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Unsafety on two wheels, or social prejudice? Proxying behavioral reports on bicycle and e-scooter riding safety – A mixed-methods study

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ABSTRACT

The use of non-motorized transportation and micro-mobility is increasing in many cities. Bicycle riding and e-scooter use are now more common and affordable than ever. However, users of these devices face certain key issues. These include their own risky behaviors as well as involvement in conflicts with other road users. Self-report data may not adequately capture these behaviors and interactions. Despite this, more objective data (i.e., how third parties perceive these users' road behaviors) is scarce. Aims: This study aimed to understand whether e-scooter riders have comparable or different riding behaviors than cyclists. This was investigated using a mixed-method study. Methods: This paper is divided into two sub-studies. In Study 1, 950 Spanish non-cyclists and non-e-scooter riders (mean age 31.98 ± 13.27 years; 55.3% female) provided external ratings (proxies) regarding the perceived behaviors of bicycle and e-scooter riders. In Study 2, collective Rapid Assessment Processes (RAPs; n = 23) were used to develop qualitative configurations of some of the key risky behaviors highlighted in Study 1. Results: There were significant differences in the perceived errors and violations rated by proxies for both types of riders (with e-scooter riders perceived as having higher rates of risky behaviors). However, there were also structural differences in the effects of external raters' risk perceptions, traffic rule knowledge, and traffic incidents with two-wheeled riders on how they rated the behaviors. Conclusion: The results of both studies suggest that external raters' perceptions provide further understanding of the causes, dynamics, and conflicts related to road behaviors performed by certain groups of road users. This is particularly apparent when there is no clear legislation and information on safe riding in urban areas. In this sense, improving infrastructure could promote safer interactions. Finally, road safety education could focus on promoting safer practices and interactions in order to improve how others perceive riders' behavior.

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1. Introduction

Bicycles and personal mobility devices (PMDs – especially electronic scooters or e-scooters) are among the most frequently chosen means of transport in European cities, particularly for daily commuting (Anke, Francke, Schaefer, & Petzoldt, 2021; Glenn et al., 2020; Goh, Leong, Cheng, & Teo, 2019; Liew, Wee, & Pek, 2020; Pérez-Carbonell, Gene-Morales, Bueno-Gimeno, & Gené-Sampedro, 2020; Sikka, Vila, Stratton, Ghassemi, & Pourmand, 2019). This is partly due to the infrastructural transformations over the last decades and social distancing recommendations for urban trips (Harrington & Hadjiconstantinou, 2022; Li, Zhao, Haitao, Mansourian, & Axhausen, 2021).

Bicycles and e-scooters are also a cheap, eco-friendly, and easy-to-use alternative to motorized vehicles (Harrington & Hadjiconstantinou, 2022; James, Swiderski, Hicks, Teoman, & Buehler, 2019; Sikka et al., 2019; Useche, Gene-Morales, Siebert, Alonso, & Montoro, 2021; Zagorskas & Burinskienė, 2019). However, riders of bicycles and PMDs are some of the least protected road users (Beck et al., 2016; Kim, Kim, Ulfarsson, & Porrello, 2007; Nisson, Ley, & Chu, 2020).

Road crashes involving e-scooters, bicycles, and other road users (i.e., pedestrians, motorized vehicles) are important public health issues (Goh et al., 2019; Liew et al., 2020; Mitchell, Tsao, Randell, Marks, & Mackay, 2019; Nisson et al., 2020; Robartes & Chen, 2017; Sikka et al., 2019; Störmann et al., 2020; Trivedi et al., 2019; Useche, Esteban, Alonso, & Montoro, 2021; Vanparijs, Panis, Meeusen, & de Geus, 2015; Zagorskas & Burinskienė, 2019). For example, 30.6% of all e-scooter crashes in Singapore occurring between 2015 and 2016 involved another road user (Liew et al., 2020).

Therefore, analyzing the on-road relationships between cyclists, e-scooter riders, and other road users, and understanding why they might be problematic, is necessary to improve road safety. One way to achieve this is to gain insight into behavior of these road users, and how this behavior relates to crash involvement.

1.1. Behavioral questionnaires: Only meant for self-reports?

Traditionally, risky road user behaviors are assessed through behavioral questionnaires (BQs). This paradigm is useful to understand risky (violations and errors) and positive behaviors of different types of road users and their underlying motivations (Hezaveh, Zavareh, Cherry, & Nordfjærn, 2018; Granié, Pannetier, & Guého, 2013; Reason, Manstead, Stradling, Baxter, & Campbell, 1990; Useche, Montoro, Tomas, & Cendales, 2018, 2020). However, the behavioral questionnaire paradigm relies on individual road users self-reporting their own behaviors, which may not be accurate reflection of the actual frequency or intensity.

In addition to self-reported behaviors, recent research has shown that the use of external raters (although in a relatively preliminary state of the art in traffic psychology) might add useful information to understand road behaviors and their related dynamics (Alvarez-Nebreda et al., 2019; Useche et al., 2021; Useche, Philippot, Ampe, Llamazares, & de Geus, 2021). External raters are valuable for gaining knowledge regarding road user interactions through proxied reports of road user behavior (see Chaurand & Delhomme, 2013; Snow, Cook, Lin, Morgan, & Magaziner, 2005 for additional discussion regarding "proxies"). However, the term "proxy" technically refers to someone who speaks for a patient who cannot (Snow et al., 2005). Therefore, rather than use "proxy", the term "external raters" is used in this paper.

External-rater reports can be regarded as less prone to (although not exempt from) several common biases associated with self-reports (Ruiz-Hernandez, Pina, Puente-López, Luna-Maldonado, & Llor-Esteban, 2020; Classen et al., 2010). For instance, non-cyclist road users were recently surveyed to rate cyclists' behavior using the **E**xternal rater **C**ycling **B**ehavior **Q**uestionnaire (ECBQ; Useche et al., 2021). The differences encountered between the cyclists' external-rated behavior and their self-reported behavior were significant (Useche et al., 2021). Also, data on cyclists (Useche et al., 2021) suggest that externally rated reports are effective to understand factors that may contribute to crash involvement. In this regard, psychosocial factors seem to influence both road user behaviors and their perceptions (Useche, Hezaveh, Llamazares, & Cherry, 2021; Hezaveh & Cherry, 2018; Useche et al., 2021). As far the authors are aware, no previous research has analyzed e-scooter riders' behavior under the behavioral questionnaire paradigm nor compared the externally rated behavior of cyclists with that of e-scooter riders. However, understanding these differences provides an important foundation for future studies to address whether there is a "social prejudice" against these road user groups.

1.2. Objectives and hypotheses

The aim of this research was to compare the external-rated behavior of cyclists and e-scooter riders employing the **E**xternal rater **C**ycling **B**ehavior **Q**uestionnaire (ECBQ) and **E**xternal rater **S**cooter riding **B**ehavior **Q**uestionnaire (ESBQ), respectively. In summary, we were interested in understanding whether road users (non-cyclists and non-e-scooter riders) perceive differences between the behavior of e-scooter riders and cyclists, and if so, in what direction. For this purpose, a mixed-method design was conducted and is reported as Study 1 and Study 2.

In Study 1, the results of the ECBQ and ESBQ were quantitatively compared. We evaluated whether sociodemographic factors, road safety-related skills and experiences of the external raters could influence how they perceived the behavior of others. In Study 2, a qualitative exploration was conducted. This was done to gain insights on the specific causes and dynamics of four risky behaviors identified in Study 1 as most frequently perceived by external raters in both bicycle and e-scooter riders.

As e-scooter riders are thought to have less experience on the road, it was hypothesized that e-scooter riders would be perceived by the external raters as having higher rates of risky behaviors compared to cyclists, in both Study 1 (quantitative) and Study 2 (qualitative). Moreover, we expected to find that certain external raters' sociodemographic factors, road safety-related skills and experiences would influence their perception of riders' risky behaviors.

2. Methods

2.1. Research protocol

This study followed a cross-sectional external-rated design. Initially, the aim was to obtain data on how non-riders (road users who rarely or never use bicycles or e-scooters) perceived the behavior of bicycle and e-scooter riders. However, to gain a more comprehensive answer to this question, a mixed quantitative (Study 1) and qualitative (Study 2) approach was employed.

The study was conducted using a Spanish sample. As is happening throughout much of the European Union, the presence of bicycles and e-scooters on urban roads is increasing in Spain. In Spain, e-scooters and bicycles share similar traffic regulations. These regulations coincide in the use of mobile devices, riding under the influence of alcohol and/or drugs, and prohibition of circulating on the sidewalk (DGT, 2019). On the other hand, while bicycles are considered urban vehicles and can circulate up to the speed limit of the streets, e-scooters must operate a maximum speed of 25 km/h.

The design and the protocol of the research were authorized by the Ethics Committee of Research at the Research Institute on Traffic and Road Safety at the University of Valencia (IRB approval number HE0002171219). All participants signed an electronic informed consent form, informing them on the purpose of the study and the anonymization of their personal data and provided information, that would be solely used for research purposes.

3. Study 1: External-rated questionnaires

3.1. Sample

Potential participants (non-cyclists and non-e-scooter riders) were randomly selected from an interinstitutional mailing list shared by different universities and research groups from various Spanish regions. Questionnaires (e-forms) about the perception of the road behavior of cyclists and e-scooter riders (see Section 2.3) were emailed to the participants. Participants were also encouraged to inform others about the survey. Anyone who heard about the survey from a participant who had been emailed, emailed the researchers and were subsequently sent a copy of the questionnaire. A total of 1,610 questionnaires were emailed to potential participants, and 950 questionnaires were completed. This is a response rate of 59% and provided a sufficient power to detect an effect. This was based on an a priori power analysis (G*Power) showing that a minimum of 905 responses were needed to obtain an effect size (d) of 0.12, a power (1-ß) of 0.95, and a maximum margin of error/confidence of 5%.

The sample (55.3% female and 44.7% male) were all non-riders (bicycle and e-scooter) from all of the 17 Spanish regions. The mean age of the sample was 31.98 ± 13.27 years, with a 95% Confidence Interval (CI) = [31.14–32.83]. Descriptive sociodemographic features of the sample and summary statistics for the Risk Perception and Regulation Scale (RPRS; described in detail in Section 2.3) are displayed in Table 1.

Table 1
Sociodemographic features and Risk Perception and Regulation Scale (RPRS) descriptive values of Study 1 sample (external raters).

Variable		Frequency	Percent
Age groups	Young adults (≤25 years)	468	49.3%
	Adults (26–50 years)	358	37.7%
	Aging adults (>50 years)	124	13.1%
Gender	Female	525	55.3%
	Male	425	44.7%
Occupation	Unemployed	50	5.3%
	Employee	340	35.8%
	Self-employed	69	7.3%
	Student	422	44.4%
	Retired	25	2.6%
	Householding	25	2.6%
	Other	19	2.0%
Education	Primary school	71	7.5%
	High school	223	23.5%
	Technical studies	188	19.8%
	University degree	364	38.3%
	University post-graduate degree	104	10.9%
Factor		**Mean**	**SD**
RPRS [a]	Knowledge of traffic regulations	2.83	0.85
(Self-report)	Risk perception	2.87	0.80
Incidents	Traffic incidents with 2-wheeled users (2 years)	0.18	0.67

Notes for the table: [a] Mean value of knowledge of traffic regulations and risk perception are presented on a scale between 0 and 4. SD: standard deviation; RPRS: Risk Perception and Regulation Scale.

3.2. Instruments

ECBQ and ESBQ: Based on its validated version, the Cycling Behavior Questionnaire (CBQ; Useche et al., 2018) was adapted into an external-rater approach. The resulting "External rater Cycling Behavior Questionnaire" (ECBQ; Useche et al., 2021) consists of a 29-item scale. It follows the structure developed by Reason et al. (1990) and updated by Özkan and Lajunen (2005) with the Driving Behavior Questionnaire. The three-factor behavioral questionnaires measure the frequency in which a road user performs certain traffic violations, errors, and positive or protective road behaviors. Both questionnaires (CBQ and ECBQ) have Cronbach's alphas ranging between α = [0.70–0.85] (O'Hern, Estgfaeller, Stephens, & Useche, 2021; Useche et al., 2021; Useche et al., 2021).

All 29 statements in the CBQ described behaviors that apply to both bicycle and e-scooter riders. Therefore, the validated CBQ was also adapted to obtain external-rated information on e-scooter riders. This new test was named the "External rater e-Scooter riding Behavioral Questionnaire" (ESBQ). Both questionnaires were applied to a Spanish-speaking sample using an external rater methodology. A 5-level, frequency-based Likert scale as per the original version of the CBQ (0 = never; 1 = hardly ever; 2 = sometimes; 3 = frequently; 4 = almost always) was followed.

The Risk Perception and Regulation Scale (RPRS): Self-reported risk perception and knowledge of traffic regulations were measured using the RPRS (Useche et al., 2018). This is a 12-item scale that measures risk perception (7 items) and knowledge of traffic rules for road users (5 items). Both factors are considered as two core 'road safety skills' in previous literature (Useche, Alonso, Montoro, & Garrigós, 2019; Khan et al., 2015). Responses were given on a five-point Likert scale (0 = strongly disagree, to 4 = strongly agree). The Risk Perception and Regulation Scale demonstrated an acceptable internal consistency with Cronbach's alphas ranging between α = [0.66 to 0.72] (O'Hern et al., 2021; Useche et al., 2018). The summary statistics for the Risk Perception and Regulation Scale (RPRS) are displayed in Table 1.

Other data: Information on the main demographic factors of the external raters (i.e., age, gender, education, occupation, the preferred mode for commuting, and their commuting length) was collected. Also, external raters were asked about the number of road incidents (significant discussions/fights, near-misses, or crashes) they remembered having with riders of bicycles and e-scooters in the previous 2 years.

3.3. Data processing (analysis strategy)

Descriptive analyses were performed with IBM© SPSS (Statistical Package for Social Sciences) – version 26.0. Differences between test items and dimensions were assessed through paired *t*-tests. The effect size was calculated with Cohen's d, with $d < 0.50$ constituting a small effect, $0.50 \leq d \leq 0.79$ a moderate effect, and $d \geq 0.80$ a large effect. Preliminary exploratory analyses (correlations and between-group comparisons) were also conducted.

Multi-group structural equation modeling (MGSEM) was used to assess the multivariate relationships among demographic factors (age and education), road safety skills (risk perception and traffic rule knowledge), and the number of traffic incidents involving bicycles or e-scooters (in the last 2 years). Given the available theoretical and empirical background on the topic of risky road user behaviors, MGSEM was selected. It follows a confirmatory nature and is similar to multiple regression analysis (Chen & Donmez, 2016). For this study, only risky behaviors (violations and errors) were considered dependent variables. This was due to the lack of empirical support necessary to perform such confirmatory analyses in the case of positive behaviors. This is due to the fact that they are currently *emergent* in applied research on traffic safety.

The goodness-of-fit of both factors (i.e., Violations and Errors) was assessed through multiple indicators (Kline, 2011). These included the minimum discrepancy ratio (CMIN/df, that is the ratio between the x^2 test and the degrees of freedom given to the model); Confirmatory Fit Index (CFI), Normed Fit Index (NFI), Tucker-Lewis Index (TLI), Incremental Fit Index (IFI) and Root Mean Square Error of Approximation (RMSEA) with 90% Confidence Intervals. Goodness-of-fit was decided based on cut-off criteria identified in the literature: RMSEA < 0.08; incremental indices (CFI/NFI/TLI/IFI) > 0.9, and a CMIN/df ratio over 5 (Miles & Shevlin, 2007; Marsh, Hau, & Wen, 2004). IBM SPSS AMOS (version 26.0) was used for the structural equation modeling.

4. Study 2: Rapid assessment procedure interviews

4.1. Sample

For the second study, 23 individuals (12 males and 11 females) aged between 20 and 49 (M = 31.5) years were randomly selected from the participants of Study 1. They completed semi-structured interviews with questions applied through group interviews. These participants presented a mean score of 2.98 ± 1.24 for traffic norm knowledge and 3.10 ± 1.16 for risk perception (see "Instruments—The Risk Perception and Regulation Scale (RPRS)" section). Additionally, they had been involved in a mean of 0.17 ± 0.65 traffic incidents with two-wheeled users in the last two years.

4.2. Rapid assessment procedures (RAPs)

Rapid assessment procedures are a rapid and efficient qualitative assessment tool. They are focused on performing brief assessments about significant topics or issues pre-selected by researchers. RAPs consider factors such as knowledge, attitudes, local conditions, needs, and practices (Holdsworth et al., 2020). It helps gather qualitative data on local conditions and needs, knowledge, attitudes, and practices, on short timelines (Holdsworth et al., 2020). RAP is useful for studying naturalistic settings and their processes, organizational practices, and implementation, and uncovering "how" and "why" things work (Holdsworth et al., 2020). One key advantage of RAPs is the potential to identify single or multiple qualitative configurations explaining an outcome (Palinkas, Mendon, & Hamilton, 2019; Holdsworth et al., 2020). This includes perceived and/or observed behaviors performed by an individual or a group (Palinkas et al., 2019; Holdsworth et al., 2020). Such is the case of this study. In this sense, a "qualitative configuration" can be understood as a particular arrangement of sentence meaning, material, and competence (Ihlström, Henriksson, & Kircher, 2021).

Rapid assessment procedures were conducted following previous research (Holdsworth et al., 2020). First, we analyzed the results of the ECBQ and ESBQ to identify the main topics or spheres regarding the behavior of cyclists and e-scooter riders to be included in the interview. The four topics or spheres of the riders' road behavior addressed in the qualitative study were: red-light running (Topic 1), speeding (Topic 2), wrong way and sidewalk riding (Topic 3), and distracted riding (Topic 4). Afterward, an interview guide was

Table 2
Item content, the factor the item belongs to, mean (M), standard deviation (SD), and reliability of the ECBQ and ESBQ.

Factor	#	Item (behavior)	ECBQ (Bicycle)		ESBQ (E-Scooter)		Mean differences (paired t-tests)		
			M	SD	M	SD	t	Sig.	d
Factor 1: Traffic violations	1	Riding under the influence of alcohol and/or other drugs or hallucinogens.	1.33	0.91	1.36	0.92	0.935	0.350	0.03
	2	Going in the opposite direction of traffic (wrong way).	1.98	0.99	2.16	1.08	4.791	**<0.001**	0.17
	3	Zigzagging between vehicles when using a mixed lane.	1.91	1.13	2.00	1.16	2.259	**0.024**	0.08
	4	Handling potentially obstructive objects while riding (food, packs, cigarettes…).	1.53	1.09	1.64	1.09	2.951	**0.003**	0.10
	5	Going at a higher speed than they should.	1.98	1.12	2.50	1.14	12.679	**<0.001**	0.46
	6	Crossing what appears to be a clear crossing, even when there is a red traffic light.	2.20	1.12	2.12	1.10	2.360	**0.018**	0.08
	7	Carrying a passenger on the bicycle/scooter without it being adapted for it.	1.54	1.05	1.61	1.19	1.442	0.150	0.05
	8	Having a disputing because of speed or "race" with another rider or driver.	1.18	1.07	1.42	1.11	6.635	**<0.001**	0.22
Factor 2: Errors	9	Crossing the street without looking properly, forcing another vehicle to brake to avoid a crash.	1.68	1.08	1.88	1.10	5.436	**<0.001**	0.18
	10	Colliding (or being close to it) with a pedestrian or another user while riding distractedly.	1.25	1.03	1.50	1.09	7.230	**<0.001**	0.24
	11	Braking suddenly and being close to causing an accident.	1.51	1.04	1.73	1.07	6.061	**<0.001**	0.21
	12	Failing to notice the presence of pedestrians crossing when making a turn.	1.83	1.09	1.99	1.09	4.285	**<0.001**	0.14
	13	Not braking on a "Stop" or "Yield" sign and being close to colliding with another vehicle or pedestrian.	2.07	1.14	2.08	1.15	0.083	0.934	0.003
	14	Braking abruptly on a slippery surface.	1.54	1.02	1.70	1.05	4.650	**<0.001**	0.16
	15	Not realizing that a pedestrian intended to cross a crosswalk and not stopping to let him or her do so because of being distracted.	1.68	1.05	1.78	1.04	2.877	**0.004**	0.10
	16	Not realizing that a parked vehicle intends to leave and having to brake abruptly to avoid colliding with it.	1.67	1.08	1.75	1.06	2.391	**0.017**	0.08
	17	Not realizing that a passenger is getting out of a vehicle or bus, thus being close to hitting him or her when driving on the right side.	1.69	1.03	1.81	1.04	3.195	**0.001**	0.11
	18	Trying to overtake a vehicle that had previously signaled with its indicators that it was going to make a turn and therefore having to brake.	1.59	1.10	1.68	1.10	2.332	**0.020**	0.08
	19	Misjudging a turn and hitting something on the road or being close to losing balance (or falling).	1.20	1.01	1.55	1.05	9.840	**<0.001**	0.33
	20	Hitting a parked vehicle unintentionally.	1.19	1.02	1.40	1.05	6.657	**<0.001**	0.21
	21	Not being aware of the road conditions and therefore falling over a bump or hole.	1.31	1.02	1.60	1.05	8.278	**<0.001**	0.28
	22	Mistaking one traffic signal for another and maneuvering according to the latter.	1.23	1.03	1.52	1.08	8.080	**<0.001**	0.27
	23	Trying to brake but not being able to use the brakes properly due to poor hand positioning.	1.41	1.06	1.55	1.08	3.717	**<0.001**	0.13
Factor 3: Positive behaviors	24	Stopping and looking at both sides before crossing a corner or intersection.	1.74	1.05	1.62	1.00	3.212	**0.001**	0.12
	25	Trying to move at a prudent speed to avoid sudden mishaps or braking.	1.78	0.99	1.48	1.02	7.914	**<0.001**	0.30
	26	Keeping a safe distance from other riders or vehicles.	1.73	1.03	1.54	1.01	5.120	**<0.001**	0.18
	27	Always use the indicated lane when using the bike path (or bike lane).	2.07	1.05	1.86	1.05	5.734	**<0.001**	0.21
	28	Avoid riding under adverse weather conditions.	2.01	1.02	2.01	1.07	0.179	0.858	0.006
	29	Avoid riding if feeling very tired or sick.	1.94	1.00	1.80	1.02	3.980	**<0.001**	0.13

Notes for the table: Mean values are expressed on a scale between 0 and 4. M: mean; SD: standard deviation; t: statistic value of the paired *t*-test; Sig.: significance; d: Cohen's d as a measure of the effect size (small effect: $d < 0.50$; medium effect: $0.50 \leq d \leq 0.79$; large effect: $d > 0.80$). ECBQ: External rater of Cycling Behavior Questionnaire; ESBQ: External rater Scooter riding Behavior Questionnaire; Shaded cells highlight the 3 most frequently external-rated road behaviors for each transport mode in the three factors of the questionnaire.

prepared. This guide contained a list of questions outlining the areas to be covered during the formal semi-structured interviews. The main configurations for perceived risky riding behaviors were addressed in two ways. One of them was (*i*) jointly – through the general perceptions of two-wheeled users' risky behaviors. The other one was (*ii*) differentially – following a parallel category-based discourse pooling approach.

In total, four collective Rapid Assessment Processes (RAPs) involving between five and six participants and with a duration of 25 min, were performed. The core aim of the interviews was to gather rich contextualized data. This data involved their road interactions with bicycle and e-scooter riders, and their surrounding perceptions, concepts, attributions, and practices. Participants were free to withdraw from interviews at any time, although there were no such cases. All interviews were performed by the research team leader. Moreover, they were recorded, with written consent provided by all participants.

4.3. Data processing (analysis strategy)

Qualitative analyses were predominantly inductive. The information obtained from the interview was analyzed with the aim of providing deeper insight into the four categories addressed. This process can be summarized in three main (and successive) steps:

Firstly, all qualitative data were read in detail several times to become familiar with the content and to identify underlying themes. Secondly, the data were coded and sectioned, depending on whether they referred to general riding behaviors, bicycle riders' or e-scooter riders' behaviors. A content analysis method was followed aiming at depicting risky behaviors approached as social practices (Renz, Carrington, & Badger, 2018). Thirdly, categories were created following the "content code" approach. This approach is commonly used in thematic analysis (see Guest, MacQueen, & Namey, 2012). Code labels were assigned, and key speech sections were highlighted. This was carried out to confirm the resulting configurations and their supporting qualitative analysis insights.

Qualitative analysis (coding and interpretation) was performed by two experienced qualitative researchers. Analyses showed a high degree of agreement. A *kappa* (inter-reliability) coefficient between $\kappa = [0.80–0.90]$ (qualitatively considerable to be strong) was identified for all the four issues studied. MAXQDA Analytics Pro (version 20.2.1) was used for speech coding and the categorization tasks.

5. Results

5.1. Descriptive results

Table 2 shows the descriptive outputs of Study 1 and the values for each item and comparisons between scales. Statistically significant differences, albeit with small effect sizes (Cohen's *d*), were found between almost all components of both questionnaires.

The participants of Study 1 gave a mean score of 1.71 ± 0.78 for the violations of cyclists and 1.85 ± 0.82 for e-scooter riders (*Mean Difference* [M_{Diff}] = 0.14, 95% CI [0.10 - 0.19], p <.001, $d = 0.18$); 1.52 ± 0.82 for the errors of cyclists and 1.70 ± 0.87 for e-scooter riders ($M_{Diff} = 0.18$, 95% CI [0.13 - 0.22], p <.001, $d = 0.21$); and 1.88 ± 0.77 for the positive behaviors of cyclists and 1.72 ± 0.79 for e-scooter riders ($M_{Diff} = 0.16$, 95% CI [0.11 - 0.21], p <.001, $d = 0.21$).

The external raters perceived significantly more positive behaviors than errors ($M_{Diff} = 0.36$, 95% CI [0.28-0.43], p <.001, $d = 0.38$) and violations ($M_{Diff} = 0.17$, 95% CI [0.09-0.24], p <.001, $d = 0.18$), and more violations than errors ($M_{Diff} = 0.19$, 95% CI [0.15 - 0.22], p <.001, $d = 0.23$) in cyclists.

Regarding e-scooter riders, the external raters reported significantly more violations than errors ($M_{Diff} = 0.15$, 95% CI [0.11-0.19], p <.001, $d = 0.18$) and positive behaviors ($M_{Diff} = 0.13$, 95% CI [0.06-0.21], p <.001, $d = 0.14$). Similar scores (non-significant differences) were obtained for positive behaviors and errors ($M_{Diff} = 0.02$, 95% CI [−0.10 - 0.06], p =.635, $d = 0.02$) of these users.

5.2. The structural model

Our structural assumptions were based on the exploratory analyses conducted and the study hypotheses (i.e., that external raters' demographic factors and road safety-related skills and experiences would influence the external raters' perception of riders' risky road behaviors). MGSEM analyses were used to assess the multivariate relationships between the independent variables in relation to (*i*) Traffic Violations (*Model A*), and (*ii*) Errors (*Model B*). The exogenous variables remained fixed for both models. This is statistically more accurate than testing groups in separate models or imputing dummy variables since, in addition to corresponding to confirmatory (theoretically based) models, it considers the full sample parameters and their covariances for fitting the models.

Although beta coefficients are standardized and can be regarded as if they are controlling the effects of other predictors within the

Table 3
Structural equation models' goodness-of-fit coefficients.

Model	X^2	df[1]	p	CMIN/df[2]	RMSEA[3]	90% CI for RMSEA		CFI[4]	NFI[5]	IFI[6]	TLI[7]
						Lower	Upper				
Model A	31.093	8	<0.001	3.887	0.055	0.036	0.076	0.962	0.952	0.964	0.931
Model B								0.963	0.951	0.963	0.930

Notes: [1]df = Degrees of freedom; [2]CMIN/df = Minimum discrepancy between X^2 and df; [3]RMSEA = Root Mean Square Error of Approximation; [4]CFI = Confirmatory Fit Index; [5]NFI = Normed Fit Index; [6]Incremental Fit Index; [7]Tucker-Lewis Index.

model. The errors of highly correlated independent (exogenous) variables were covaried, namely: age ↔ education (demographics), and risk perception ↔ traffic rule knowledge (road safety skills). The goodness-of-fit coefficients of the structural equation models are presented in Table 3.

Slight differences in terms of the incremental indexes were retained (CFI, NFI, IFI, and TLI). The same confirmatory theoretically based structure was retained to explain external raters' perceptions of traffic violations and of errors performed by riders. Therefore, the basic features of the model (e.g., χ^2 test, degrees of freedom, disparity ratio, and Root Mean Square Error of Approximation) remained stable between them. All coefficients were good-to-optimal in the light of the cut-off criteria described in the data processing section (Section 2.4). The standardized path coefficients (presented in the form of solid lines in Fig. 1 when significant, and in Table 4 with model coefficients) suggest that:

5.2.1. Model A – Traffic violations:

External raters' demographic variables (age and educational level) had no direct effects on the endogenous variable of the model. This was a commonality found when explaining external-rated traffic violations from both bicycle and e-scooter riders.

Meanwhile, the variables significantly explaining bicycle riders' (Group 1) perceived traffic violations were: the external raters' risk perception ($\beta = 0.193$; $p < .001$) and traffic rule knowledge ($\beta = 0.143$; $p < .010$), although not with previous traffic incidents involving two-wheeled riders. As for perceptions of traffic violations of e-scooter riders (Group 2), it was found that the external raters' risk perception ($\beta = 0.194$; $p < .001$) and traffic incidents ($\beta = 0.094$; $p < .01$) were significant predictors. Meanwhile, the external raters' rule knowledge had no significant effects on the exogenous variable.

5.2.2. Model B – Errors:

Unlike the case of traffic violations, no structural differences were found between the two reference groups. The significant predictors of external-rated riding errors were the external raters' risk perception ($\beta = 0.210$; $p < .001$ for Group 1, and $\beta = 0.194$; $p < .001$ for Group 2), and the number of previous traffic incidents experienced with two-wheeled vehicles ($\beta = 0.124$; $p < .010$ for Group 1, and $\beta = 0.151$; $p < .010$ for Group 2). Neither the external raters' age, education, nor self-reported traffic rule knowledge of external raters had a significant effect on the exogenous variable.

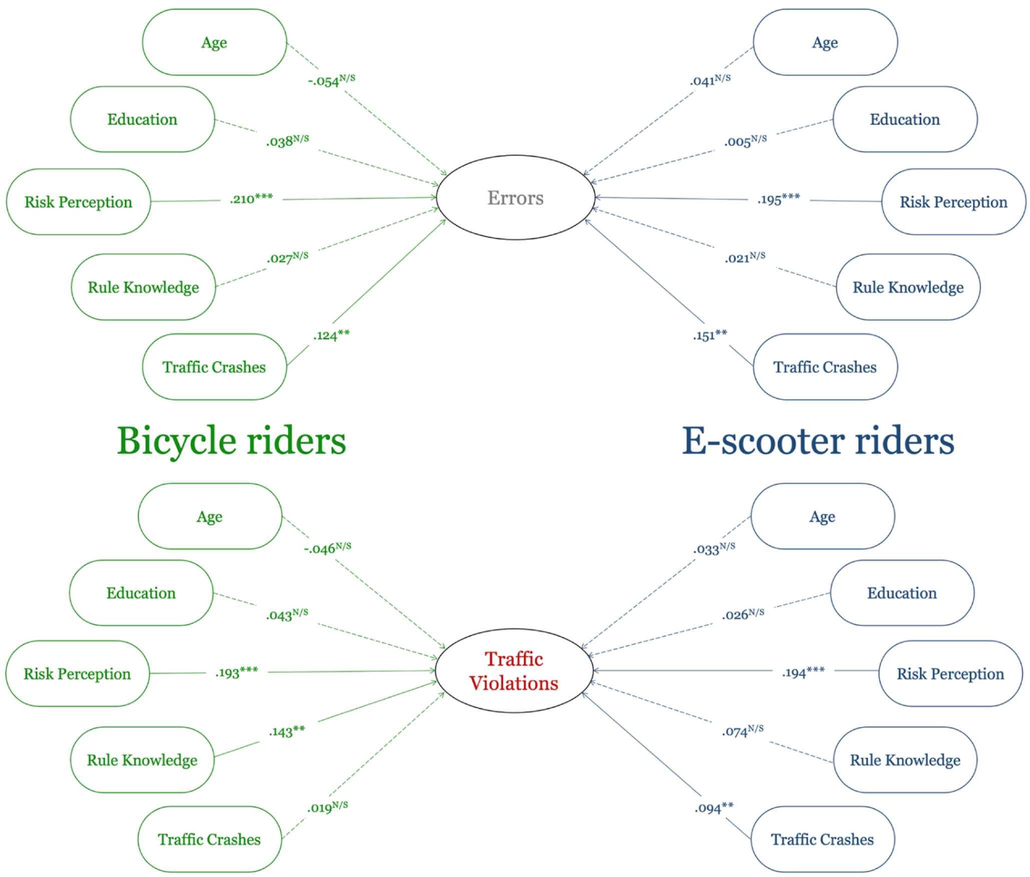

Fig. 1. Two-group MGSEM showing standardized path coefficients for external-rated riders' traffic violations (above) and errors (below): bicycle riders (left) and e-scooter riders (right). $^{N/S}$ Non-significant path (discontinuous arrows); path significant at the level **p <.010; path significant at the level ***p <.001. Additional data on the model's paths and coefficients are presented in Table 4.

Table 4
MGSEM Models to predict external raters' perceived frequency of deliberate and undeliberate risky behaviors among riders.

Path			SPC[a]	S.E.[b]	C.R.[c]	p[d]
Model A: Traffic Violations						
Group A: Bicycle riders						
Traffic Violations	⟵	Age	−0.046	0.002	−1.414	0.157
Traffic Violations	⟵	Education	0.043	0.022	1.305	0.192
Traffic Violations	⟵	Risk Perception	0.193	0.043	3.389	<0.001
Traffic Violations	⟵	Rule Knowledge	0.143	0.038	2.471	0.006
Traffic Violations	⟵	Traffic Incidents	−0.019	0.090	0.559	0.577
Group B: E-scooter riders						
Path			**SPC**	**S.E.**	**C.R.**	**p**
Traffic Violations	⟵	Age	−0.033	0.002	−1.006	0.314
Traffic Violations	⟵	Education	0.089	0.023	−0.786	0.432
Traffic Violations	⟵	Risk Perception	0.194	0.043	4.441	<0.001
Traffic Violations	⟵	Rule Knowledge	0.074	0.040	1.803	0.071
Traffic Violations	⟵	Traffic Incidents	0.094	0.088	2.378	0.008
Model B: Errors						
Group A: Bicycle riders						
Path			**SPC**	**S.E.**	**C.R.**	**p**
Errors	⟵	Age	−0.054	0.002	−1.648	0.099
Errors	⟵	Education	0.038	0.023	1.161	0.245
Errors	⟵	Risk Perception	0.210	0.041	4.141	<0.001
Errors	⟵	Rule Knowledge	0.027	0.040	0.654	0.513
Errors	⟵	Traffic Incidents	0.124	0.096	2.725	0.002
Group B: E-scooter riders						
Path			**SPC**	**S.E.**	**C.R.**	**p**
Errors	⟵	Age	−0.041	0.002	−1.255	0.209
Errors	⟵	Education	−0.005	0.025	−0.153	0.879
Errors	⟵	Risk Perception	0.195	0.045	3.992	<0.001
Errors	⟵	Rule Knowledge	0.002	0.042	0.497	0.619
Errors	⟵	Traffic Incidents	0.151	0.090	3.454	0.001

Notes for the Table: [a] SPCs = Standardized Path Coefficients; [b] S.E. = Standard Error; [c] C.R. = Critical Ratio; [d] p-value; ** = path is significant at the p <.01; *** = path is significant at the p <.001.

5.3. *Qualitative analysis results: Main configurations of risky behaviors among bicycle and e-scooter riders*

The main risky behaviors identified in cyclists and e-scooter riders by the external raters were: red-light running (item 6, mean ECBQ = 2.20, mean ESBQ = 2.12), speeding (item 5, mean ECBQ = 1.98, mean ESBQ = 2.50), opposite direction (item 2, mean ECBQ = 1.98, mean ESBQ = 2.16), sidewalk/pavement riding (item 2, mean ECBQ = 1.98, mean ESBQ = 2.16), and distracted riding (items 12 and 17, mean ECBQ = 1.83 and 1.69, respectively; items 9 and 12, mean ESBQ = 1.88 and 1.99, respectively). The qualitative results and main configurations are presented according to the four categories, or "types of risky behavior" addressed.

5.3.1. *Red-light running: "Collective Daltonism" or the "Chicken-and-egg" problem?*

The highest-rated risky behavior perceived by participants in Study 1 was related to red traffic light running (see Table 2). Therefore, this was the first discussion topic with participants of Study 2. It was found that participants perceived certain differences in the factors enhancing red-light running between bicycles and e-scooters. However, certain points in common should be highlighted, for example, those related to the perception of a *generalized* practice of red-light running among two-wheeled riders. Additionally, the configuration of red-light running is markedly founded on the differentiation between four-wheeled vehicles and e-scooters and bicycles. The incurrence in red-light running of two-wheeled vehicles is defined as usual. Two of the participants in the interview made the following statements:

"Nowadays, it is rather weird to see that a car sneaks among pedestrians to cross quicker when there is a red traffic light. However, what is weirder is that it works backward in the case of two-wheeled vehicles; I feel like clapping when I see one of them (riders) patiently waiting for the traffic light to turn green behind the crosswalk".	"It seems that bicycles and e-scooters (their riders) live in a different reality, or really struggle to differentiate between green and red colors".

Two issues can be highlighted with regards to the differences attributed to the factors enhancing red light-related risky behaviors. The first is the relatively high tolerance for red-light running among bicycle riders. The second is the scarce knowledge of how traffic regulations apply to e-scooters. Additionally, there is a perception that riders will not be fined when running red lights while using two-wheeled vehicles.

"Some people believe that, given that practically all of us are familiar with bikes, they are allowed to cross anytime, even if there are pedestrians (…) Since we grew up with bikes *zigzagging* around us, there is much tolerance for their most regular dangerous behaviors (being this one the most usual), (…) Bikes are much older than regulations to avoid risky riding, or maybe nobody realized before that these norms existed".	"Everybody seems to know little about e-scooters and what exactly are the rights and duties they have (or not), this is as recent as it is dangerous and problematic. As there has been a lot of talking in the media about the fact that '*they should behave like drivers'*, one assumes the obvious: they do wrong, and they really don't mind. However, I can understand them: it is easier to cross in red when (if you are lucky) nothing will happen… I mean, it's all about not being crashed, because being fined is clearly unlikely".

Retrospectively speaking, bicycle riders' red-light running behaviors can be compared to the "Chicken-and-egg" problem. It proves difficult for participants to sequence the origin of cyclists' red-light running and the existing rules for preventing them. Moreover, the perceived lack of awareness of the importance of avoiding red-light running among two-wheeled users is important to explain this problem and its long tradition.

On the other hand, participants expressed difficulties in understanding what is, or is not, acceptable while riding an e-scooter. The idea that e-scooter riders' red-light running is undesirable is founded on a motto ("they should behave like drivers"), rather than on a proper knowledge of their rights and duties. In addition, participants highlight that both policing and enforcement are considerably poor in this regard. This might increase the likelihood of red-light running.

5.3.2. Running "La Vuelta", and the "disguised motorcycles" …on the bike lane

Apart from the already existing (and numerous) controversies on this matter, the most rated risky behavior for e-scooter riders in Study 1 was speeding. Therefore, this was the second point assessed during the qualitative phase. According to what was suggested by the outcomes of Study 1, participants expressed a generalized concern on one particular issue: the belief that making cities "bike-friendly" may also be enhance the frequency of risky riding behaviors. Overall, external raters show to believe that cities are often seen as racetracks by both cyclists and e-scooter users, who are equally permitted to ride on them.

The main configuration related to speeding was the set of infrastructural transformations. Most cities have been recently undergoing these transformations to promote the use of bicycles and e-scooters as a component of environmental sustainability policies. In brief, participants wonder whether these *riding-friendly* spaces could increase risks for other users because of the absence of speed regulations (and their enforcement).

"The authorities believe that (exaggerating a bit) the use of non-contaminating vehicles should be promoted at all costs. To do this, they have built many bike lanes in the last years in every part of the city (…). This is, however, ambivalent: on the one hand, you are reducing traffic conflicts with drivers, such as riders zigzagging among cars, and cyclists' runovers. On the other, maybe you simply redirected the problem: these lanes play the role of car-free racetracks with which pedestrians must haphazardly cross all the time, in every corner, and there's no way to control the riders' speed through, e.g., cameras or radars".

The participant cited above illustrates how non-riders perceive greater risks at crossroads shared with bikes and e-scooters than with cars. Essentially this is because of their speeding-related risky behavior and their disrespect for pedestrian crossings. In addition, the lack of effective control measures may exacerbate the issue, as was also previously pointed out in the case of red-light running. However, some conflicting opinions also emerged based on the different modes:

"Great bicycle races have taken place in Spain (referring to *La Vuelta,* the famous Spanish race), and the bike allows you to experience pleasurable sensations that are more difficult to feel when walking, or especially in a car –roads are full of cameras and radars. Riding, apart from being beneficial for your health, gives you a certain feeling of freedom, and sometimes you may forget that you are going too fast. (…) Cyclists seem to be more respectful than other types of riders, as they are used to interacting with pedestrians".	"All know that there are speed limitations for e-scooters, but the truth is that when you drive a car and are overtaken by an e-scooter (rarely by a bike) going on their lane, you can be sure that, even without having a speedometer- they rarely go $<$ 20 km per hour. At the first glance, you think it is someone riding a (disguised) motorcycle".	"When riding a bike, the body warns you when you go too fast (because you get tired), but on an e-scooter, you may get distracted when you are already going too fast.".

Independently, the cases for bicycle and e-scooter riders show different configurations, especially regarding what makes them ride faster. As for the first, participants define physical activity benefits and sensation seeking as factors potentially explaining the predisposition to speeding, even though not aiming to explicitly break the rules or harm other users. Regarding the case of e-scooter riders, two core issues emerge regarding their speeding behaviors. Firstly, there is the awareness on the problem of electric vehicles' speed that appears to make them seen as "motorcycles allowed to go on the bike lane". Secondly, the possible influence of the lack of physical efforts influencing speed control.

5.3.3. "Wrong (or simply any) way…"

Using incorrect lanes, traveling in the wrong direction, and/or on sidewalks was chosen as the third issue to discuss with participants of Study 2. In this regard, the first configuration of this practice can be structured through three core issues. First, the lack of contribution from both riders and road users to solve the issue of wrong-way travelling. Second, the fact that authorities have difficulty finding effective solutions (the two of them framed within a historical perspective). Third, the notion that the wrong-way and sidewalk travelling is strengthened by transportation dynamics (i.e., traffic areas ranging from dynamics in traffic flow, travel behavior, logistics, and transport policy, to traffic control (Lo & Sumalee, 2013). This is also related to the e-commerce and on-demand delivery-based employment platforms (pointed out within a more recent time frame). Some of the interviewed participants stated:

"Although this is not a new issue (I have been aware of it since I was a kid), it seems that authorities really struggle to solve it, and people (riders and not riders) do not help either".	"In the past, there was a lot of talking about the problem with cyclists and reckless drivers going the opposite direction, but with law enforcement and cameras only those who do not have a license plate seem to persist in it".	"The introduction of "riders" (last mile deliverers) in cities has multiplied the problem. Although wrong-way circulation used to be seen with some frequency, now you find that people working informally and under time pressure earn more money if they go faster, that is, wherever and at any cost".

Another noteworthy finding was the problematization of this type of risky behavior of two-wheeled riders over car drivers throughout time. This was the same as for the case of speeding and red-light running. For example, participants perceived that it was very unlikely they would encounter a car travelling in the opposite direction. Yet, it is assumed that small vehicles can go in any direction, given the "allowance" of urban facilities for this purpose:

"When I was a child, my mother taught me to look both sides of the street before crossing (even if it was a one-way road), because she was afraid that a car might run me over. Nowadays, I tell the same to my children, but what makes me afraid are small vehicles; those going through anywhere, in any direction".	"While you cannot interchangeably go on the pavement and the mixed way in a car, there are very few things you cannot do on two wheels".

The most marked reference in the configuration of wrong-way and sidewalk riding of cyclists and e-scooter riders was related to road users' flows. However, efficiency was the predominant factor to explain the matter. Below, some participants of both reference groups elaborate on the possible causes of this issue, separately.

"Probably, cyclists' disrespect towards flow directions is an issue that society has implicitly harmonized, as they do it rather carefully when there are not many people".	"European cities are characterized by having a lot of narrower (one way) roads dating from various centuries ago, also limiting the speed on these lanes, making sometimes it barely legal, although not necessarily safe".	"Although I do not ride a bike, I can understand that it takes more time to go around the whole block, instead of cutting the road and going in the opposite direction if no one is coming".

"While bicycles can be observed on the sidewalk during nighttime, or whenever there are not many pedestrians around, it seems that e-scooter riders have not realized yet they are not walking, and they pass between pedestrians and run over them if necessary (hyperbole)".	"I think that one of the big problems with e-scooters riding on the sidewalk, or the other way around, is that they have a very small (still heavy, though) vehicle – plus the fact that being able to carry their devices makes them feel like pedestrians".

These responses allow us to build up a particular configuration attaining the balance between risk and regulation: in many cases, bicycle riders can perform potentially risky (although not illegal) behaviors under relative law-abiding social acceptance. For instance, going against the traffic flow in many European cities with certain infrastructures (e.g., pseudo-pedestrianized and narrow urban streets).

Restrictions on e-scooters seem to be perceived, to a certain extent, as more rigorous, and their riders as more reckless when committing this type of risky behavior. Precisely, and regarding sidewalk riding (usually forbidden in both cases), this risky behavior is usually attributed to the small size and handleability of e-scooters. These characteristics could reduce riders' risk perception when riding on the sidewalk.

5.3.4. *"In their thoughts": Peoples' views on distracted riding*

Although not directly addressed by behavioral questionnaires, "Riding while distracted" was selected. This can be understood as a predisposition to commit riding errors. Distracted riding was addressed as the fourth point of the interview, given the proven relevance of distracting sources in transportation safety in urban areas.

A general configuration of two-wheeled distracted riding could be arranged based on current urban transport issues. In other words, participants assume that using bicycles and/or e-scooters in everyday life (e.g., going to work, studying) may negatively affect riding performance.

"Cities were not bike-friendly before, so you usually rode outside the city, disconnecting, family-enjoying, and having a pleasant time in nature while exercising. For a few years now, bike lanes have been emerging, and bikes came to be (same as e-scooters) mostly used for daily commuting, and it seems that this results in people traveling stressed, more in a hurry, easily distractable dodging obstacles or dealing with the misbehaviors of other people on the road, and practically not realizing what is happening around them".

The quote appended above illustrates a feeling of concern about the interference of daily commuting stress factors on riding safety.

This could interfere with attention, perception, and overall riding performance and safety. In other statements, it is highlighted that road conflicts and unsafe behaviors of other users seem to act as riding distractions. External raters consider that road conflicts make it difficult to keep attention on the riding task. Particularly speaking about cyclists vs. e-scooter riders, it was found that:

"The blame for the distractions of cyclists is not so much on them as on the laxity from authorities: companies are allowed to advertise products (literally) next to bike lanes. This produces a sensory over-stimulation: lights, noises, and colors".	"The unfavorable environment added to the strain of riding with masks, predisposes them to make mistakes, in addition to the fact that many of them are frequently 'in their own thoughts' while crossing intersections, or talking on the phone with headphones".	"It's not rare that you go to a mall and are offered to buy an e-scooter at 0% bank interest. They also offer a mobile app to you as a gift, or an actual holder to put (and use) the phone while you are riding. They help you stay distracted. (…) Also, those wireless headphones don't help. They can be hidden inside the helmet."	"Cities are full of billboards, new traffic signs that they hardly know (there are no e-scooter riding schools nor licenses, and as it came by just 3–4 years ago, most of the drivers are inexperienced), and reckless users doing unexpected things. I wonder how they don't crash more often".

The main configuration to external raters' perception of distracted cycling refers to the lack of competence of bicycle riders when dealing with all the environmental demands imposed by the urban context. Also, the use of mobile devices or derivates (e.g., hand-free devices, headphones) is highlighted. Similarly, the case of e-scooter riders' distracted riding configuration is presented with two differential issues. The first is the "smartness" of increasing affordability of e-scooters (including app- and Bluetooth-based features). The second is the existence of many physical devices that facilitate holding cellphones while riding. Moreover, the emergence of new traffic rules and conventions for e-scooters. Their existence and meaning can be probably ignored by e-scooter riders, due to the limited requirements to ride.

6. Discussion

The first objective (Study 1) was to quantitatively compare the road behaviors of cyclists and e-scooter riders using external-rated behavioral questionnaires (ECBQ and ESBQ). Also, a profile of the behaviors that external raters perceived as riskier was tested. The second aim (Study 2) was to qualitatively explore configurations on other users' perceptions of the four most frequent risky behaviors identified through the quantitative study. In both the quantitative and qualitative analysis, e-scooter riders were perceived as 'riskier' users than cyclists, thus endorsing the first study hypothesis. Bearing this in mind, the discussion of our findings will be developed, first, focusing on cyclists' and e-scooter riders' behaviors and, second, on the profile of the external raters.

6.1. External-rated numbers: Are e-scooter riders actually seen as "worse road users" than cyclists?

First, it is worth highlighting that the mean scores of external-rated risky behaviors substantially differ from previous applications of similar, but self-reported, questionnaires. Self-reported risky behaviors measured through the CBQ (Cycling Behavior Questionnaire) have ranged (in a 0–4 scale) between $M = [0.54–1.46]$ in previous experiences (O'Hern et al., 2021; Useche et al., 2018; Useche et al., 2021; Useche et al., 2021). An initial application of the ECBQ has shown how these mean scores tend to significantly increase to $M = [1.53–1.70]$ if the data source is an external rater, instead of a rider (Useche et al., 2021).

In the present study, external-rated risky behaviors of cyclists ranged between $M = [1.52–1.71]$ (see Table 2). The external-rated risky behaviors of e-scooter riders were higher, ranging between $M = [1.70–1.85]$ (see Table 2). Nowadays it is tautological to expect that external-rated data may "penalize" the analyzed users more than self-report questionnaires (at least when dealing with road behavior). Therefore, it seems convenient to make comparisons exclusively focusing on a *uniform* data source, being external raters the core informants of this study.

One of the most relevant findings of Study 1 was that e-scooter riders were seen to have significantly worse road behavior compared to cyclists. Even though the effect sizes were small, e-scooter riders were also considered more "problematic" road users in the interviews of Study 2. Restrictions on e-scooters are perceived by non-riders as more rigorous. This notion could be understood as a social prejudice. These results are in line with previous research that highlighted road crashes involving e-scooters as a public health issue (Coelho et al., 2021; Oh & Kim, 2021; Sikka et al., 2019).

A reasonable interpretation for this social prejudice may be the increasing number of e-scooters, and the lack of familiarity of other road users with such personal mobility devices. This could bring the attention of other users onto them (James et al., 2019). In addition, the perception external raters have within the road context may be conditioned by the "safety in numbers effect". This suggests that road users perceive road user groups they are familiar with as safer (Fyhri, Sundfør, Bjørnskau, & Laureshyn, 2017; Jacobsen, 2003; Jacobsen, Ragland, & Komanoff, 2015; James et al., 2019).

Another possible explanation for this may be related to the relatively smaller size of e-scooters, compared to bicycles. This refers to an overestimation of the arrival time of small vehicles compared to larger vehicles called the "size-arrival effect" (Caird & Hancock, 1994; Cavallo et al., 2015; Horswill, Helman, Ardiles, & Wann, 2005). Specifically, observers show less accuracy when judging the speed of smaller vehicles, such as motorcycles compared to cars (Cavallo et al., 2015). This can make road users who have interacted with bikes and e-scooters perceive the latter as less safe.

Although they do not rigorously follow the same study design, it is worth comparing our findings with the studies by James et al. (2019) and Nikiforiadis et al. (2021), which contrasted the perception of road safety and attitudes reported by e-scooter riders and non-riders. This set of findings highlights significant differences in users' perceptions of e-scooters as unsafe means of transportation, showing that 5% of riders and 38% of non-riders reported a negative assessment of their own group-based road safety behaviors and attitudes (James et al., 2019). In brief, their respondents reported feeling less safe when walking or driving around e-scooters compared to different types of bicycles. These results are in line with our findings in both Studies 1 and 2.

These authors (James et al., 2019; Nikiforiadis et al., 2021) also associate the “worse” results for e-scooters with the fact that people are more familiar with certain types of vehicles and the “safety in numbers” effect (James et al., 2019). Furthermore, it is worth mentioning the lack of infrastructure as a critical aspect identified by both riders and non-riders (Nikiforiadis et al., 2021).

In further support of this, the qualitative configurations in our study, three out of the four specific types of risky riding behaviors were largely based on temporality criteria. That is the novelty of e-scooters in transportation dynamics. This could also be associated with the “safety in numbers effect” (James et al., 2019). Also, the lack of legislation (or the unawareness about it), and the ambiguity of road design were highlighted and were stated as potential enhancers of e-scooter riders’ deliberate risky road behaviors.

Another key point from the interviews was the role that authorities play in this matter. This is in accordance with recent literature (Oh & Kim, 2021) that highlights the role of urban transport planners and policymakers in promoting e-scooters and bicycles as a means of urban transport. However, as also reported by the participants in the interviews, authorities should ensure compliance with the regulations and the education on road safety of these users (Liew et al., 2020). The development of studies with external-rater approaches may enhance the findings of self-reported studies regarding road interactions between different groups of road users.

6.2. *There is not an actual external-rater profile concerning the perception of cyclists and e-scooter riders’ behavior*

The structural analyses showed that external-rated risky behaviors of bicycle and e-scooter riders do not significantly differ between groups if these are based on the external raters’ gender, age, occupation, and/or education. On the contrary, the factors which correlated the most to external-rated errors and violations of both types of users were their risk perception and rule knowledge (road safety skills), and previous on-road incidents (experiences) with two-wheeled users. These results are in line with previous research that did not find an association between the external-rated behavior of cyclists and the gender or age of the raters (Useche et al., 2021; Useche et al., 2021). Also, proxies’ or external raters’ road safety skills (i.e., risk perception and rule knowledge) and road distractions were associated with more perceived risky behaviors (Alonso, Gonzalez-Marin, Esteban, & Useche, 2020; Useche et al., 2021). Considering the scarce literature in this regard, future studies should aim to demographically and psychosocially profile external raters and their perceived data.

Additionally, and although structurally similar in terms of errors, the structural differences found in terms of traffic violations of bicycle and e-scooter riders are worthy of attention. The external raters with a higher risk perception (greater values in the Risk Perception and Regulation scale) tended to perceive more traffic violations in both types of riders. Meanwhile, the external raters with higher levels of traffic rule knowledge seemed to perceive more violations among cyclists, but not among e-scooter riders. However, the external raters that had experienced more traffic incidents were found to be more likely to perceive higher rates of traffic violations among e-scooter riders, but not among cyclists. These dissonances between the profile of road users perceiving riskier behaviors may be linked to road safety-related skills, such as fostering knowledge of traffic regulations and risk perception (Alonso et al., 2020, 2021; Assailly, 2017). These road safety skills have shown a certain value for both behaviors and perceptions among road users of different ages (Alonso et al., 2020, 2021; Assailly, 2017).

In the light of these findings, it is necessary to promote and enforce regulations to reduce risky road behaviors among cyclists and e-scooter riders. Moreover, a continued increase in two-wheeled road users may be causing a prejudice amongst other road users due to their behavior. Hence, achieving safe, harmonious road interactions may improve both road safety practices and policies, not only infrastructures.

7. Conclusion

This research compares the behavior of bicycle and e-scooter riders as reported by non-rider raters, instead of riders themselves. Overall, both the quantitative and qualitative data show that, for the external raters involved in this study, the behavior of e-scooter riders is perceived as worse than that of cyclists.

As for the quantitative study, structural differences show that external raters’ risk perception, knowledge of traffic rules, and previous incidents with two-wheeled users may influence the evaluations of risky riding behaviors. On the other hand, the external raters’ demographic factors (age and education) did not significantly influence perceptions of risky behaviors.

In qualitative terms, configurations of risky riding behaviors of cyclists and e-scooter riders show a high degree of concordance with the questionnaire-based outcomes. This highlights the need to enhance policymaking, awareness of traffic norms, and positive interactions between two-wheeled (especially e-scooter) riders and other road users.

Also, in practical settings, future research should be conducted to confirm whether this negative behavior is actually performed by e-scooter riders, or whether it is conditioned by road prejudices. The contents presented in this research may be useful for authorities when considering road interactions between different means of transportation and other sustainable vehicles in cities.

8. Limitations of the study and future research

Although the statistical and qualitative-analytic parameters were carefully tested, and all procedures were done to the best of the knowledge of the authors of this paper, some key limitations must be acknowledged. This study used a sample of non-riders who would therefore have little experience of riding and may not understand certain riding behaviors. Future studies could include cyclists and e-bike riders to further examine any social prejudice, i.e., understand what perceptions those in the same group have of each other. For the purpose of finding out if there is an actual social prejudice against these road users, it could be of great interest to compare the actual behavior, the self-reported behavior, and the external rated behavior. Also, further experiences would also find useful to assess non-riders' exposure to bicycles and e-scooters as a variable moderating behavioral assessments.

The recruitment method, although underpinned with an inclusion criteria, could be a source of bias. Additionally, the geographical coverage of the study can be a key issue, if region-based differences are considered (*how common cycling or e-scooting is?)*. In other words, recent studies made in non-European regions show how key differences in terms of bicycle and e-scooter usage (and their motives) may potentially modify their behaviors. They also illustrate how are they perceived by other users (e.g., Hezaveh et al., 2018; O'Hern et al., 2021; Useche et al., 2021; Zheng, Ma, Li, & Cheng, 2019). However, nowadays Europe constitutes a core focus for two-wheeled and non-motorized transportation. Another geographical limitation that should be mentioned is that rules for both bicycle and e-scooter use may differ among countries. Thus, affecting both behaviors and external rater perceptions. For example, in some countries, both bicycles and e-scooters are legally allowed to be ridden on the sidewalk, while in some coutnries e-scooters are notallowed in bike lanes. In addition, red-light running may be more or less common among countries.

Moreover, it is important to consider that the results of this study are based on subjective ratings, albeit of another person's behavior. Some studies have found that, although better characterizing some issues referred to rated individuals, under certain conditions external-rated information may tend to overestimate the degree and/or severity of the problematic features, traits, or behaviors (Alvarez-Nebreda et al., 2019; Hogset & Barrett, 2010; Nasaescu, Zych, Ortega-Ruiz, Farrington, & Llorent, 2020).

On the other hand, it is true that self-reports have been widely criticized when used as a single measure to assess road behaviors (Af Wåhlberg, 2010; Chai, Qu, Sun, Zhang, & Ge, 2016) and that external raters provide a complementary measure that is a little more objective (Classen et al., 2010; Snow et al., 2005). However, studies on proxied behavioral data are still scarce and our results become difficult to validate in the absence of similar research in the field. Also, future studies would benefit from comparing riders' both self-reported and proxied behaviors with a key third source of data: objectively measured behavior, perhaps through naturalistic observations.

Finally, a unique aspect of the qualitative analysis was the use of RAPs, commonly used in other research areas (e.g., health sciences) different from the transportation field (Holdsworth et al., 2020). While still uncommon, it is worth encouraging other researchers to develop further insights on this method and evidence of its usefulness for road safety studies.

CRediT authorship contribution statement

Sergio A. Useche: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Steve O'Hern:** Visualization, Investigation, Writing – review & editing. **Adela Gonzalez-Marin:** Investigation, Resources. **Javier Gene-Morales:** Investigation, Data curation, Writing – original draft. **Francisco Alonso:** Visualization, Resources, Supervision. **Amanda N. Stephens:** Conceptualization, Investigation, Supervision, Writing – review & editing.

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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