norway.

The entire survey looked at users' and non-users' opinions about, and experiences with, e-scooters. It began with a series of screening questions to check that the participants were of legal age (18+) and resided in an eligible country.

The respondents were classified as e-scooter users if they reported "riding" an e-scooter at least "one to a few days per month" "at this time of year". In Sweden, the definition was slightly different, stating that the respondents were classified as e-scooter users if they reported "ever riding" an e-scooter at least "one to a few days per month" "at this time of year", Questions about general mobility patterns, attitudes toward e-scooters, environmental attitudes, barriers to the more frequent use of e-scooters, interactions with other road and path users, near misses and crashes, risky and protective behaviors, knowledge, compliance, support for e-scooter rules, and demographic characteristics were included in the questionnaire.

A master version of the questionnaire was created in English, with members of the study team translating it into French and Flemish (Belgian variants), Czech, Norwegian, and Swedish. The questionnaire was created using a variety of online survey tools, depending on the study contributors' licensing. Except in Australia, it was necessary to answer all the questions.

Participants were mostly recruited through sponsored Facebook ads and participant sharing (snowball sampling). Data were collected throughout Europe during the period July–October 2020 and in Brisbane, Australia, during the period July–September 2020. The surveys were carried out individually in each nation, with data files provided to a Belgian partner who merged them into a single SPSS data file.

2.3. Regulations governing the use of e-scooters on sidewalks in participating countries

In Norway, Sweden, and Belgium, the legal regulations governing the use of e-scooters are similar in that e-scooters can be ridden (it is legal to ride) on the sidewalk at a walking speed. In Australia (specifically in the State of Queensland, where the data were collected) using sidewalks, off-road bike paths, and shared pedestrian-bike paths is allowed unless there is a no e-scooter sign present. E-scooters are not permitted on sidewalks in the Czech Republic. To sum up, in four countries involved in the study (Norway, Belgium, Sweden, and Australia) it is allowed to ride an e-scooter on the sidewalk, while in one country (Czech Republic) this is not allowed (for detailed information see also Table 3). Further implications regarding the results of this study are mentioned in the Discussion section.

2.4. Research sample

The study sample comprised a total of 3313 completed responses. The data were provided by respondents from Australia (n=1,041, 31%), Belgium (n=308, 9%), the Czech Republic (n=581, 18%), Norway (n=865, 26%), and Sweden (n=518, 16%). The general characteristics of the sample, presented separately for users and non-users, are summarized in Table 1, Table 2, Table 3.

Table 1. Sample size by countries.

	Australia		Belgium		Czech Rep.		Norway		Sweden		TOTAL
	n	%	n	%	n	%	n	%	n	%	
TOTAL e-scooter riders	448	31	89	6	283	19	374	26	259	18	1453
TOTAL non-riders	593	32	219	12	298	16	491	26	259	18	1860

Table 2. Characteristics of e-scooter riders by country.

Variable	Category	Australia		Belgium		Czech Rep.		Norway		Sweden		χ^2 (*df*)	Cramer *V*
		n	%	n	%	n	%	n	%	n	%		
Gender	Man	240	54	70	79	176	62	232	62	118	46	328.58	0.27
	Woman	83	19	16	18	102	36	135	36	27	10	(12)	
	Neither/Other	4	0.89	0	0	1	0.35	3	0.8	0	0		
	Does not want to/no answer	121	27	3	3.4	4	1.4	4	1.1	114	44		
Age	18–24 years	98	22	5	5.6	34	12	68	18	29	11	176.68	0.17
	25–34 years	133	30	21	24	120	42	140	37	70	27	(24)	
	35–44 years	98	22	16	18	86	30	104	28	68	26		
	45–54 years	70	16	23	26	34	12	42	11	53	20		
	55–64 years	49	11	15	17	5	1.8	18	4.8	30	12		
	65+ years	0	0	9	10	4	1.4	2	0.53	5	1.9		
	No answer	0	0	0	0	0	0	0	0	4	1.5		
Education	Primary	4	0.89	0	0	8	2.8	8	2.1	2	0.77	483.75	0.29
	Secondary	48	11	23	26	124	44	56	15	30	12	(24)	
	Post-school	79	18	16	18	29	10	43	11	29	11		
	Bachelor's	135	30	27	30	46	16	144	39	37	14		
	Master's	65	15	23	26	76	27	123	33	52	20		
	No answer	117	26	0	0	0	0	0	0	109	42		
Occupation	Employed	234	52	64	72	224	79	276	74	121	47	684.69	0.34
	Stay-at-home	2	0.45	1	1.1	30	11	69	18	1	0.39	(24)	
	Student	72	16	1	1.1	29	10	29	7.8	16	6.2		
	Retired	8	1.8	13	15	0	0	0	0	3	1.2		
	Unemployed	12	2.7	3	3.4	0	0	0	0	0	0		
	Other	2	0.45	7	7.9	0	0	0	0	0	0		
	No answer	118	26	0	0	0	0	0	0	118	46		
Area type	Suburban	207	46	57	64	168	59	149	40	54	21	379.85	0.36
	Urban	119	27	32	36	115	41	225	60	97	37	(8)	
	No answer	122	27	0	0	0	0	0	0	108	42		
Completion	Full	329	73	89	100	283	100	374	100	151	58	312.39	0.46
	Partial	119	27	0	0	0	0	0	0	108	42	(4)	
TOTAL		448	31	89	6	283	19	374	26	259	18	1453	

Note. All χ^2 tests are significant at p<.001.

Table 3. Characteristics of non-riders by country.

Variable	Category	Australia		Belgium		Czech Rep.		Norway		Sweden		χ^2 (*df*)	Cramer *V*
		n	%	n	%	n	%	n	%	n	%		
Gender	Man	201	34	136	62	114	38	226	46	96	37	379.91	0.26
	Woman	197	33	78	36	177	59	258	53	77	30	(12)	
	Neither/Other	6	1	0	0	2	0.67	3	0.61	0	0		

Variable	Category	Australia		Belgium		Czech Rep.		Norway		Sweden		χ^2 (*df*)	Cramer *V*
		n	%	n	%	n	%	n	%	n	%		
	Does not want to/no answer	189	32	5	2.3	5	1.7	4	0.81	86	33		
Age	18–24 years	193	33	1	0.46	62	21	43	8.8	5	1.9	562.44	0.30
	25–34 years	161	27	25	11	115	39	145	30	31	12	(24)	
	35–44 years	101	17	32	15	63	21	149	30	60	23		
	45–54 years	83	14	45	21	37	12	91	19	65	25		
	55–64 years	55	9.3	64	29	19	6.4	50	10	51	20		
	65+ years	0	0	52	24	2	0.67	13	2.6	35	14		
	No answer	0	0	0	0	0	0	0	0	12	4.6		
Education	Primary	1	0.17	56	26	6	2	47	9.6	19	7.3	1267.10	0.41
	Secondary	78	13	15	6.8	55	18	52	11	33	13	(24)	
	Post-school	61	10	73	33	139	47	149	30	61	24		
	Bachelor's	197	33	71	32	0	0	234	48	57	22		
	Master's	256	43	0	0	0	0	0	0	85	33		
	No answer	0	0	4	1.8	98	33	9	1.8	4	1.5		
Occupation	Employed	234	39	133	61	204	68	391	80	134	52	989.67	0.36
	Stay-at-home	9	1.5	3	1.4	66	22	48	9.8	2	0.77	(24)	
	Student	131	22	2	0.91	28	9.4	52	11	11	4.2		
	Retired	16	2.7	59	27	0	0	0	0	26	10		
	Unemployed	18	3	7	3.2	0	0	0	0	0	0		
	Other	7	1.2	15	6.8	0	0	0	0	0	0		
	No answer	178	30	0	0	0	0	0	0	86	33		
Area type	Suburban	274	46	164	75	150	50	192	39	63	24	508.10	0.37
	Urban	132	22	55	25	148	50	299	61	117	45	(8)	
	No answer	187	32	0	0	0	0	0	0	79	31		
Completion	Full	414	70	219	100	298	100	491	100	179	69	356.07	0.44
	Partial	179	30	0	0	0	0	0	0	80	31	(4)	
TOTAL		593	32	219	12	298	16	491	26	259	14	1860	

Note. All χ^2 tests are significant at $p<.001$.

In terms of age, the respondents in Australia were more likely to be in the 18–34 category, in Belgium, the respondents tended to be 45+, and in the Czech Republic and Norway the respondents were generally 25–44 years old. In Sweden the distribution of respondents was balanced with regard to age, although the largest number of respondents was in the 25–64 age category.

The lowest mean age of the respondents was recorded in the Czech Republic and Australia. Higher age levels were found in Norway and Sweden, and the oldest respondents were in Belgium. The total ANOVA was significant, $F(4, 3296)=142.05$, $p<.001$, $\eta^2=0.15$, and the Games-Howell post-hoc test showed significant differences between all the groups ($p<.001$), with the exception of the Czech Republic and Australia.

In terms of sex, it can be concluded that males outnumbered females in the sample to a larger degree, especially in Australia, Belgium, and Sweden, although the latter country recorded a great number of missing responses to this question. In terms of education, people with higher levels of education predominated in all the countries with the exception of the Czech Republic, where the distribution of responses with regard to the level of education is rather balanced. In terms of employment, respondents with employment ("employees") predominated in all the countries; a significant number of students participated in Australia. The representation of the respondents' domicile (suburban; urban) differed from country to country. In Australia and Belgium, the majority of the respondents were from suburban areas, in the Czech Republic, the representation was rather proportionate, and in Sweden and Norway, people residing in urban areas predominated among the respondents (in Sweden 43% of the respondents provided no answer for this question).

The percentages of submitted questionnaires which were incomplete varied dramatically, ranging from 0 (Norway and the Czech Republic) to 43% (Sweden). This is due to the different data collection and inquiry methods (different online questionnaire platforms) employed in the different countries (in Norway and the Czech Republic a forced-answer design was applied).

The numbers of questionnaires fully completed by users and non-users differed from country to country. In Australia, Belgium, and Norway more questionnaires were completed by non-users and in the Czech Republic and Sweden the numbers were rather similar. In the further analysis presented in the Results section all the questionnaires were included in the analysis, not just those that were complete.

3. Results

In this section the results will be presented according to the stated research questions.

3.1. Do e-scooter riders travel faster than walking pace on sidewalks and under what legislative circumstances?

According to our data, e-scooter users ride on sidewalks in all five countries, albeit with different frequencies. We asked users *“Over the last 30 days, how often did you ride an e-scooter at a higher speed than walking (*> 6 km/h*) on a sidewalk?”* and similarly non-users: *“Over the last 30 days, how often did you interact with people riding an e-scooter at a higher speed than walking (*> 6 km/h*) on a sidewalk?”* As the travel code is different for each country and using the sidewalk is a violation of the rules in some countries, we mention the traffic rules for each country (also see Table 4).

Table 4. Using sidewalks in countries according to users and non-users.

	Australia	Belgium	Czech rep.	Norway	Sweden
ES on sidewalks	✓	✓	x	✓ <6 km/h	✓ <6 km/h
ES on shared pedestrian-bike paths	✓	✓	✓	✓	✓
ES on bike paths	✓	✓	✓	✓	✓
ES on road	x	✓	✓	✓	✓
users (almost) using sidewalks (>6 km/h) during the last 30 days “*(almost) always*” or “*often*”	65.3% (243)	18.0% (16)	45.2% (128)	32.6% (122)	11.0% (18)
non-users interacted with e-scooter riders on sidewalks (>6 km/h) during the last 30 days “*(almost) always*” or “*often*”	53.8% (257)	29.7% (65)	77.9% (232)	68.2% (335)	63.4% (126)

In Australia using sidewalks, off-road bike paths, and shared pedestrian-bike paths is allowed unless there is a no e-scooter sign and there is no specific speed limit on sidewalks for e-scooters (other than the 25 km/h general limit for them). However, giving way to pedestrians on sidewalks and shared paths is required. 65% (n=243) of the Australian users reported “(almost) always” or “often” using the sidewalk. Only 11% (n=44) of the users answered “never”. Likewise, the e-scooter non-users (53.8%; n=257) reported interaction with e-scooter riders “(almost) always” or “often” on sidewalks.

In Belgium an e-scooter rider can be considered a pedestrian if riding at walking speed and acting as a pedestrian, and in those cases an e-scooter rider is allowed to use the sidewalk. If the rider travels at a higher speed they are considered to be a cyclist and thus they are forbidden to use a sidewalk and should use a bike lane or a road. According to our data, Belgian e-scooter riders use sidewalks for riding rather less: 57% of e-scooter riders (n=51) reported “never”. However, 33.8% (n=74) of e-scooter non-users reported “never” interacting over the last 30 days.

In the Czech Republic an e-scooter rider is considered a cyclist and is forbidden to use a sidewalk under any circumstances. We found that Czech e-scooter riders violated this rule; 61% (n=173) stated that they “often” or “sometimes” used a sidewalk. Czech non-riders (77.9%, n=232) interacted with e-scooter riders “almost always” and “often”, which is in concordance with the e-scooter riders' reports.

In Norway e-scooters are considered to be bikes and can be legally ridden on the roadway, bike lanes, on sidewalks, and in pedestrian areas. E-scooter riding on a sidewalk is allowed if there are few pedestrians or if the riding does not endanger or obstruct pedestrians, and if riding near pedestrians the rider is required to do so at a good distance and approximately at a maximum speed of 6 km/h. In the Norwegian sample, 59.3% (n=222) of the users reported having ridden on a sidewalk at more than 6 km/h “sometimes” or more often during the last 30 days. Differently, non-users think e-scooter users violate the traffic code more often as they reported (68%, n=335) “(almost) always” and “often”.

In Sweden, similarly as in Norway, e-scooters (less than 250W and with a maximum speed of 20km/h) are classified as bicycles. As such they should use bike lanes, or if there is no bike lane they should use the road. They are, however, allowed to use the sidewalk or walking zones if they ride at "walking pace". Swedish e-scooter riders who reported "never" using a sidewalk in the last 30 days represented the biggest group in comparison with the other countries (62%, n=102). Interestingly, Swedish non-users reported interaction with e-scooter users on sidewalks at a higher speed than walking (>6km/h) "(almost) always" and "often" (63.4%, n=126).

As we can see from the data, e-scooter riders use sidewalks for riding in all five countries; however, there are differences. In Brisbane, Australia, where e-scooters are permitted on sidewalks, users and non-users report similar levels of usage of sidewalks. On the contrary, the Swedish traffic code allows e-scooters on sidewalks and that is the country with the biggest discrepancy between users' and non-users' reports. Even though both countries allow e-scooters to be ridden on sidewalks, Sweden encourages riding on on-road bike paths, whereas Brisbane did not allow this at the time of the study. The other reason for the discrepancy might be caused by the population that was targeted. The Swedish questionnaire had a different definition of "user": those who had ridden an e-scooter once were considered users. There could be a higher number of "users" with poor experience with riding an e-scooter so that they might have reported never using a sidewalk (and they really did not use one); however, in practice regular e-scooter riders do use sidewalks. Another explanation for such a discrepancy is that e-scooter riders ride on sidewalks only for a short distance and they do not even notice they were on a sidewalk.

The Czech respondents use the sidewalk in a similar way to the Norwegian ones, though the legislation in these countries is not the same (in the Czech Republic e-scooters are forbidden on sidewalks, while in Norway they are allowed under some circumstances). We suggest that the discrepancies between those non-user and user reports about using sidewalks might be caused by differences of perception. Non-users may perceive e-scooter riders on sidewalks as people violating the traffic code, which is why they may be more sensitive when they see someone riding an e-scooter. Another explanation of such discrepancies may be that one e-scooter user interacts with many non-users.

To control for the effect of gender, age, and overall frequency of riding during the last 30 days, we used ordinal logistic regression and predicted how often e-scooter users rode on a sidewalk at a faster speed than walking (more than 6km/h) during the last 30 days.

The overall model was significant: $\chi^2(10)=443.96$, $p<.001$. All the coefficients of the model are shown in Table 5. As you can see, all the predictors (i.e., gender, age, overall riding frequency, and country) entered into the model were significant. The effect of gender was relatively small, but indicated that compared to women, men had significantly higher odds of selecting a higher-frequency category by a factor of approximately 1/0.74=1.4. The effect of age (converted to decades) was negative (*OR*=0.80, 95% CI [0.73, 0.88]). That is, every ten years of age increased the odds of selecting a lower-frequency category by a factor of approximately 1/0.8=1.3. Furthermore, a higher overall riding frequency ("How often have you used an e-scooter over the last 30 days?") was associated with more frequent riding on a sidewalk (for exact values, see the effects of overall riding frequency in Table 5).

Table 5. Ordinal logistic regression with the frequency of riding on a sidewalk at a faster speed than walking as an outcome variable.

Predictors	***B***	***SE_B***	***Wald Z***	**χ^2 (*df*)**	***p***	***OR* [95% CI]**
Intercepts (thresholds)						
Never | At least once	−2.36	0.26	−8.99		<.001	
At least once | Sometimes	−1.48	0.26	−5.72		<.001	
Sometimes | Often	−0.37	0.26	−1.45		.147	
Often | (Almost) always	0.91	0.25	3.56		<.001	
Gender				6.40 (2)	.041	
Man (reference category)						
Woman	−0.30	0.12	−2.53		.012	0.74 [0.59, 0.94]
Other answer	−0.09	0.22	−0.41		.680	0.91 [0.59, 1.41]
Age (in decades)	−0.22	0.05	−4.71		<.001	0.80 [0.73, 0.88]
Overall riding frequency				83.53 (3)	<.001	
None (reference category)						
One to a few days	1.08	0.19	5.70		<.001	2.95 [2.03, 4.27]
One to a few days per week	1.55	0.18	8.45		<.001	4.72 [3.29, 6.76]
At least five days a week	1.51	0.20	7.75		<.001	4.54 [3.09, 6.66]
Country				311.24 (4)	<.001	–

Predictors	*B*	SE_B	*Wald Z*	χ^2 (*df*)	*p*	*OR* [95% CI]
Australia (reference category)						
Belgium	−2.77	0.25	−11.14		<.001	0.06 [0.04, 0.10]
Czech Republic	−1.01	0.15	−6.77		<.001	0.37 [0.27, 0.49]
Norway	−1.47	0.14	−10.26		<.001	0.23 [0.17, 0.31]
Sweden	−2.93	0.20	−14.67		<.001	0.05 [0.04, 0.08]

Note. N users listwise=1281. Omnibus test of the model: $\chi^2(10)=443.96$, $p<.001$.

Finally, we compared the differences between all the pairs of countries (controlling for the effect of all other predictors) using Tukey's HDS (honest significance difference – a single-step multiple comparison procedure, a series of t-tests for comparing all possible pairs of means method to adjust for the family-wise error rate [38]. Almost all the differences were significant except for the difference between Belgium and Sweden. Australian riders showed the highest frequency of riding on a sidewalk: *OR*=15.98 (95% CI [8.11, 31.51]) vs. Belgium, *OR*=2.73 (95% CI [1.82, 4.10]) vs. the Czech Republic, *OR*=4.33 (95% CI [2.93, 6.39]) vs. Norway, and *OR*=18.76 (95% CI [10.88, 32.37]) vs. Sweden. Belgian riders reported significantly lower frequency of riding on a sidewalk than Czechs (*OR*=0.17, 95% CI [0.08, 0.34]) and Norwegian riders (*OR*=0.27, 95% CI [0.14, 0.53]), but not than Swedes (*OR*=1.17, 95% CI [0.56, 2.47], *p*=.977). Furthermore, Czech e-scooter users rode on sidewalks significantly more frequently than Norwegians (although this difference was rather small, *OR*=1.58, 95% CI [1.08, 2.32], *p*=.009) and Swedes (*OR*=6.87, 95% CI [3.96, 11.90]). Lastly, Norwegian riders rode on sidewalks more frequently than Swedes (*OR*=4.33, 95% CI [2.56, 7.34]). If not stated otherwise, the *p*-values for the comparisons between countries are lower than .001.

To estimate the overall effect size, we computed expected values for each respondent, as ordinal regression produces the probabilities of each response category (which sums up to one for each respondent) and these probabilities can easily be multiplied by the numeric values of a given category to compute the expected values. We then computed the correlation between the expected and observed values (that is, the numeric values of the observed response categories). This correlation was $r=.53$, 95% CI [.49, .57]. This indicates a substantial overall effect, corresponding to (pseudo) R^2 of approximately .25.

3.2. What are the attitudes of non-users towards e-scooter riders, especially in terms of safety?

To find out the answer to the research question, we determined non-users' attitudes towards e-scooter safety. Therefore, we asked “*In general, how safe would it be for you to ride an e-scooter?*” According to Fig. 1, non-users from Australia, the Czech Republic, Norway, and Sweden thought riding an e-scooter would be slightly unsafe for them: around half of the respondents, 32–36%, evaluated safety at level 3 on a Likert scale (*1 “Very unsafe” – 5 “Very safe”*) and 23–29% evaluated it at level 2. Only the Belgian non-users thought it would be very unsafe for them to ride an e-scooter (60%, n=132) and less than 1% (n=2) reported that an e-scooter would be very safe. On the other hand, (10%, n=49) of the Australian non-user respondents perceived e-scooters as being very safe.

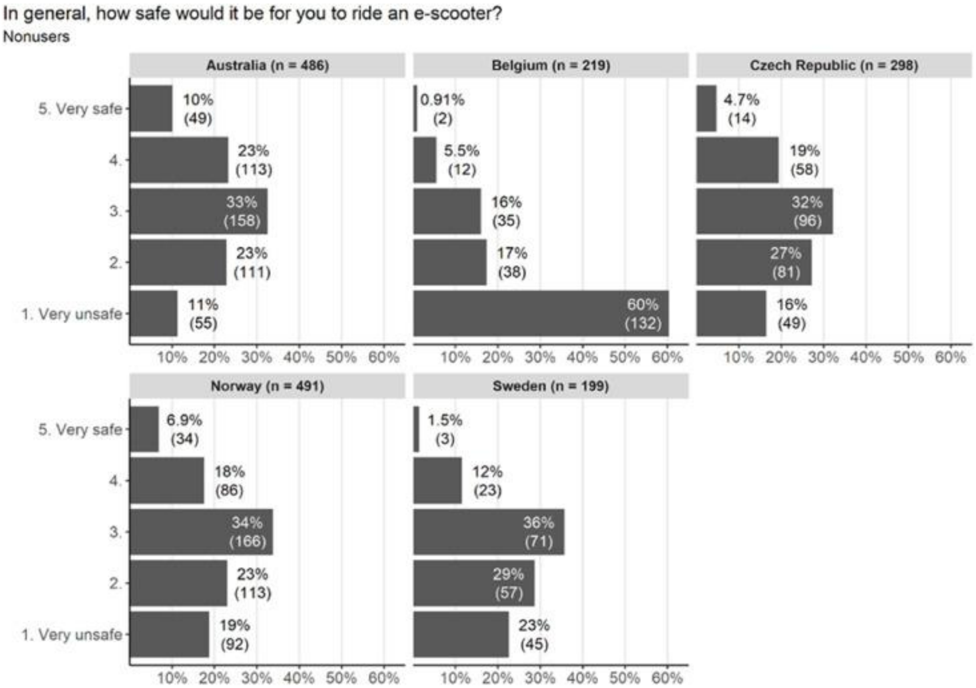

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Fig. 1. In general, how safe would it be for you to ride an e-scooter? Responses of non-users.

We also asked the non-users *"In general, how safe is it for other road users when someone is riding an e-scooter?"*. The greatest perception that riding an e-scooter posed a risk to other road users was found among the Belgian non-user respondents (53%; n=117 rated it as "very dangerous"), while the perception was lowest among the Australian non-users (16%; n=79 rated it as "very dangerous"). When comparing their own perceived safety (Fig. 1) and the perceived safety of e-scooters for other road users (Fig. 2), the non-user respondents considered riding an e-scooter safer for themselves than for other road users. This is particularly apparent among the Czech non-user respondents, of whom 16% (n=49) of the non-users of e-scooters considered riding an e-scooter "very dangerous" for themselves, while 30% (n=89) of the same respondents thought that when someone is riding an e-scooter it is "very dangerous" for other road users.

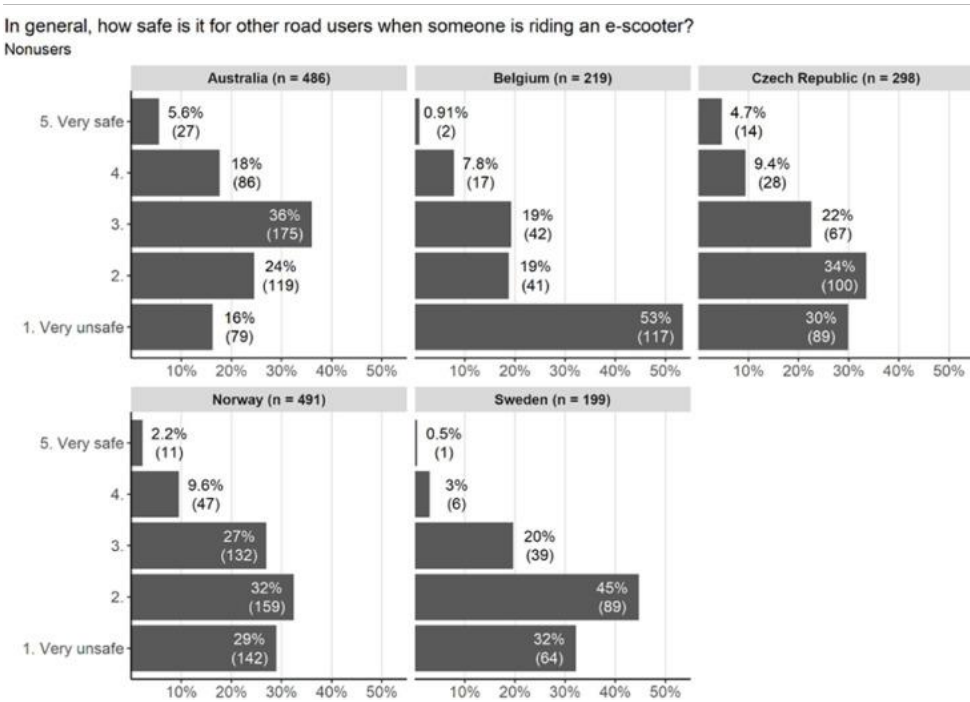

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Fig. 2. In general, how safe is it for other road users when someone is riding an e-scooter? Responses of non-users.

In summary, the non-users perceived riding an e-scooter as being rather unsafe for themselves. The respondents from Belgium were those who reported being most frightened. What is more, non-users perceived riding an e-scooter as being more unsafe for other road users than for themselves. This finding might be affected by their own experience: non-users may perceive some interaction from their point of view as more dangerous than e-scooter riders, who feel their operation is safe. Another reason why non-users may see e-scooters as more dangerous (especially for other road users) might be their lack of experience. They are not accustomed to e-scooter riders' behavior on sidewalks as well as on roads and they are not able to assess, for example, the speed or operating characteristics of an e-scooter.

Since the answers to both questions about the safety of riding an e-scooter ("In general, how safe would it be for you to ride an e-scooter/is it for other road users when someone is riding an e-scooter?") in non-riders were strongly correlated, r=0.61, 95% CI [0.57, 0.63], we averaged them to form one variable, perceived safety. Then we used linear regression to predict the scores on this variable on the basis of: (1) gender, (2) age, (3) having ridden an e-scooter at any time, (4) experiencing a near miss or (5) an accident in the past (related to an e-scooter), and (6) country.

The overall model was significant, $F(10, 1540)=57.64$, $p<.001$, and explained approximately 27% of the variance in perceived safety (R^2=0.272, 95% CI [0.23, 0.31], adj. R^2=0.268). All predictors were significant (see Table 6 for all coefficients of the model).

Table 6. Linear regression with perceived safety of e-scooters by both users/non users as an outcome variable.

Predictors	***B* [95% CI]**	SE_B	**β**	***t***	***F***	***df***	***p***
Intercept	+3.55 [+3.35, +3.75]	0.10		35.47		1540	<.001
Gender					4.61	2, 1540	.010
Man (reference category)							
Woman	−0.29 [−0.38, −0.20]	0.05	−.14	−6.16		1540	<.001
Other answer	−0.11 [−0.30, +0.07]	0.10	−.03	−1.19		1540	.233
Age (in decades)	−0.08 [−0.11, −0.04]	0.02	−.11	−4.25		1540	<.001
Riding experience	+0.29 [+0.19, +0.39]	0.05	.14	5.65		1540	<.001
Near miss experience	−0.67 [−0.77, −0.58]	0.05	−.31	−13.86		1540	<.001
Accident experience	−0.33 [−0.49, −0.17]	0.08	−.09	−4.02		1540	<.001
Country					3.08	4, 1540	.015
Australia (reference category)							
Belgium	−0.83 [−0.98, −0.67]	0.08	−.28	−10.15		1540	<.001
Czech Republic	−0.30 [−0.43, −0.16]	0.07	−.11	−4.28		1540	<.001
Norway	−0.21 [−0.33, −0.09]	0.06	−.09	−3.50		1540	<.001
Sweden	−0.39 [−0.62, −0.17]	0.11	−.08	−3.47		1540	<.001

Note. N non-users listwise=1550. R^2=0.272, adj. R^2=0.268. Omnibus test of the model: $F(10, 1540)=57.64$, $p<.001$. The outcome variable was coded in such a way that a higher score indicated higher perceived safety; therefore, positive effects mean that perceived safety tends to increase with higher levels of the predictor, while negative effects mean that perceived safety tends to decrease with higher levels of the predictor.

Women, compared to men (B=−0.29, 95% CI [−0.38, −0.20]) and older people (B=−0.08, 95% CI [−0.11, −0.04], for every ten years of age) were more inclined to perceive e-scooters as unsafe. Furthermore, experiencing a near miss (B=−0.67, 95% CI [−0.77, −0.58]) or an accident (B=−0.33, 95% CI [−0.49, −0.17]) with an e-scooter predicted lower perceived safety, but riding an e-scooter in the past (B=0.29, 95% CI [0.19, 0.39]) predicted higher perceived safety.

Finally, we compared the differences between all the pairs of countries (controlling for the effect of all the other predictors) using Tukey's HDS method to control the family-wise error rate. Australian non-riders perceived e-scooter riding as significantly safer than respondents from all the other countries, including Belgium (B=0.83, 95% CI [0.60, 1.05]), the Czech Republic (B=0.30, 95% CI [0.11, 0.48]), Norway (B=0.21, 95% CI [0.05, 0.37], p=0,004), and Sweden (B=0.39, 95% CI [0.08, 0.70], p=0,005). Furthermore, Belgians perceived e-scooter riding as more dangerous than did Czechs (B=−0.53, 95% CI [−0.77, −0.29]), Norwegians (B=−0.62, 95% CI [−0.82, −0.41]), and Swedes (B=−0.43, 95% CI [−0.75, −0.11], p=.002). Although Czechs perceived e-scooter riding as more dangerous than Norwegians did (B=−0.09, 95% CI [−0.27, 0.09], p=.682) but safer than Swedes did (*B*=0.10, 95% CI [−0.22, 0.41], *p*=.914), these differences were not statistically significant. Lastly, Norwegian non-riders perceived e-scooters as safer than Swedes did (*B*=0.19, 95% CI [−0.12, 0.49], *p*=.451), but this difference was not significant either (if not stated otherwise, the *p*-values for the comparisons are lower than 0.001).

Furthermore, we asked e-scooter riders how demanding it is to interact with vehicles or other road users (Fig. 3). E-scooter users reported finding it demanding to interact with motor vehicles (cars/taxis, trucks, and trams/buses) in Belgium, the Czech Republic, and Norway. Pedestrians were seen as equally demanding to interact with as motor vehicles, especially in Sweden and Norway. We hypothesize that the chief factor which influences users' perceptions of who it is demanding to interact with could be the degree to which all road users are accustomed to e-scooters.

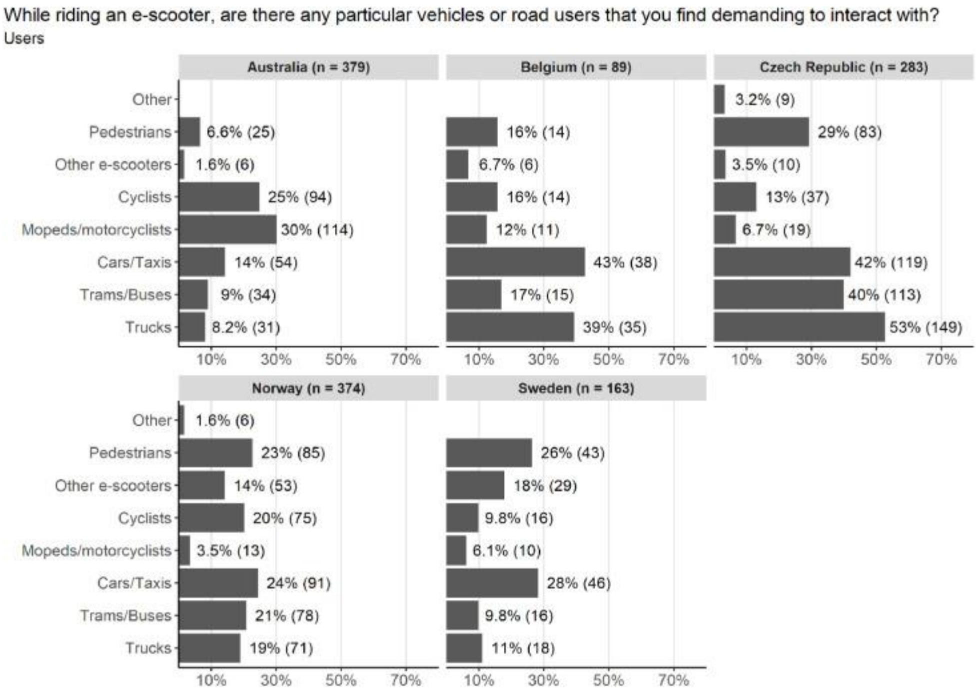

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Fig. 3. Road users that e-scooter users find it demanding to interact with.

3.2.1. Do non-users perceive e-scooters as annoying?

In this research study we asked the non-rider respondents about their interactions with e-scooter riders when walking (*"In general, how would you describe interactions with e-scooter riders when you are walking*?") on a 1–5 scale from annoying to pleasant. According to Fig. 4, the most common response in all the countries except Australia was to describe the interaction as annoying, which might be ascribed to the speed of the e-scooter. The non-user respondents who had the greatest perception of e-scooter riders as being annoying were the Belgian (67%) and Swedish (60%) non-users. Additionally, half of the Norwegian and Czech non-users reported being annoyed. In Australia, non-users seem to be accustomed to e-scooter riders as only 30% of them perceived them as annoying. In addition, some non-users could have had experience with an e-scooter (according to our definition those who had tried an e-scooter before were considered as non-users), which may indicate that they are more positive towards e-scooters. There is an evident trend: in every country most non-users (possibly in many cases pedestrians) describe the interaction as annoying.

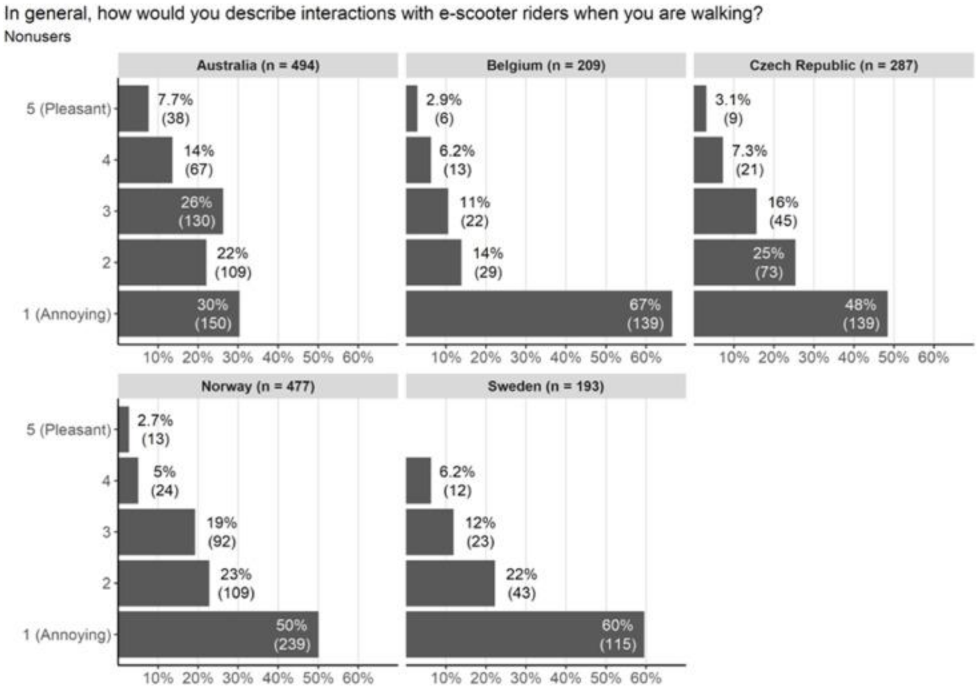

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Fig. 4. In general, how would you describe interactions with e-scooter riders when you are walking?.

To sum up, according to our data, more than half of the non-user respondents (from 48 up to 67%) from four countries described pedestrian-e-scooter interaction as "very annoying". In those countries, the traffic code is similar in some way: e-scooters are forbidden on sidewalks (in the Czech Republic) or permitted if they ride at walking speed (Belgium, Norway, and Sweden). In Australia, where riding on a sidewalk is permitted, although the riders must give way to pedestrians, the percentage of respondents who described the interaction as annoying is the lowest of the five countries. In the other countries, where e-scooters are not allowed on sidewalks (the Czech Republic) or must ride slowly on them (Belgium, Norway, Sweden), non-users perceive e-scooters as annoying. Moreover, on the evidence of our findings concerning perceived safety, the non-user respondents perceive riding an e-scooter as being generally unsafe for themselves and even more unsafe in general for other road users.

We then used ordinal regression to predict the attitudes (from 1="annoying" to 5="pleasant") of non-users toward e-scooter riders with (1) gender, (2) age, (3) having ridden an e-scooter at any time, (4) experiencing a near miss or (5) an accident in the past (related to an e-scooter), and (6) country as predictors.

The overall model was significant, $\chi^2(10)=495.37$, $p<.001$. All the coefficients of the model are shown in Table 7. As you can see, although female gender and higher age were associated with slightly more negative attitudes toward e-scooter riders, their effects were not significant. However, the effects of e-scooter riding experience, experiencing a near miss or an accident with an e-scooter rider, and country were statistically significant (all *p*-values <.001). Those respondents who had ridden an e-scooter in the past rated interactions with e-scooter riders more positively. However, respondents who had experienced a near miss or an accident involving an e-scooter rider rated interaction with e-scooter riders more negatively.

Table 7. Ordinal logistic regression with the attitudes of non-riders toward e-scooter riders as an outcome variable.

Predictors	***B***	SE_B	***Wald Z***	χ^2 (*df*)	***p***	***OR* [95% CI]**
Intercepts (thresholds)						
Annoying) | Rather annoying	−2.10	0.23	−9.08		<.001	
Rather annoying | Neutral	−0.90	0.23	−3.99		<.001	
Neutral | Rather pleasant	0.57	0.23	2.53		.012	
Rather pleasant | Pleasant	1.89	0.25	7.67		<.001	
Gender				0.25 (2)	.882	

Predictors	*B*	SE_B	*Wald Z*	χ^2 (*df*)	*p*	*OR* [95% CI]
Man (reference category)						
Woman	−0.05	0.11	−0.50		.619	0.95 [0.77, 1.17]
Other answer	−0.04	0.21	−0.18		.855	0.96 [0.64, 1.45]
Age (in decades)	−0.08	0.04	−1.84		.067	0.93 [0.85, 1.01]
Riding experience	0.82	0.11	7.29		<.001	2.27 [1.82, 2.83]
Near miss experience	−1.75	0.11	−15.60		<.001	0.17 [0.14, 0.22]
Accident experience	−0.92	0.21	−4.48		<.001	0.40 [0.27, 0.60]
Country				60.24 (4)	<.001	
Australia (reference category)						
Belgium	−1.16	0.19	−5.99		<.001	0.31 [0.21, 0.46]
Czech Republic	−0.83	0.15	−5.45		<.001	0.44 [0.32, 0.59]
Norway	−0.72	0.13	−5.58		<.001	0.49 [0.38, 0.63]
Sweden	−1.18	0.27	−4.37		<.001	0.31 [0.18, 0.52]

Note. N non-users listwise=1521. Omnibus test of the model: $\chi^2(10)=495.37$, $p<.001$.

Again, we compared the differences between all the pairs of countries using Tukey's HDS method to control the family-wise error rate. The Australian respondents rated interaction with e-scooter riders significantly more positively than the respondents from all other countries, including Belgium (*OR*=3.20, 95% CI [1.88, 5.42]), the Czech Republic (*OR*=2.29, 95% CI [1.51, 3.47]), Norway (*OR*=2.06, 95% CI [1.46, 2.93]), and Sweden (*OR*=3.27, 95% CI [1.56, 6.84], all *p*-values <.001).

All the other differences between the countries were not significant, including the difference between Belgium vs. the Czech Republic (*OR*=0.72, 95% CI [0.41, 1.27], *p*=.499), Belgium vs. Norway (*OR*=0.64, 95% CI [0.39, 1.07], *p*=.124), Belgium vs. Sweden (*OR*=1.02, 95% CI [0.46, 2.27], *p*=.999), the Czech Republic vs. Norway (*OR*=0.90, 95% CI [0.60, 1.35], *p*=.951), the Czech Republic vs. Sweden (*OR*=1.43, 95% CI [0.67, 3.03], *p*=.698), and Norway vs. Sweden (*OR*=1.59, 95% CI [0.77, 3.29], *p*=.410).

To estimate the overall effect size, we computed the correlation between the expected and observed values: *r*=0.54, 95% CI [0.51, 0.59]. This indicates a substantial overall effect, corresponding to (pseudo) R^2 of around 0.25.

3.3. What is the prevalence and what are the influencing factors of conflicts and crashes including non-users and e-scooters?

In this paper, we focus on e-scooter and non-user (possibly often pedestrian) conflicts and their prevalence. We asked both users and non-users about crashes and near misses. First, we present the results about near misses. We defined a near miss as *“an unplanned event that has the potential to cause an accident but does not actually result in one”* and asked: *“How many times have you ever experienced a near miss when riding an e-scooter?”*. Half of the e-scooter users (49%, n=627) had experienced at least one near miss and for 54% of these respondents, their most recent near miss involved another road user. Those who had experienced a near miss in which another road user had been involved (n=341) were asked *“For your last near miss, what best describes the situation? I almost collided with …”*. and 298 answered it. We excluded Belgium from this statistic, as only five user respondents answered this question. According to Fig. 5, the situation is similar in the Czech Republic (56%, n=59), Norway (40%, n=28), and Sweden (47%, n=9), where an e-scooter near miss with a car was the most common type, according to our user respondents. In those countries e-scooter riders are legally required to use roads or are highly recommended to do so. Other frequent road users involved in near misses were pedestrians (from 11 up to 23%) in those countries. On the other hand, e-scooter users from Australia report near misses with pedestrians (40%, n=40) slightly more in comparison with near misses with cars (37%, n=37). This may be affected by the local traffic code (e-scooters are allowed on sidewalks and not allowed on most roads). Interestingly, near misses with another e-scooter rider were not mentioned often.

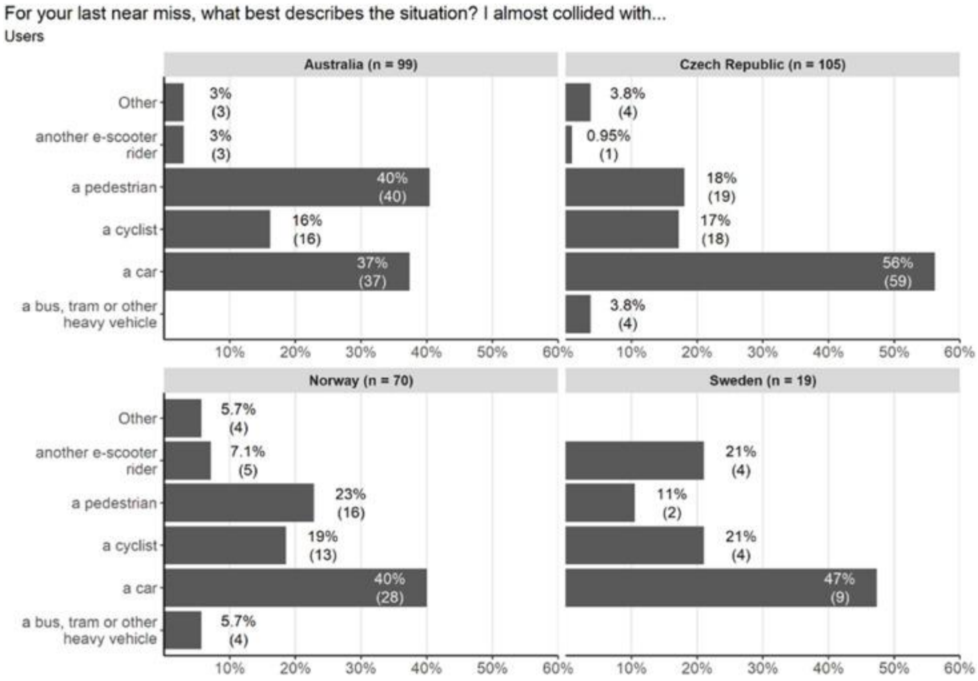

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Fig. 5. For your last near miss, what best describes the situation? I almost collided with … E-scooter user responses only.

We asked non-users, *"How many times have you ever experienced a near miss when interacting with someone riding an e-scooter?"*. Of the 1860 non-user respondents, 85% (n=1586) answered this question. The vast majority of them (77%, n=1069) had experienced a near miss (in contrast to 49% of the users). Fig. 6 shows the percentages of users and non-users who had experienced a near miss. It is evident that the non-users report near misses more than the e-scooter users in all five countries. As presented above, we conclude that the prevalence of near misses is not perceived as the same among non-users and users. Even if there are differences, the number (half of the users and three-quarters of the non-users) of respondents who had experienced at least one near miss is not negligible. We suggest that the difference in the prevalence of near misses may be caused by the various interpretations of the respondents. A rider on an e-scooter usually feels in control, so there are probably many situations where someone on a scooter is passing close to a pedestrian. However, the pedestrian is scared and thinks it was a near miss, but the rider on the e-scooter feels it was perfectly safe. This corresponds to the non-users reporting far more near misses with e-scooters than the users. Alternatively, the discrepancy could reflect some under-reporting of actual near misses by e-scooter users or could also reflect the possibility that one e-scooter rider could have had near misses with many non-users.

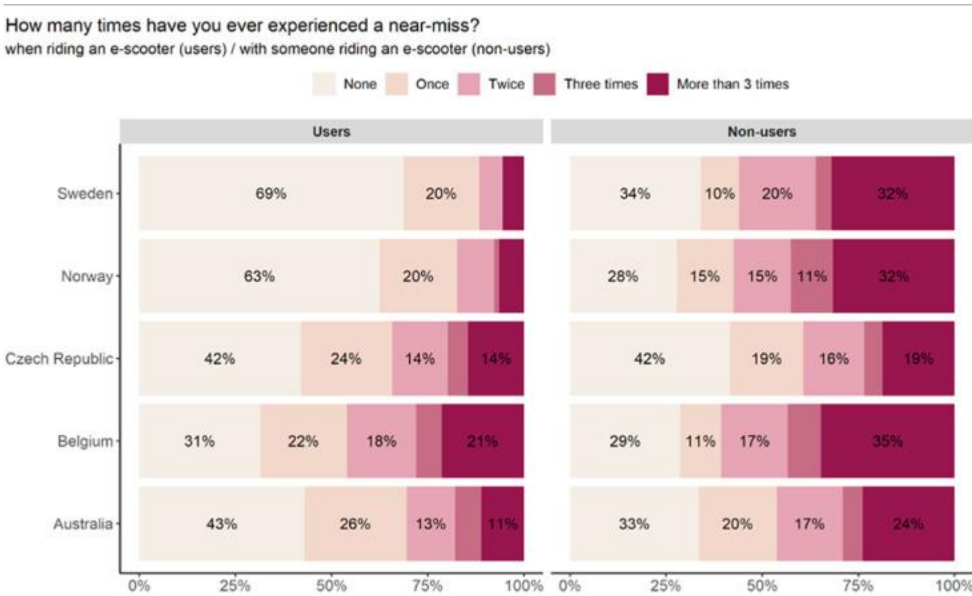

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Fig. 6. How many times have you ever experienced a near miss?.

We also explored the factors that contributed to the near misses: "For your last near miss, to what extent do you think that the following factors contributed to the near miss?" Both users and non-users perceive "another road user" as "the main cause of the risk". However, there are differences: e-scooter users who had experienced at least one near miss thought that another road user was the main cause less frequently than non-users who had experienced at least one near miss did. To depict this in greater detail, around half of the Swedish (54%) and Belgian (49%) user respondents marked "another road user" as "the main cause of the risk". According to non-users, "another road user" was the main cause of the risk in Belgium (83%), in the Czech Republic, in Sweden, and in Norway (68-59%). Only the Australian non-users perceived e-scooter operation (39%, compared to "another road user", 25%) as the main cause of the risk. The same factor (e-scooter operation) was also perceived by non-users as common in Sweden (61%, compared to "another road user", 63%). Differently, users think "e-scooter operation" did not contribute to the risk at all or contributed little in all the countries except Sweden, where 44% of the user respondents marked e-scooter operation as the main cause. Road design or a slippery or uneven surface "did not contribute at all" or "may have contributed a little", according to non-users. On the other hand, some users (less than 20%) thought these factors "certainly contributed".

Second, we present results about accidents (see Fig. 6). The question *"Have you ever had an accident when riding an e-scooter?"* was responded to by 1272 users, of whom 232 (18%) had been involved in such an accident. The vast majority of accidents did not involve another road user; only 45 respondents (20%) had collided with someone else. As the frequencies are low, we did not differentiate among countries: the greatest number of users (41%, n=18) had had a collision involving a car. After that, pedestrians (23%, n=10) were involved.

The number of non-user respondents who reported an accident is lower compared to that of users: only 8.5% of the non-users (n=143) answered 'yes' when they were asked *"Have you ever had an accident involving someone riding an e-scooter?"* Although the numbers of accidents reported by non-users are very small in some countries (e.g., in Sweden ten non-user respondents reported having been involved in an accident), the majority of respondents stated that the main cause of the accident was "another road user" and "e-scooter operation" (see Fig. 6).

According to our data 18% (n=232) of users reported an accident, versus 8.5% (n=143) of non-users. The highest prevalence reported by users was from Belgium (28%) and Australia (23%). Interestingly, the lowest prevalence reported both by users and non-users was from Sweden (see Fig. 7).

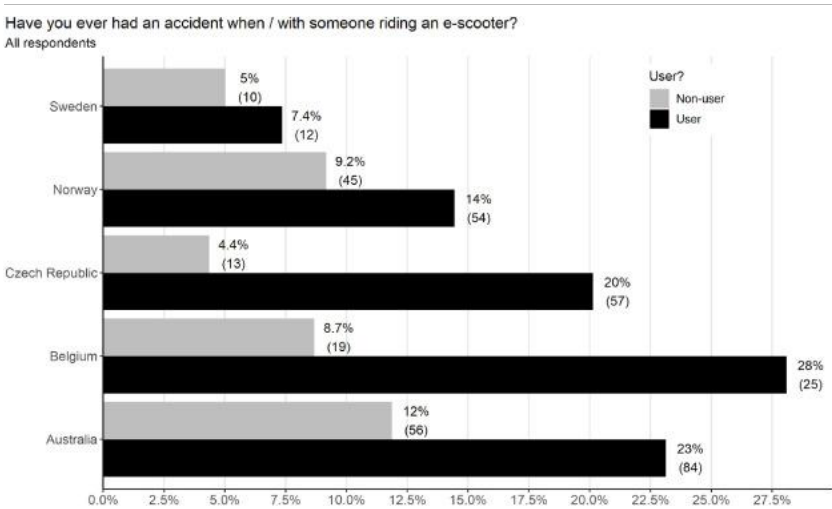

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Fig. 7. Have you ever had an accident when/with someone riding an e-scooter?.

We were interested in factors that contributed to accidents, which is why we asked both user and non-user respondents who had experienced at least one accident *"For your last accident, to what extent do you think that the following factors contributed to the accident?"* It seems that the most common cause of accidents reported by users is "uneven surface" in all the countries that were studied. A slippery surface appears as another cause of accidents in the Czech Republic, Norway, and Belgium (29-25%); however, the numbers of responses in some countries is low (e.g., Sweden, n=12).

Next, 133 non-users reported about factors that contributed to accidents. Again, we do not differentiate among countries, as the numbers are very small in some of them. The majority of the non-users thought the main causes of the accidents were "the behavior of the e-scooter rider" and "e-scooter operation".

To sum up this section, n on-users report more near misses, which can be caused by different perceptions of a near miss. Users report near misses with cars most in those countries where e-scooters must use roads or are highly recommended to do so and with pedestrians in countries where riding on sidewalks is allowed. “Another road user” is seen as the factor making the greatest contribution by both users and non-users.

Less than one-tenth of the non-user respondents reported having had an accident. “Another road user” was perceived as the most common cause of an accident by non-users. However, users report “uneven surface” as being the cause more often. This difference might be caused by differences in experience: a pedestrian who has been involved in a crash can think the e-scooter rider made a mistake, but the rider may have crashed into somebody because of an unexpected uneven surface.

4. Discussion and conclusions

The goal of this study was to describe the potential impacts of e-scooters on pedestrians, or, more broadly, walking as a mode of transportation, in urban environments. In particular, the focus was on: pedestrian-e-scooter interaction, communication, and attitudes; pedestrians' perceived safety in the presence of e-scooters; conflicts and crashes involving e-scooters and pedestrians; and the sharing of spaces devoted to pedestrians with e-scooters. We also presented an international comparison in this topic based on data collected from five nations (Australia, Belgium, the Czech Republic, Norway, and Sweden). Following the logic of the presentation of the results, we will discuss each topic according to the stated research questions.

Firstly, we examined whether e-scooter riders use sidewalks and under which circumstances (e.g., riding faster than at walking speed). We found out that more or less 20–30% of e-scooter users report riding on sidewalks at greater than walking pace. Interestingly, it seems that there is not a close connection between the usage of the sidewalk and whether it is allowed or is a violation of the rules. Another interesting finding is that when comparing the answers of e-scooter users and non-users (possibly mostly pedestrians), we can see a trend that pedestrians report usage of the sidewalk by e-scooter users more often than e-scooter users themselves do. This might be caused by the fact that in cases when this is not allowed the group of e-scooter users underreport this behavior and on the other hand, pedestrians who might be sensitive to the presence of e-scooters on the sidewalk (as they might perceive this as a threat) might overreport this.

Furthermore, we can conclude that a higher overall riding frequency and being male was associated with more frequent riding on a sidewalk. On the other hand, age is negatively associated with sidewalk riding; younger riders ride on the sidewalk more often than older riders. We can observe here a connection to generally known risk groups in terms of traffic safety (males, youngsters). Almost all the differences between countries were significant; Australia was associated with the highest frequency of sidewalk riding, which is probably connected to the fact that this is allowed in Australia without a <6 km/h speed limit.

We can generally conclude that the usage of the sidewalk by e-scooter riders is rather common in all the participating countries (partly besides Belgium, where both users and non-users report lower frequencies). Our findings are in line with the literature which states that e-scooter users are prone to breaking the rules and, specifically, using the sidewalk [28]. On the other hand, what is new in comparison to the existing knowledge is the comparison of the self-reporting of pedestrians and e-scooter riders, which shows that pedestrians report more sidewalk riding than riders do. This might indicate a possibility of underreporting of (mostly prohibited) sidewalk riding reported by e-scooter riders. This should be noted when implementing the results of studies based on the self-reporting of e-scooter riders. The other important and new result is the fact that there is not a close connection between the usage of the sidewalk and whether it is allowed or is a violation of the rules. This might indicate that the enforcement of a sidewalk riding ban is weak in the countries under study.

Secondly, we compared the attitudes of pedestrians and e-scooter riders in terms of perceived safety. In general, we can conclude that non-users of e-scooters tend to think that riding an e-scooter is rather dangerous (with the Australian respondents reporting the highest level of perceived safety). The pattern is the same for all the countries except Belgium. Belgian non-users report this activity as very unsafe. We do not have a clear explanation of why the Belgian sample responded differently from the non-users from other countries besides the fact that they were older. We do not find associations with either the national rules for e-scooter operation or the quality of traffic infrastructure. This conclusion remains open for future elaboration.

More specifically, women and older people were more inclined to perceive e-scooters as unsafe. Experiencing a near miss or an accident with an e-scooter predicted lower perceived safety. On the other hand, riding an e-scooter in the past predicted higher perceived safety. This is in line with other findings from the literature [37,39] and with general social psychology theories (showing that past experience shapes our beliefs and attitudes towards reality). The innovative feature of this finding is that on the basis of a cross-country comparison we showed that this phenomenon is culture-free and is not mediated by legal regulations governing e-scooter riders. As for the practical implications of this work, this piece of knowledge is very important, showing that those who are most vulnerable perceive e-scooter operation as a threat. We believe that in modern urban mobility, safety standards have to be based on the needs of those who are most vulnerable.

The next question we focused on was how non-users of e-scooters perceive the safety of e-scooter operation for other users or, to put it in other words, how big a threat the operation of e-scooters is for others. We did not specify “other road users”, although we might hypothesize that in this respect pedestrians and cyclists were understood and that in the first place the respondents were probably thinking of vulnerable road users rather than car drivers. In any case, we can see the same patterns as in the question dealing with the safety of riding e-scooters, but the trend to "very unsafe" responses is evident. Thus we might conclude that non-users state that the operation of e-scooters is a threat to others rather than to e-scooter riders themselves. This is in line with the literature[33] showing that e-scooter operation might be a factor reducing the comfort and perceived safety of pedestrians and possibly other road users.

The third research question focused on whether pedestrians perceive e-scooters as annoying. We have already partly answered it above. Moreover, we can see a very clear pattern here, showing that across all the nations under study, pedestrians perceive e-scooter riders (and e-scooter operation) as annoying.

Older non-users, women, and respondents who had experienced a near miss or an accident involving an e-scooter rider reported more negative attitudes towards e-scooter riders, while on the other hand respondents who had ridden an e-scooter in the past rated interactions with e-scooter riders more positively. Australian respondents rated interaction with e-scooter riders significantly more positively than the respondents from all the other countries. This might be so because of the good quality of the infrastructure and regulations which are both "friendly" to pedestrians and also enforced. Our findings confirmed what is rather known from the literature, that non-users, especially pedestrians, perceive e-scooter riders, or better to say e-scooter operation in the public space, as a threat and as annoying. In line with other findings, again older non-users, women, and those who had experienced conflict with an e-scooter rider in the past perceive this more intensively. What is new and very important for traffic safety work is the finding (based on the cross-national comparison) that well-designed and well-maintained infrastructure, together with effective legal regulations (and enforcement), which is balanced with regard to the needs of both pedestrians and e-scooter riders, may lead to a considerable reduction of feelings of being unsafe or annoyed.

In any case, further elaboration and description of the factors which lie behind this is definitely needed. We believe that the core factor influencing this is the enforcement of the rules, not the rules themselves.

Next, we focused on the prevalence and influencing factors of conflicts and crashes including pedestrians and e-scooters. We can conclude that half of the e-scooter users had experienced a near miss at some point in the past and that more than 50% of these near misses involved another road user. In the majority of the countries the most common type of road user involved in the collision was a car (not true for Australia), followed by pedestrians and cyclists. In contrast, the non-users reported experiencing a near miss with an e-scooter in 77% of cases. We can see a clear pattern – that the non-users report more near miss experiences – in all the countries under study. This discrepancy might be caused by the different perception of a near miss. We might hypothesize that this has something to do with the subjective perception of safety. Those road user groups who perceive the situation as less risky (a higher subjective sense of safety) might tend to evaluate mutual interaction (of a pedestrian and e-scooter) as less risky and thus not as a near miss. If we were to accept this argumentation, we might conclude that e-scooter riders perceive the same situations as less risky than pedestrians and that e-scooter riders show a higher subjective sense of safety than pedestrians. This might be connected to a more general social psychology theory dealing with the distribution of power [40]. According to this theory, those who possess more power (those who are mastering the situation) feel safer than those who do not. In the recent literature the topic of e-scooter crashes and their severity and injuries, including another conflicting party (e.g., cars, pedestrians etc.), is broadly discussed. Very little attention is paid to near misses (or conflicts), or to other surrogate safety measures. In this respect our findings are quite new, showing that near misses can potentially be used as a predictor of future crashes with the potential to mitigate crash risks (as broadly used in other modes of traffic). The other important finding is that near misses are perceived differently by pedestrians and by e-scooter riders. In future work dealing with the calibration and operationalization of e-scooter near misses, this will have to be taken into account.

When dealing with accidents, we first have to take into account that we are interpreting a rather smaller number of responses (up to 10%). There are no major differences between the groups of users and non-users (besides the Czech Republic), with the users reporting slightly more accidents in all the countries. The quite high frequencies of non-users reporting accidents might confirm that in the majority of cases e-scooter accidents (and possibly also near-misses) are accidents that involve other road users.

4.1. Limitations

As for the limitations of our study, we identify two major issuers. The first one is the data collection process in the different countries. The data were collected using snowball sampling, which was based on sponsored Facebook ads and participant sharing. Although the authors tried to control all the contributing factors influencing the data collection and sample in all five countries as far as possible, we are aware that the samples might differ slightly, which complicates the international cooperation. The other issue is the preparation of questionnaires and data collection process (e.g., using different online platforms to collect the data) in five different national versions, which in some cases led to minor differences in the coding and furthermore to complications when comparing (and interpreting) the data from different countries. To be more specific, the main factors which complicated the comparison of data from different countries were: the somehow different definition of e-scooter users in Sweden than in the other countries (although, on the basis of the statistical analysis provided and the comparison between countries, we did not identify any indications which would suggest that the results are biased); forced answer design only in some countries and not in others; and differences in the national regulations which might have led to differences in the interpretation of some questions in the questionnaire. In the table below we list all the limitations which we consider relevant for this study (Table 8).

Table 8. Study limitations.

Limitation
Different processes of data collection between the countries
Differences in the wording of some questions and definitions in different language versions
Different definition of an e-scooter user in Sweden
Different legal regulations in the countries under study
Results based on self-reported data
Sampling method based on social media advertisements and snowball sampling

4.2. Implications for practice

On the basis of the findings presented here we believe that the most relevant suggestion for the implications for road safety management, or rather sustainable (urban) mobility more generally, is to take steps which will separate e-scooter riders and pedestrians, or, so to say, to ensure that the space which is devoted to pedestrians (usually sidewalks) will remain a space which will be safe and comfortable for all those who use it, including vulnerable road users, such as the elderly, children, or pedestrians with special needs. If it is necessary and this space has to be shared, it is important to enforce a rule that e-scooter riders must proceed at no more than walking speed and are supposed to yield to pedestrians. More specifically, to follow these principles, we make the following recommendations.

To develop safe infrastructure, we suggest that e-scooters should be banned from sidewalks but alternatives are thus required. Cycle paths need to be wide enough to allow different types of vehicles to use this infrastructure together safely. The literature shows that sidewalk riding increases when a bike lane is not available or where motor vehicle speeds are higher [39]. In this respect, sidewalk riding served as an indication that e-scooter riders do not feel safe riding with motor vehicles in the roadway.

Improper e-scooter parking obstructs the paths of pedestrians and poses a tripping hazard. In this respect we recommend that e-scooters be parked outside of the pedestrian zone (e.g., the sidewalk), in the furniture zone.

Various mechanisms might be implemented to attempt to reduce (illegal) sidewalk riding. Besides effective legal regulations and police enforcement, other – mostly GPS- and sensor- or camera-based – systems are emerging. A technology called 'geofencing' (a set of lines, defined by geographical coordinates, that demarcate an area where special regulations apply) can be used to oblige e-scooters to be used and parked only where they are legally allowed. Speeds could also be regulated using geofences.

The other implication for practice is training, including both skills and knowledge (e.g., maneuvering, regulations) but also higher levels of the GDE matrix on motivations and responsibilities when riding an e-scooter [41]. In this context, traffic training for children at secondary school could also be expanded, with all types of personal mobility devices being addressed. Last but not least, the extension of driver training for motor vehicle users is equally important.

Author contribution statement

Matúš Šucha; Elisabeta Drimlová: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Karel Rečka: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Narelle Haworth; Katrine Karlsen: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Aslak Fyhri; Pontus Wallgren; Peter Silverans; Freya Slootmans: Conceived and designed the experiments; Performed the experiments.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Appendix A. Supplementary data

The following is the Supplementary data to this article.

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Multimedia component 1.

Recommended articles

References

[1] D. Schellong, P. Sadek, C. Schaetzberger, T. Barrack
The Promise and Pitfalls of E-Scooter Sharing
Boston Consulting Group (2019)
Retrieved 17th February 2021 from
https://image-src.bcg.com/Images/BCG-The-Promise-and-Pitfalls-of-E-Scooter%20Sharing-May-2019_tcm55-220107.pdf
Google Scholar

[2] J.K. Mathew, M. Liu, S. Seeder, H. Li, D.M. Bullock
*A*nalysis of E-scooter trips and their temporal usage patterns. Institute of Transportation Engineers
ITEA J., 89 (6) (2019), pp. 44-49
https://search.proquest.com/scholarly-journals/analysis-e-scooter-trips-their-temporal-usage/docview/2251991862/se-2?accountid=16730
Google Scholar

[3] C.S. Kopplin, B.M. Brand, Y. Reichenberger
*C*onsumer acceptance of shared e-scooters for urban and short-distance mobility
Transport. Res. Transport Environ., 91 (2021) (2021), Article 102680, 10.1016/j.trd.2020.102680
View PDF View article View in Scopus Google Scholar

[4] B. Laa, U. Leth
Survey of E-scooter users in Vienna: who they are and how they ride
J. Transport Geogr., 89 (2020), Article 102874
View PDF View article View in Scopus Google Scholar

[5] M. Radics, T. Shibayama, G. Emberger
Shared Electric Scooters in Vienna: Analyzing Usage Characteristics with Limited Data
https://repositum.tuwien.at/bitstream/20.500.12708/17200/1/Radics%20-%202020%20-%20Shared%20Electric%20Scooters%20in%20Vienna%20Analyzing%20Usage%20Characteri....pdf (2020)
Google Scholar

[6] K. Reinhardt, E. Deakin
Best Practices for the Public Management of Electric Scooters
UC Office of the President: University of California Institute of Transportation Studies (2020), 10.7922/G289144Q
https://escholarship.org/uc/item/8x67x360
Google Scholar

[7] E. Park-Lee, C. Ren, M.D. Sawdey, A.S. Gentzke, M. Cornelius, A. Jamal, K.A. Cullen
Notes from the field: e-cigarette use among middle and high school students—national Youth Tobacco Survey, United States, 2021
MMWR (Morb. Mortal. Wkly. Rep.), 70 (39) (2021), p. 1387
CrossRef View in Scopus Google Scholar

[8] C. Hardt, K. Bogenberger
Usage of e-scooters in urban environments

Transport. Res. Procedia, 37 (2019), pp. 155-162

View PDF View article View in Scopus Google Scholar

[9] C.S. Smith, J.P. Schwieterman
E-scooter Scenarios: Evaluating the Potential Mobility Benefits of Shared Dockless Scooters in Chicago
TRID (2018)
https://las.depaul.edu/centers-and-institutes/chaddick-institute-for-metropolitan-development/research-and-publications/Documents/E-ScooterScenariosMicroMobilityStudy_FINAL_20181212.pdf
Google Scholar

[10] P. Allem, A. Majmundar
Are electric scooters promoted on social media with safety in mind? A case of study on Bird's Instagram
Prev. Med. Rep., 13 (2013) (2019), pp. 62-63, 10.1016/j.pmedr.2018.11.013
View in Scopus Google Scholar

[11] J. Hollingsworth, B. Copeland, J.X. Johnson
Are e-scooters polluters? The environmental impacts of shared dockless electric scooters
Environ. Res. Lett., 14 (2019), Article 84031, 10.1088/1748-9326/ab2da8
Google Scholar

[12] H. Moreau, L. de Jamblinne Meux, V. Zeller, P. D'Ans, C. Ruwet, W.M.J. Achten
Dockless E-scooter: a green solution for mobility? Comparative case study between dockless E-scooters, displaced transport, and personal E-scooters
Sustainability, 12 (2020), p. 1803, 10.3390/su12051803
View in Scopus Google Scholar

[13] M. Aizpuru, K.X. Farley, J.C. Rojas, R.S. Crawford, T.J. Moore, E.R. Wagner
Motorized injuries in the era of scooter-shares: a review of the national electronic surveillance system
AJEM (Am. J. Emerg. Med.), 37 (6) (2019), pp. 1133-1138, 10.1016/j.ajem.2019.03.049
View PDF View article View in Scopus Google Scholar

[14] K.L. Ioannides, P.C. Wang, K. Kowsari, V. Vu, N. Kojima, D. Clayton, *et al.*
E-scooter related injuries: using natural language processing to rapidly search 36 million medical notes
PLoS One, 17 (4) (2022), 10.1371/journal.pone.0266097
Google Scholar

[15] A. Badeau, C. Carman, M. Newman, J. Steenblik, M. Carlson, T. Madsen
Emergency department visits for electric scooter-related injuries after introduction of an urban rental program
AJEM (Am. J. Emerg. Med.), 37 (8) (2019), pp. 1531-1533, 10.1016/j.ajem.2019.05.003
View PDF View article View in Scopus Google Scholar

[16] D. Uluk, T. Lindner, M. Dahne, J.W. Bickelmayer, K. Beyer, A. Slagman, *et al.*
E-scooter incidents in Berlin: an evaluation of risk factors and injury patterns
Emerg. Med. J., 39 (4) (2022), pp. 295-300, 10.1136/emermed-2020-210268
Epub 2021 Jun 7. PMID: 34099458; PMCID: PMC8961771
Google Scholar

[17] I. Shichman, O. Shaked, S. Factor, A. Weiss-Meilik, A. Khoury
Emergency department electric scooter injuries after the introduction of shared e-scooter services: a retrospective review of 3,331 cases
World J. Emerg. Med., 13 (1) (2022), p. 5, 10.5847/wjem.j.1920-8642.2022.002
PMID: 35003408; PMCID: PMC8677920
View in Scopus Google Scholar

[18] N.K. Dhillon, C. Juillard, G. Barmparas, T. Lin, D.Y. Kim, D. Turay, A.R. Seibold, S. Kaminski, T.K. Duncan, G. Diaz, S. Saad, D. Hanpeter, E.R. Benjamin, A. Tillou, C. Hardt, K. Bogenberger
Usage of e-scooters in urban environments
Transport. Res. Procedia, 37 (2019) (2019), pp. 155-162, 10.1016/j.trpro.2018.12.178

Google Scholar ↗

[19] T. Moftakhar, M. Wanzel, A. Vojcsik, F. Kralinger, M. Mousavi, S. Hajdu, S. Aldrian, J. Starlinger
Incidence and severity of electric scooter related injuries after introduction of an urban rental programme in Vienna: a retrospective multicentre study
Arch. Orthop. Trauma Surg., 141 (7) (2021), pp. 1207-1213, 10.1007/s00402-020-03589-y ↗
View in Scopus ↗ Google Scholar ↗

[20] B. Trivedi, M.J. Kesterke, R. Bhattacharjee, W. Weber, K. Mynar, L.V. Reddy
Craniofacial injuries seen with the introduction of bicycle-share electric scooters in an urban setting
J. Oral Maxillofac. Surg., 77 (11) (2019), pp. 2292-2297, 10.1016/j.joms.2019.07.014 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[21] N. Sikka, C. Vila, M. Stratton, M. Ghassemi, A. Pourmand
Sharing the sidewalk: a case of E-scooter related pedestrian injury
Am. J. Emerg. Med., 37 (9) (2019), pp. 1807.e5-1807.e7, 10.1016/j.ajem.2019.06.017 ↗
View PDF View article Google Scholar ↗

[22] K. Fang, A. Weinstein Agrawal, J. Steele, J.J. Hunter, A.M. Hooper
Where Do Riders Park Dockless, Shared Electric Scooters? Findings from San Jose
Mineta Transportation Institute Publications, California (2018)
Google Scholar ↗

[23] A. Brown, N.J. Klein, C. Thigpen, N. Williams
Impeding access: the frequency and characteristics of improper scooter, bike, and car parking
Transp. Res. Interdiscip. Perspect., 4 (2020) (2021), Article 100099, 10.1016/j.trip.2020.100099 ↗
Google Scholar ↗

[24] M. Zakhem, J. Smith-Colin
Micromobility implementation challenges and opportunities: analysis of e-scooter parking and high-use corridors
Transport. Res. Transport Environ., 101 (2021), Article 103082
View PDF View article View in Scopus ↗ Google Scholar ↗

[25] A. Maiti, N. Vinayaga-Sureshkanth, M. Jadiwala, R. Wijewickrama, G.P. Griffin
Impact of E-Scooter on Pedestrian Safety: A Field Study Using Pedestrian Crowd-Sensing
(2020)
arXiv:1908.05846v4
Google Scholar ↗

[26] A. Nikiforiadis, E. Paschalidis, N. Stamatiadis, A. Raptopoulou, A. Kostareli, S. Basbas
Analysis of attitudes and engagement of shared e-scooter users
Transport. Res. Transport Environ., 94 (2021) (2021), 10.1016/j.trd.2021.102790 ↗
Retrieved 12th October 2021 from
Google Scholar ↗

[27] N. Haworth, A. Schramm, D. Twisk
Comparing the risky behaviours of shared and private e-scooter and bicycle riders in downtown Brisbane, Australia
Accid. Anal. Prev., 152 (2021) (2021), 10.1016/j.aap.2021.105981 ↗
Google Scholar ↗

[28] H. Fitt, A. Curl
E-scooter use in New Zealand: Insights around some frequently asked questions
https://ir.canterbury.ac.nz/handle/10092/16336 ↗ (2019)
Google Scholar ↗

[29] J.F. Arellano, K. Fang
Sunday drivers, or too fast and too furious?
Transp. Find. (2019), 10.32866/001c.11210 ↗

Google Scholar ↗

[30] S. Tuncer, E. Laurier, B. Brown, C. Licoppe
Notes on the practices and appearances of e-scooter users in public space
J. Transp. Geogr., 85 (2020) (2020), Article 102702, 10.1016/j.jtrangeo.2020.102702 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[31] F.W. Siebert, M. Hoffknecht, F. Englert, T. Edwards, S.A. Useche, M. Rötting
Safety related behaviors and law adherence of shared e-scooter riders in Germany
H. Krömker (Ed.), HCI in Mobility, Transport, and Automotive Systems. HCII 2021, Lecture Notes in Computer Science, Springer, Cham (2021), p. 12791, 10.1007/978-3-030-78358-7_31 ↗
Google Scholar ↗

[32] O. James, J. Swiderski, J. Hicks, D. Teoman, R. Buehler
Pedestrians and E-scooters: an initial look at E-scooter parking and perceptions by riders and non-riders
Sustainability, 11 (20) (2019), p. 5591, 10.3390/su11205591 ↗
View in Scopus ↗ Google Scholar ↗

[33] R. Buehler, J. Pucher
COVID-19 impacts on cycling, 2019–2020
Transport Rev., 41 (4) (2021), pp. 393-400
CrossRef ↗ View in Scopus ↗ Google Scholar ↗

[34] H. ibson
Contested Boundaries: E-Scooter Riders' and Pedestrians' Experience of Sharing Space
University of Otago, Christchurch (2020)
https://ourarchive.otago.ac.nz/bitstream/handle/10523/10616/GibsonHebe2020MPH.pdf?sequence=1&isAllowed=y ↗
Google Scholar ↗

[35] M. Che, K.M. Lum, Y.D. Wong
Users' attitudes on electric scooter riding speed on shared footpath: a virtual reality study
Int. J. Sustain. Transp., 15 (2) (2020), pp. 152-161, 10.1080/15568318.2020.1718252 ↗
View in Scopus ↗ Google Scholar ↗

[36] R. Risser, M. Šucha
Psychological Perspectives on Walking: Interventions for Achieving Change
Routledge (2020)
Google Scholar ↗

[37] S.A. Useche, A. Gonzalez-Marin, M. Faus, F. Alonso
Environmentally friendly, but behaviorally complex? *A systematic review of e-scooter riders' psychosocial risk features*
PLoS One, 17 (5) (2022), Article e0268960
CrossRef ↗ View in Scopus ↗ Google Scholar ↗

[38] H. Abdi, L.J. Williams
Tukey's Honestly Significant Difference (HSD) Test
N.J. Salkind (Ed.), Encyclopedia of Research Design, Sage (2010), pp. 1565-1570, 10.4135/9781412961288 ↗
Google Scholar ↗

[39] National Academies of Sciences, Engineering, and Medicine
E-Scooter Safety: Issues and Solutions
http://nap.nationalacademies.org/26756 ↗ (2022)
Google Scholar ↗

[40] R.A. Feldman
Power distribution, integration, and conformity in small groups
Am. J. Sociol., 79 (3) (1973), pp. 639-664
Google Scholar ↗

[41] M. Peräaho, E. Keskinen, M. Hatakka
Driver competence in a hierarchical perspective; implications for driver education
Report to Swedish Road Administration (2003), pp. 1-52
http://media.freeola.com/other/23050/howtoteachthegde-matrix_1.pdf ↗
Google Scholar ↗

Cited by (1)

E-Scooters: Still the New Kid on the Transport Block. Assessing E-Scooter Legislation Knowledge and Illegal Riding Behaviour
2023, SSRN