Correlations of multiple rider behaviors with self-reported attitudes, perspectives on traffic rule strictness and social desirability

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Abstract

Powered Two-Wheeler (PTW) riders constitute a very vulnerable group of road users, while riding a PTW is considerably more dangerous than using any other motor vehicle. Behavioral issues have been identified major moderating factors to PTW crashes, as riders display great variability in their attitudes towards road safety. The aim of this paper is to present a thorough, overarching structure of relationships correlating various unsafe stated PTW rider behaviors (riding after alcohol consumption, speeding, helmet use and texting) with several self-reported attitude parameters and factors regarding rider perspectives on traffic rule strictness and social desirability. A structural equation model (SEM) was developed using data from the ESRA2 survey, which provided a broad sample encompassing 5,958 respondent riders from 32 countries. Numerous statistical relationships were discovered and quantified correlating the four examined unsafe rider behaviors with eight latent unobserved variables. All covariances between unsafe behaviors were found to be positive and statistically significant, indicating that a rider who will engage more frequently in every single one of the four examined unsafe riding behaviors is more likely to also engage in all the others as well.

Keywords

rider behavior; drinking and riding; speeding while riding; texting while riding; helmet use; structural equation model

1. Introduction and Background

Mopeds and motorcycles, collectively known as powered two-wheelers (PTWs), comprise an important part of vehicle fleets and the overall transport system as they offer increased mobility at a reduced cost as well as a particular sense of enjoyment. Consequently, they are used for different purposes in different regions of the world. In low and middle-income countries, PTWs are more commonly used for the transport of goods and people and as an income source (e.g. taxis or delivery vehicles). In high-income countries, they are more widespread as a transport means suitable for urban traffic congestion but also for recreation (European Commission, 2018; WHO, 2017).

However, PTW riders constitute a very vulnerable group of road users, while riding a PTW is considerably more dangerous than using any other motor vehicle. The risk of being seriously injured in a road crash as a PTW rider is significantly higher than the respective risk of a car occupant (Zambon & Hasselberg, 2006; Wegman et. al., 2008). Moreover, per vehicle mile travelled, motorcycle riders have a 34-fold higher risk of death in a road crash than the people driving other motor vehicle types (Lin & Kraus, 2009). Globally, users of motorized two- and three-wheelers represent 28% of all road fatalities (WHO, 2018). In low and middle-income countries, motorcyclists are at a higher risk of road trauma than other road users and they are over-represented in fatal road crashes (Rusli et al., 2020). These alarming numbers of potentially avoidable deaths highlight the need for increased attention to motorcycles and mopeds (WHO, 2017).

A number of studies have been published in the literature for PTWs regarding the correlation of injury severity with external variables such as speeding, drink-driving, road infrastructure characteristics and weather conditions among others. However, when the interactions between crash rates, severity and behavior are co-investigated along with other contributory factors, the crash causes and the related solutions could be better identified (Theofilatos & Yannis, 2015).

Behavioral issues are major moderating factors to PTW crashes. PTW riders display great variability in their attitudes towards road safety. Risk taking and sensation seeking are typical rider behaviors that are usually manifested through speeding, disobeying traffic signals and signs, ignoring overtaking restrictions, overlooking pedestrian crossings and maintaining short gaps with the following vehicles (Vlahogianni et al., 2012). Riding under the influence of alcohol is also another factor that affects riding skills significantly (Creaser et al., 2009), as it increases the odds of serious and fatal injuries regardless of socio-demographic characteristics (Vaez & Laflamme, 2005). Based on the literature, drinking and riding is more prevalent among younger riders (Elliott et al., 2009) and male riders (Tsai et al., 2010; Papadimitriou et al., 2014).

Apart from riding under the influence of alcohol, it can be surmised from the results of several dedicated studies across the literature that PTW riders' behavior is related to age and gender. PTW riders that speed seem to be more often younger and male (Manan et al., 2017; Hong et al., 2020). This might be attributed to the demand of younger people for speed, maneuverability and sensation seeking. Moreover, overconfidence is a primary cause for risky riding behavior of young PTW riders (Vlahogianni et al., 2012). A study carried out in Taiwan pointed out that young and male riders are more likely to disobey traffic regulations compered to female ones (Chang & Yeh, 2007). In addition, young riders do not seem to wear protective equipment (De Rome et al., 2011, Wadhwaniya et al., 2017). Furthermore, the results of a self-reported questionnaire survey of motorcyclists in Bali indicated that male motorcyclists are more likely to fail giving priority and violate parking signs than female riders (Wedagama, 2017). On the other hand, older road users might seek slower travelling speeds or the comfort of a private car, switch to a bicycle or on foot travelling, or limit their exposure by travelling less (Ziakopoulos et al., 2018).

Riding a PTW is a quite complex task demanding a high degree of attention, reflexes and physical riding skills. Recent in-depth crash research indicates that the most common causal factors of PTW crashes were related to errors in observation by the PTW rider or the driver of the other vehicle, typically called ‘looked but failed to see’ accidents (Brown et al., 2021). In addition to risk perception, the attitudes of PTW riders are considered crucial factors reflecting their on-road riding behavior, as determined in past studies (e.g. Golias & Karlaftis, 2001; Iversen, 2004). In addition, attitudes towards road safety are directly associated with risky riding behavior in traffic (Chen, 2009). In a comparison between PTW riders and car drivers, results indicated that even if there are no differences in their attitudes toward road safety rules, differences do appear when the road rules compliance is assessed in specific imagined situations, with PTW riders declaring to be more prone to traffic rule violations than car drivers (Cordellieri et al., 2019).

The identification of factors that influence mobile phone use during motorcycling was the main objective of a study that was conducted in Indonesia. The behavioral model that was developed in the framework of that research pointed out that the factors that influenced rider intentions to avoid mobile phone use while riding were attitude, perceived behavioral control, and cues to action (Widyanti et al., 2020). The results of another study conducting a comparison of personality theories on motorcyclists’ riding behavior revealed that personality traits, sensation seeking and aggression were strongly associated with riding errors, speeding, and especially performing stunts (Antoniazzi & Klein, 2019). Lifestyle is also associated with risky behavior of riders and their involvement in road crashes (Stanojević et al., 2020).

Finally, riding experience seems to also have a significant effect on riding behavior. Based on the results of a simulator-experiment that compared the hazard perception abilities of experienced and novice motorcycle riders, it was found that experienced riders crashed less often, received better performance evaluations, and approached hazards at more appropriate speeds than inexperienced riders (Liu et al., 2009).

Naturally, PTW rider behavior and fatality rates vary considerably between different countries or regions. Indicatively, PTW riders have displayed noticeably high rates of injury in developing countries (Ameratunga et al., 2006); Lin & Krauss (2009) propose different prevalence of PTW riders, riding exposure, purpose of PTW riding, PTW type and intervention programs as the respective contributing factors. It is also important to remember that the infrastructure and road network profile is different between regions: European PTW crashes occur predominantly in urban areas, while Australian PTW crashes occur predominantly on local area roads (Vlahogianni et al., 2012).

Fluctuations of rider behavior can be attributed to various factors such as relevant legislation, level of enforcement, educational and licensing practices, riding outlooks and road safety culture and other socio-economic indicators. The nationality of PTW riders has been determined to play an important role in terms of aggressive violations (Nævestad et al., 2020). An earlier investigation of crash causes found similarities in fatal PTW crash patterns between United States and Australia but discrepancies with European figures; this was attributed to different PTW rider demographics across the regions (Haworth et al., 2009). The analysis of Jiwattanakulpaisarn et al. (2013) revealed that helmet use is influenced by the awareness of helmet law enforcement, a parameter with considerable variations between countries and regions. Moreover, helmet use by PTW riders is reported to be low in smaller cities in developing countries or countries of hot climate (Dandona et al., 2006, Li et al., 2008). Various economic indicator parameters of the study areas such as gross domestic product and income per capita are associated with PTW behavior and related outcomes (Law et al., 2005; Law et al., 2009; Houston & Richardson, 2008). Brown et al. (2021) note that, due to different regional variations, certain standardization and harmonizing of PTW crash datasets is critical to determine cases where road safety policies can work uniformly and cases where more specific approaches are needed.

Studies on the field of road safety-related behavior often utilize Structural Equation Model (SEM) structures to analyze data often obtained by questionnaires or surveys and to correlate and group variables based on theoretical concepts termed latent variables. The SEM approach offers remarkable flexibility to researchers for the investigation of several theoretical model forms and the selection of the ones that are most appropriate, regarding first their logic and second their mathematical and statistical soundness. Indicatively, Chen (2009) utilized SEM to integrate social cognitive and personality traits for the simultaneous investigation of instances of risky driving and attitudes towards it. Sukor et al. (2017) employed the road safety measures of inclusive versus exclusive lanes as input variables, correlating them with several psychological variables such as desire to speed, attitude towards speeding, perception of danger, perception of behavioral control and perception that other riders do not use helmets and subsequently correlated these psychological factors with risky behaviors, i.e. speeding and (lack of) helmet use. In a study pertinent to the present one, Satiennam et al. (2018) investigated factors influencing red light running by young PTW riders. Their findings support the Theory of Planned Behavior (TPB) and indicate that behavioral, normative and control beliefs can be used to interpret rider motivations to run red lights, and also that perceived control or controllability and perceived capacity influence differently intention of violation and rider behavior. TPB concepts were also explored via SEM by Nguyen et al. (2020), who determined that mobile use while riding, negative attitudes, perceived behavioral control were significantly correlated with behavioral intention. In that study, self-reported behavior was a separate construct correlated independently with mobile use while riding habits and behavioral intention.

Based on the aforementioned, the aim of this paper is to present a thorough, overarching structure of relationships correlating various unsafe stated PTW rider behaviors (riding after alcohol consumption, speeding, helmet use and texting) with several self-reported attitude parameters and factors regarding rider perspectives on traffic rule strictness and social desirability.

The main research questions formulated to achieve the aim of the present research are as follows:

1. Can the overarching structure of relationships correlating various unsafe stated PTW rider behaviors be appropriately captured via Structural Equation Modelling (SEM)?

2. Can the self-declared inputs of PTW riders be converted to meaningfully represent unobserved theoretical constructs expressing (i) demographic profiles, (ii) attitudes towards risk factors, (iii) positive attributes towards road safety, and (iv) social desirability?

3. Are the four self-reported unsafe PTW behaviors influenced by self-reported attitude parameters, rider perspectives on traffic rule strictness and social desirability, and with each other?”

The main a priori hypotheses are that these four unsafe stated PTW rider behaviors are (i) correlated simultaneously with examined self-reported attitude parameters, rider perspectives on traffic rule strictness and social desirability and (ii) positively correlated with each other, meaning that a driver who engages in one unsafe behavior is more likely to engage in the other behaviors as well.

In order to achieve the aim and answer to the research questions of the study, data from the second version of the E-Survey of Road users' safety Attitudes (ESRA2) were utilized, which provided a broad sample encompassing 5,958 respondent riders from 32 countries. A SEM is fitted as the most appropriate tool that could incorporate theoretical latent variables in a multiple-input, multiple-output framework.

The present paper is organized as follows: Initially, the ESRA methodology which generated the utilized data is thoroughly presented, followed by descriptive statistics and relevant figures outlining the sample. An overview of the SEM mathematical background is provided, followed by the fitted model and the commenting of results. The paper concludes with a discussion on the implications of the present findings and future research directions.

2. ESRA Methodology

The ESRA project is a joint initiative of road safety institutes, research organisations, public services and private sponsors, aiming at collecting comparable international data on road users’ opinions, attitudes and behavior with respect to road traffic risks. It is an extensive online panel survey, using a representative sample (at least N = 1,000) of the national adult population of each participating country. A jointly developed questionnaire was translated into the participant country languages. The survey addresses different road safety topics (e.g. speeding, driving under the influence of alcohol, distraction) and targets car occupants, motorcycle and moped drivers, cyclists and pedestrians. More details concerning the methodology, the data processing and the questionnaire are described by Meesmann et al. (2021) and Pires et al. (2020). An overview of the project and its reports are available online (ESRA, 2018).

The present research is based on the first iteration of the ESRA2 survey spanning 32 countries (20 European, 2 North American, 5 Asian-Oceanian and 5 African) in 2018. These countries are presented in Figure 1. In more detail, the ESRA survey covered the following regions: Europe (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, United Kingdom), North America (Canada, USA), Asia and Oceania (Australia, India, Israel, Japan, Republic of Korea), Africa (Egypt, Kenya, Morocco, Nigeria, South Africa).

Key findings of the ESRA2 survey have also been presented in related publications, such as cross-cultural perspectives on vulnerable road users’ performance and attitudes (Yannis et al., 2020b), age and road safety performance (Lyon et al., 2020), and impaired driving due to alcohol or drugs (Goldenbeld et al., 2020).

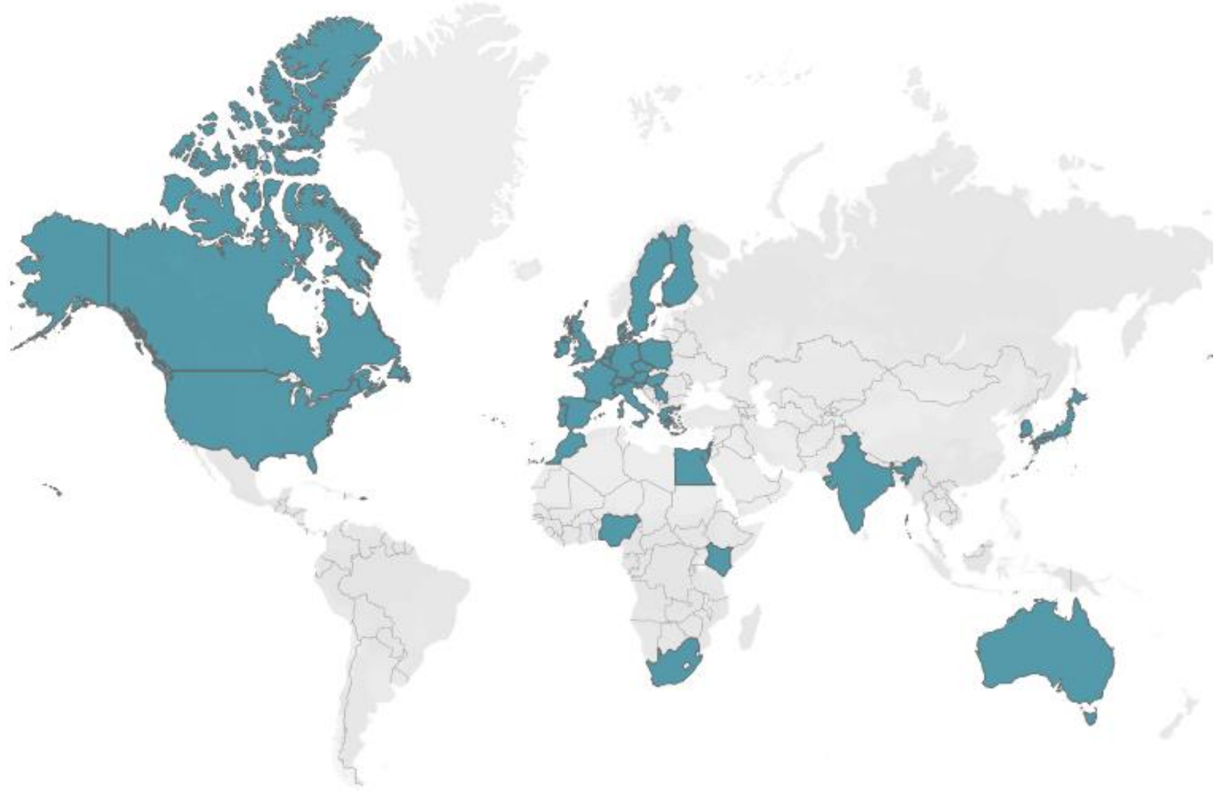

Figure 1: ESRA2 geographical coverage in 2018

The sample of the present study includes 5,958 respondent riders from the 32 participant countries (male: 66%, female: 34% - mean age: 38.2 years old, standard deviation of age: 14.5 years). They are all riders who have stated in the survey that they ride a moped (electric or conventional) or a motorcycle (electric or conventional) at least a few days a month. The questions of the ESRA2 survey that were utilized for the objectives of this study regarding PTW riders' demographic characteristics, attitudes towards unsafe behavior in traffic, risk perception, support for policy measures, agreement with stricter traffic rules, social desirability and self-declared behavior are presented in Table 1. This particular grouping for the examined variables was selected based on cohesion (i.e. similarity of topics) and interpretability, as explained in Section 5 as well. It should be noted that, to counter some of the inherent bias of self-reporting studies, ESRA2 included questions examining the social circle of friends of the respondents, rather than the respondents themselves.

Table 1: List of variables and abbreviations obtained from the ESRA2 questionnaire for PTW riders

Abbreviation	**Demographic characteristics**	**Scale**
Country	Country	1-32
Gender	Gender [1: male, 2: female]	1-2
Age (3 categories)	Age (3 categories) [1: 18-34, 2: 35-54, 3: $\geq$ 55]	1-3
Education level	What is the highest qualification or educational certificate that you have obtained? [1: none, 2: primary education, 3: secondary education, 4: bachelor's degree or similar, 5: master's degree or higher]	1-5
Abbreviation	**Attitude towards alcohol - To what extent do you agree with each of the following statements?**	**Scale**
Friend_dr_alc	Most of my friends would drive after having drunk alcohol	1-5
Short_tr_alc	For short trips, one can risk driving under the influence of alcohol	1-5
Trust_self_drive	I trust myself to drive after having a glass of alcohol	1-5
Drive_after_party	I have the ability to drive when I am a little drunk after a party	1-5

Drive_after_large_amount	I am able to drive after drinking a large amount of alcohol (e.g. half a liter of wine)	1-5
Drive_often_drunk	I often drive after drinking alcohol	1-5
Sometimes_drive_much_alc	It sometimes happens that I drive after consuming a large amount of alcohol (e.g. a liter of beer or half a liter of wine)	1-5
Abbreviation	**Attitude towards speeding - To what extent do you agree with each of the following statements?**	**Scale**
Friend_dr_over20	Most of my friends would drive 20 km/h over the speed limit in a residential area	1-5
Have_2_dr_fast	I have to drive fast; otherwise, I have the impression of losing time	1-5
Respect_limits_boring	Respecting speed limits is boring or dull	1-5
Trust_self_faster	I trust myself when I drive significantly faster than the speed limit	1-5
Able_fast_curve	I am able to drive fast through a sharp curve	1-5
Often_faster_limit	I often drive faster than the speed limit	1-5
Like_fast_curve	I like to drive in a sporty fast manner through a sharp curve	1-5
Abbreviation	**Attitude towards distraction - To what extent do you agree with each of the following statements?**	**Scale**
Save_time_mobuse	To save time, I often use a mobile phone while driving	1-5
Trust_chk_msg	I trust myself when I check my messages on the mobile phone while driving	1-5
Can_write_msg	I have the ability to write a message on the mobile phone while driving	1-5
Can_talk_mob	I am able to talk on a hand-held mobile phone while driving	1-5
Sometimes_txt_mob	It happens sometimes that I write a message on the mobile phone while driving	1-5
Often_talk_mob	I often talk on a hand-held mobile phone while driving	1-5
Often_chk_msg	I often check my messages on the mobile phone while driving	1-5
Abbreviation	**Risk perception - How often do you think each of the following factors is the cause of a road crash involving a car?**	**Scale**
Often_alc_causes_crash	Driving after drinking alcohol	1-6
Often_speed_causes_crash	Driving faster than the speed limit	1-6
Often_mobuse_causes_crash	Using a hand-held mobile phone while driving	1-6
Abbreviation	**Support for policy measures - Do you support or oppose a legal obligation to require all moped drivers and motorcyclists to:**	**Scale**
Support_law_helmet	…wear a helmet?	1-5
Support_law_reflect	…wear reflective material when driving in the dark?	1-5
Abbreviation	**Agreement with stricter traffic rules - What do you think about the current traffic rules and penalties in your country for:**	**Scale**
Think_rules_alc	…driving or riding under the influence of alcohol? The traffic rules should be stricter	0-1
Think_rules_speed	…driving or riding faster than the speed limit? The traffic rules should be stricter	0-1
Think_rules_mobuse	…using a mobile phone while driving or riding? The traffic rules should be stricter	0-1
Abbreviation	**Social desirability - To what extent are the following statements true?**	**Scale**
Always_respect_code	I always respect the highway code, even if the risk of getting caught is very low	1-5
Respect_limits_no_police	I would still respect speed limits at all times, even if there were no police checks	1-5
Never_dr_red	I have never driven through a traffic light that had just turned red	1-5
Not_care_drivers	I do not care what other drivers think about me	1-5
Always_remain_calm	I always remain calm and rational in traffic	1-5
Confident_reaction	I am always confident of how to react in traffic situations	1-5
Abbreviation	**Self-declared behavior - Over the last 30 days, how often did you as a moped driver or motorcyclist:**	**Scale**
Self_30_alcohol	…ride when you may have been over the legal limit for drinking and driving?	1-5
Self_30_speeding	…ride faster than the speed limit outside built-up areas (but not on motorways/freeways)?	1-5
Self_30_helmet	…ride a moped or motorcycle without a helmet?	1-5
Self_30_texting	…read a text message/email or check social media (e.g. Facebook, twitter, etc.) while riding a moped or motorcycle?	1-5

3. Descriptive statistics

Before more detailed analysis, it is fruitful to reports basic descriptive statistics on the variables that were used in the framework of this paper. Figures 2 to 7 depict the PTW riders' answers to the questions presented in Table 1 concerning attitudes towards unsafe behaviors in traffic, risk perception, support for policy measures, agreement with stricter traffic rules, social desirability and self-declared behavior.

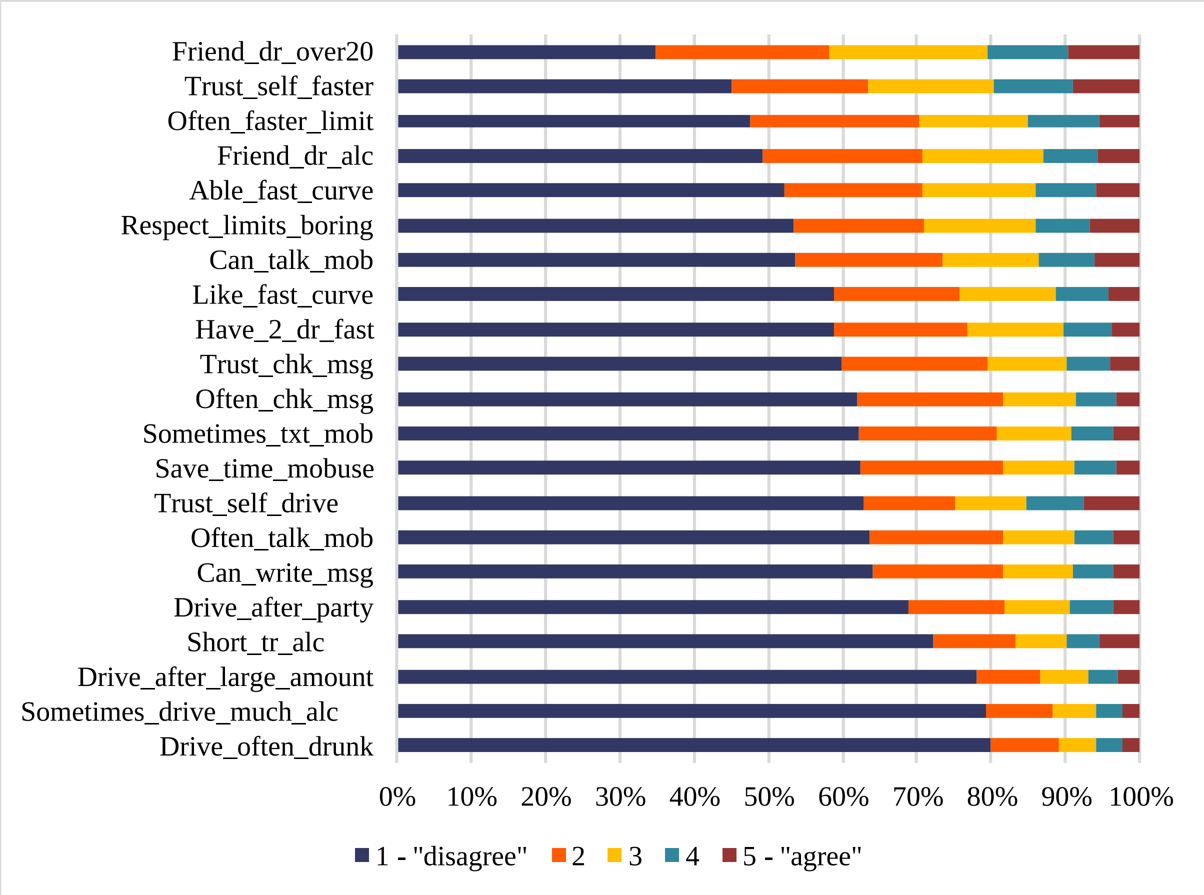

Figure 2: Attitudes towards unsafe behaviors in traffic (% of riders)

Figure 2 shows that the highest disagreement rates correspond to driving under the influence of alcohol. However, it is noteworthy that the percentage of PTW riders who disagree with the statement “most of my friends would drive after having drunk alcohol” is much lower than the rates of the rest of the alcohol-related questions. On the contrary, it appears that speeding-related behaviors are those with the lowest disagreement rates reported by PTW riders. Based on Figure 3, it is also evident that driving after drinking alcohol is reported as the most frequent cause of a road crash. Regarding support for policy measures, it can be observed from Figure 4 that both the use of helmets and the use of reflective material when driving in the dark receive high rates of support from PTW riders, with slightly higher percentages corresponding to helmet use. Figure 5 shows that about seven out of ten PTW riders believe that traffic rules should be stricter (ranging from 65% for speeding to 74% for alcohol). Lastly, the answers of PTW riders to social desirability questions are presented in Figure 6.

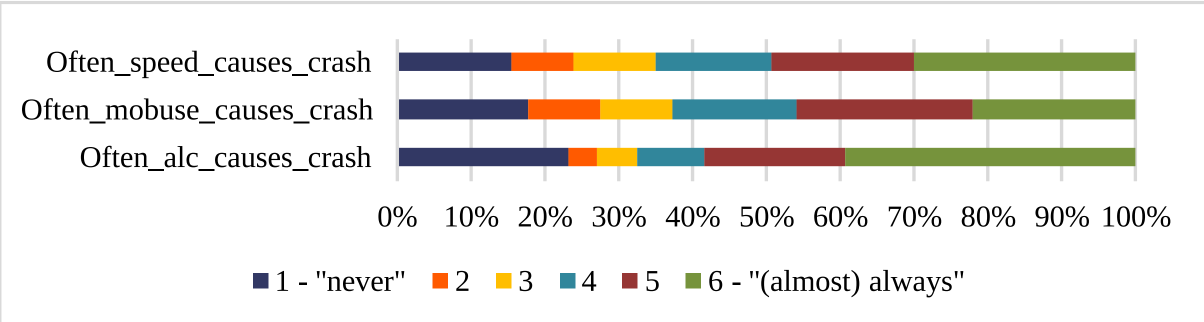

Figure 3: Risk perception (% of riders)

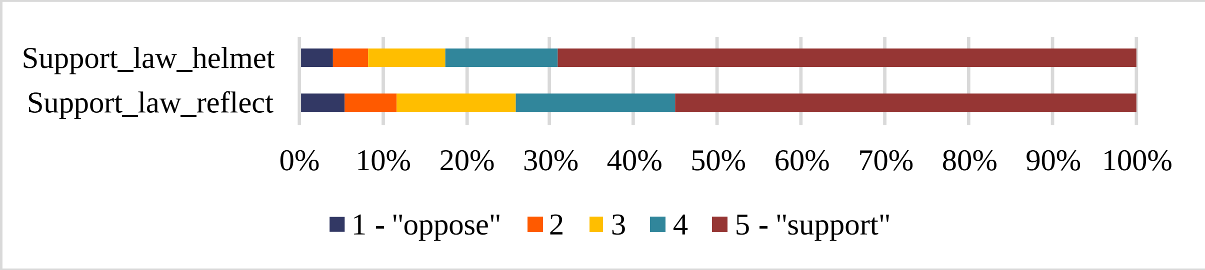

Figure 4: Support for policy measures (% of riders)

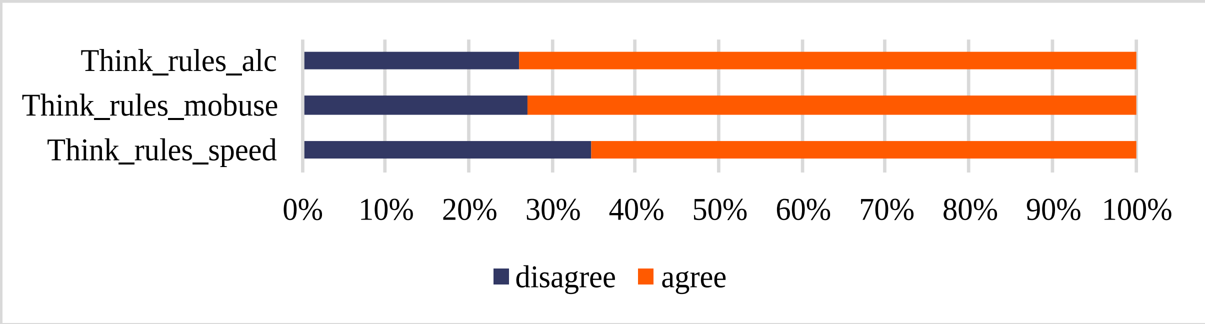

Figure 5: Agreement with stricter traffic rules (% of riders)

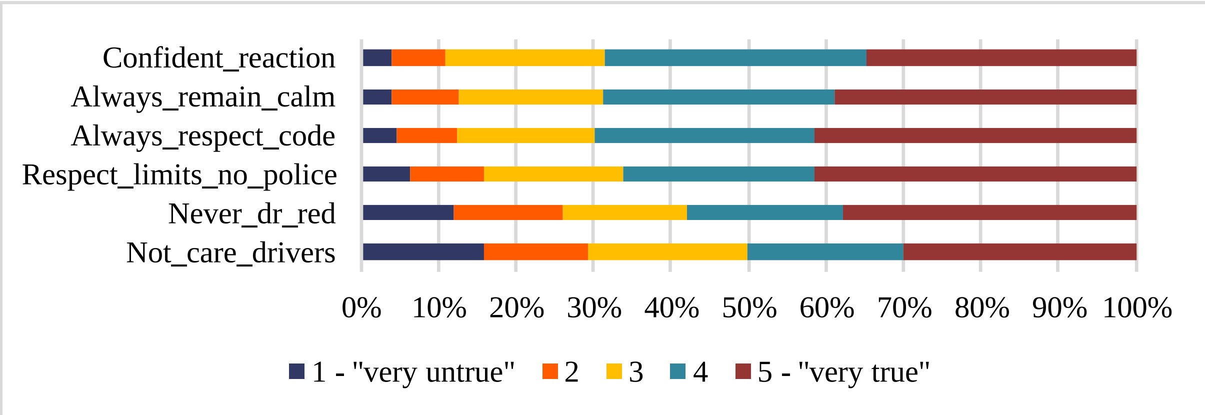

Figure 6: Social desirability (% of riders)

Afterwards, basic descriptive statistics on the self-declared behavior of PTW riders are demonstrated in Figure 7. The presented behaviors also formulate the dependent variables of the SEM that will be presented in the next sections; they concern riding after alcohol consumption, speeding, helmet use and distraction. More specifically, the percentages of PTW riders who stated that they had engaged in the respective behavior at least once in the past 30 days are presented, divided by region. In other words, these are the percentages of riders that responded with a score between 2 to 5 (i.e. not 1) on a 5-point scale, from 1 = never to 5 = [almost] always).

Based on Figure 7, it can be observed that in all regions, the most frequent unsafe behaviors reported by PTW riders are riding faster than the speed limits outside built-up areas (but not on motorways/freeways) and riding without a helmet. Regarding the differences that can be observed between the examined regions, it appears that European PTW riders are those with the highest helmet use reported rates, as self-declared riding without helmet is significantly higher in Africa (49%), North America (46%) and Asia-Oceania (39%) than in Europe (26%). Moreover, the results of PTW riders for the self-declared behavior of reading a text message/email or checking social media while riding vary from 22% in Europe to 37% in Africa. Lastly, self-declared drink riding and speeding rates do not differ much between regions.

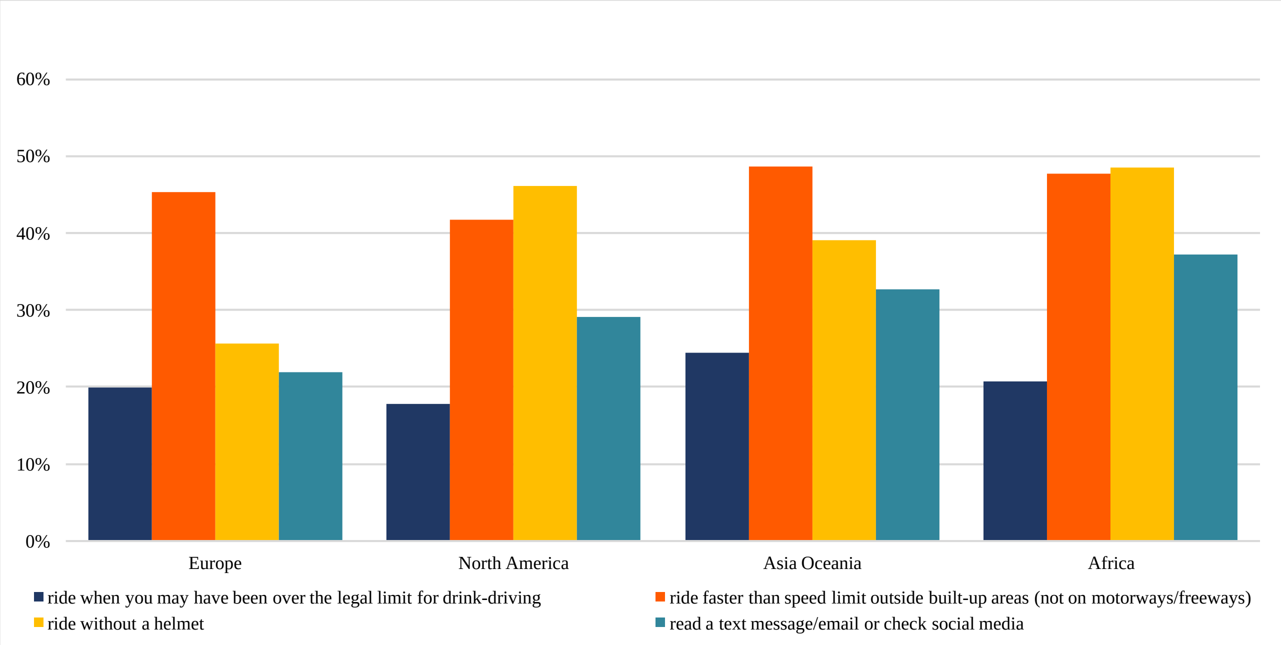

Figure 7: Self-declared behavior as a PTW rider (% of riders engaging at least once in the past 30 days)

4. SEM Overview

In this section, a brief overview covering the mathematical background of SEM is provided. Structural Equation Modelling belongs to the model family of latent variable analysis; it is a multivariate technique which can support multiple-input and multiple-output modelling. In the context of the present study, SEM provides an appropriate vehicle to formulate several unobserved constructs in the form of latent variables from the respective question groups and then investigate their correlations with the four risky PTW rider behaviors.

SEM is a well-known methodology with wide applications. Several studies have utilized it to model complex interrelationships typically involving unobserved concepts expressed as latent variables, with applications in the traffic engineering and road safety domains as well. As per the aforementioned, SEM have been applied to model psychological factors, personality and attitudes with self-reported behaviors of motorcyclists (Chen, 2009; Sukor et al., 2017; Satiennam et al., 2018). Additional examples include the use of SEM to connect anxiety, reward sensitivity and sensation seeking propensity with unsafe driving (Scott-Parker et al., 2013) or perception of risk and driving tasks on road safety attitudes of drivers (Ram & Chand, 2016).

Using matrix notation, SEM can be expressed by certain fundamental equations following Jöreskog & Sörbom (1996). These are:

The structural equation model:

$$\boldsymbol{\eta} = \mathbf{B}\,\boldsymbol{\eta} + \boldsymbol{\Gamma}\,\boldsymbol{\xi} + \boldsymbol{\zeta} \qquad \text{Eq. (1)}$$

The measurement model for y:

$$\mathbf{y} = \boldsymbol{\Lambda}_y \boldsymbol{\eta} + \boldsymbol{\varepsilon} \qquad \text{Eq. (2)}$$

The measurement model for x:

$$\mathbf{x} = \boldsymbol{\Lambda_x}\xi + \boldsymbol{\delta} \qquad \text{Eq. (3)}$$

Where:
$\boldsymbol{y}$ is a vector expressing the dependent (response) variables
$\boldsymbol{x}$ is a vector expressing the independent (predictor) variables
$\boldsymbol{\eta}$ is a vector expressing the latent dependent (unobserved) variables
$\boldsymbol{\xi}$ is a vector expressing the latent independent (exogenous) variables
$\boldsymbol{\varepsilon}$ is a vector expressing the regression error term in y
$\boldsymbol{\delta}$ is a vector expressing the regression error term in x
$\boldsymbol{\zeta}$ is a vector expressing the regression error term in η
$\boldsymbol{\Lambda_y}$ is a vector expressing the regression coefficients for the dependent variables y on η
$\boldsymbol{\Lambda_x}$ is a vector expressing the regression coefficients for the independent variables x on ξ
$\boldsymbol{\Gamma}$ is a matrix expressing the regression coefficients of ξ in the SEM relationship
$\mathbf{B}$ is a matrix expressing the regression coefficients of η in the SEM relationship

The reader is also referred to Schumacker & Lomax (2004), Kaplan (2008) and Washington et al. (2020) for further details on SEM methodology.

Several goodness-of-fit metrics are commonly used, including χ^2 (chi-squared), the goodness-of-fit index (GFI), the (standardized) root-mean-square residual ((S)RMR), the comparative fit index (CFI) and the Tucker-Lewis Index (TLI). Such criteria are based on differences between the observed and modelled variance–covariance matrices (Schumacker & Lomax, 2004). Values less than 0.07 for SRMR and RMSEA and more than 0.90 for CFI and TLI are generally accepted as indications of very good overall model fit. As a note, the topic of SEM goodness-of-fit metrics has been a matter of previous scientific debate; indicatively, the reader is referred to Mulaik et al. (1989), Kaplan (1990), MacCallum (1990) and Steiger (1990).

5. SEM Results and Discussion

As per the aforementioned, questionnaire data from the ESRA2 survey were utilized for the purposes of this research. Within the questionnaire, the attitudes of participant road users are investigated in a disaggregated and ungrouped manner (Yannis et al., 2020a). However, in order to apply SEM models correctly, a meaningful and informative structure of latent variables was required. With cohesion and interpretability as basic principles, the grouping of Table 1 was formulated and adopted as the SEM architecture. Specifically, eight latent variables were formulated by grouping replies from relevant questions: (i) demographic characteristics, (ii) attitude towards alcohol, (iii) attitude towards speeding, (iv) attitude towards distraction, (v) risk perception, (vi) support for policy measures, (vii) agreement with stricter traffic rules and (viii) social desirability. All latent variables represent unobserved constructs which are regressed on observed independent variables and subsequently correlated with the various PTW behaviors.

SEM results are presented on Table 2; statistically significant p-values (≤ 0.05) are shown in bold. The analysis of this research was conducted in R-studio (R core team, 2013) using the lavaan R package (Rosseel, 2012). As customary in latent variable/path analysis, the proposed model structure and modelled interrelationships can be visualized in a path diagram, presented in Figure 8. Green arrows denote positive correlations, while red arrows denote negative correlations – all correlations shown on the path diagram are statistically significant (p-values ≤ 0.05). It should be noted that covariances between latent variables are not depicted in the diagram for readability reasons.

Overall, the SEM appears to fit the data very well. The general model metrics (χ^2, CFI, TLI, RMSEA, SRMR) indicate excellent overall model fit. The vast majority of independent variables are statistically significant for the formulation of the latent variables and when the dependent variables directly regressed on the independent ones as well. All dependent variables have statistically significant correlations with the latent variables as well.

When looking closer at results, many informative relationships are revealed by individual variable correlations. Road user country of origin, gender and education level are positively correlated with demographic characteristics, while age is negatively correlated with that latent quantity. Demographic characteristics were, in turn, identified as positively contributing to more frequent riding without helmet and to more frequent instances of speeding of PTW riders. It should be noted that the optimal model allowed for a direct regression of gender on speeding frequency. The small positive correlation of the non-baseline gender category (i.e. females) with more frequent rider speeding is overturned by the contribution of the direct correlation, which has a larger coefficient value. In simpler terms, females engage in speeding less frequently than males overall. Similarly, categorical increases in age lead to reduction of the latent variable of demographic characteristics, and thus lower frequencies of riding without helmet or speeding. These results are reasonable and in line with past literature (Manan et al., 2017; Wadhwaniya et al., 2017; Hong et al., 2020) and serve as a sanity check of SEM model results.

The three following latent variables express attitudes towards alcohol, speeding and distraction. Across these latent variables, all contributing independent variables denote agreement with more unsafe or risky attitudes or rider overconfidence, and reasonable positive correlations are thus obtained.

In turn, more unsafe attitudes towards alcohol, as expressed by the latent variable correlations, are positively correlated with more frequent riding without a helmet, riding while under the influence (i.e. over the legal limit) of alcohol and riding while texting. Similarly, more unsafe attitudes towards speeding, are reasonably positively correlated with more frequent speeding and with more frequent riding without a helmet.

Table 2: ESRA2 SEM model results

SEM Components		**Parameters**	**Estimate**	**S.E.**	**z-value**	**P(>|z|)**
Latent Variables	Demographic characteristics	Country	1.000	–	–	–
		Gender	0.006	0.001	5.705	**0.000**
		Age (3 categories)	-0.030	0.002	-15.267	**0.000**
		Education level	0.036	0.002	16.293	**0.000**
	Attitude towards alcohol	Friend_dr_alc	1.000	–	–	–
		Short_tr_alc	1.182	0.036	32.425	**0.000**
		Trust_self_drive	1.388	0.042	32.972	**0.000**
		Drive_after_party	1.383	0.039	35.802	**0.000**
		Drive_after_large_amount	1.304	0.036	36.557	**0.000**
		Drive_often_drunk	1.204	0.033	36.535	**0.000**
		Sometimes_drive_much_alc	1.231	0.034	36.567	**0.000**
	Attitude towards speeding	Friend_dr_over20	1.000	–	–	–
		Have_2_dr_fast	1.471	0.053	27.823	**0.000**
		Respect_limits_boring	1.529	0.056	27.184	**0.000**
		Trust_self_faster	1.678	0.061	27.575	**0.000**
		Able_fast_curve	1.628	0.058	27.934	**0.000**
		Often_faster_limit	1.810	0.063	28.940	**0.000**
		Like_fast_curve	1.605	0.057	28.383	**0.000**
	Attitude towards distraction	Save_time_mobuse	1.000	–	–	–
		Trust_chk_msg	1.079	0.019	56.844	**0.000**
		Can_write_msg	1.054	0.018	57.444	**0.000**
		Can_talk_mob	1.096	0.021	52.307	**0.000**
		Sometimes_txt_mob	1.110	0.018	60.108	**0.000**
		Often_talk_mob	1.047	0.018	56.891	**0.000**
		Often_chk_msg	1.037	0.018	57.469	**0.000**
	Risk perception	Often_alc_causes_crash	1.000	–	–	–
		Often_speed_causes_crash	0.836	0.009	88.356	**0.000**
		Often_mobuse_causes_crash	0.821	0.009	87.039	**0.000**
	Support for policy measures	Support_law_helmet	1.000	–	–	–
		Support_law_reflect	1.051	0.040	26.578	**0.000**
	Agreement with stricter traffic rules	Think_rules_alc	1.000	–	–	–
		Think_rules_speed	1.136	0.023	49.459	**0.000**
		Think_rules_mobuse	1.022	0.021	49.055	**0.000**
	Social desirability	Always_respect_code	1.000	–	–	–
		Respect_limits_no_police	1.070	0.018	60.882	**0.000**
		Never_dr_red	0.861	0.020	42.139	**0.000**
		Not_care_drivers	0.376	0.021	17.500	**0.000**
		Always_remain_calm	0.778	0.016	48.188	**0.000**
		Confident_reaction	0.613	0.016	39.109	**0.000**
Regressions	Self_30_alcohol	Intercept	1.340	0.011	123.092	**0.000**
		Attitude towards alcohol	0.837	0.032	26.152	**0.000**
		Attitude towards distraction	0.111	0.018	6.300	**0.000**
		Support for policy measures	-0.087	0.018	-4.952	**0.000**
		Agreement with stricter traffic rules	0.122	0.030	4.101	**0.000**
		Social desirability	0.048	0.012	4.102	**0.000**
	Self_30_speeding	Intercept	1.933	0.035	55.075	**0.000**
		Gender	-0.082	0.024	-3.424	**0.001**
		Demographic characteristics	0.009	0.002	4.004	**0.000**
		Attitude towards speeding	1.229	0.049	25.155	**0.000**
		Agreement with stricter traffic rules	-0.083	0.042	-1.981	**0.048**
		Social desirability	-0.068	0.017	-3.889	**0.000**
	Self_30_helmet	Intercept	1.752	0.015	113.811	**0.000**
		Demographic characteristics	0.043	0.003	12.353	**0.000**
		Attitude towards alcohol	0.350	0.045	7.842	**0.000**
		Attitude towards speeding	0.296	0.057	5.167	**0.000**
		Attitude towards distraction	0.166	0.038	4.401	**0.000**
		Risk perception	0.045	0.008	5.565	**0.000**

SEM Components		Parameters	Estimate	S.E.	z-value	P(>|z|)
		Support for policy measures	-0.172	0.027	-6.265	**0.000**
	Self_30_texting	Intercept	1.461	0.012	120.910	**0.000**
		Attitude towards alcohol	0.313	0.031	9.965	**0.000**
		Attitude towards speeding	-0.073	0.037	-1.963	**0.050**
		Attitude towards distraction	0.594	0.023	25.543	**0.000**
		Risk perception	-0.018	0.005	-3.317	**0.001**
		Support for policy measures	-0.101	0.021	-4.876	**0.000**
		Agreement with stricter traffic rules	0.110	0.034	3.254	**0.001**
		Social desirability	0.067	0.014	4.669	**0.000**
Covariances	Friend_dr_alc	Friend_dr_over20	0.365	0.018	20.834	**0.000**
	Trust_self_drive	Confident_reaction	0.074	0.013	5.732	**0.000**
	Trust_self_faster	Confident_reaction	0.152	0.013	11.480	**0.000**
	Demographic characteristics	Attitude towards alcohol	-0.308	0.079	-3.917	**0.000**
	Demographic characteristics	Attitude towards speeding	-0.678	0.074	-9.106	**0.000**
	Demographic characteristics	Attitude towards distraction	0.777	0.105	7.392	**0.000**
	Demographic characteristics	Risk perception	-0.105	0.245	-0.426	0.670
	Demographic characteristics	Support for policy measures	0.592	0.120	4.914	**0.000**
	Demographic characteristics	Agreement with stricter traffic rules	0.465	0.047	9.897	**0.000**
	Demographic characteristics	Social desirability	2.369	0.135	17.525	**0.000**
	Attitude towards alcohol	Attitude towards speeding	0.199	0.010	19.557	**0.000**
	Attitude towards alcohol	Attitude towards distraction	0.312	0.011	27.413	**0.000**
	Attitude towards alcohol	Risk perception	-0.035	0.015	-2.282	**0.022**
	Attitude towards alcohol	Support for policy measures	-0.146	0.009	-16.429	**0.000**
	Attitude towards alcohol	Agreement with stricter traffic rules	-0.006	0.003	-2.195	**0.028**
	Attitude towards alcohol	Social desirability	-0.127	0.009	-14.307	**0.000**
	Attitude towards speeding	Attitude towards distraction	0.275	0.012	23.777	**0.000**
	Attitude towards speeding	Risk perception	0.005	0.014	0.343	0.732
	Attitude towards speeding	Support for policy measures	-0.124	0.008	-15.102	**0.000**
	Attitude towards speeding	Agreement with stricter traffic rules	-0.027	0.003	-9.596	**0.000**
	Attitude towards speeding	Social desirability	-0.210	0.010	-20.207	**0.000**
	Attitude towards distraction	Risk perception	-0.016	0.020	-0.802	0.423
	Attitude towards distraction	Support for policy measures	-0.156	0.011	-14.638	**0.000**
	Attitude towards distraction	Agreement with stricter traffic rules	-0.008	0.004	-2.064	**0.039**
	Attitude towards distraction	Social desirability	-0.175	0.011	-15.528	**0.000**
	Risk perception	Support for policy measures	0.344	0.025	13.946	**0.000**
	Risk perception	Agreement with stricter traffic rules	0.039	0.009	4.316	**0.000**
	Risk perception	Social desirability	0.151	0.025	5.970	**0.000**
	Support for policy measures	Agreement with stricter traffic rules	0.054	0.005	11.652	**0.000**
	Support for policy measures	Social desirability	0.291	0.014	20.676	**0.000**
	Agreement with stricter traffic rules	Social desirability	0.062	0.005	12.498	**0.000**
	Self_30_alcohol	Self_30_speeding	0.149	0.008	18.418	**0.000**
	Self_30_alcohol	Self_30_helmet	0.149	0.009	15.878	**0.000**
	Self_30_alcohol	Self_30_texting	0.163	0.007	24.138	**0.000**
	Self_30_speeding	Self_30_helmet	0.246	0.014	17.929	**0.000**
	Self_30_speeding	Self_30_texting	0.184	0.009	19.708	**0.000**
	Self_30_helmet	Self_30_texting	0.213	0.011	19.725	**0.000**
Goodness-of-fit measures		CFI	0.933			
		TLI	0.925			
		RMSEA	0.037			1.000
		SRMR	0.042			
		$\chi^2_{\text{[d.f.=845]}}$	7900.596			**0.000**

In a very interesting finding, the same unsafe attitudes towards speeding are correlated with fewer instances of texting while riding. This is arguably an indication of the fact that drivers are situationally aware of threats caused by handheld mobile phone use and reduce their speed accordingly (Caird et al., 2008), or inversely do not manipulate their phones with their hands while speeding. More unsafe attitudes towards distraction are correlated with more frequent riding without a helmet, riding while under the influence of alcohol and riding while texting as well.

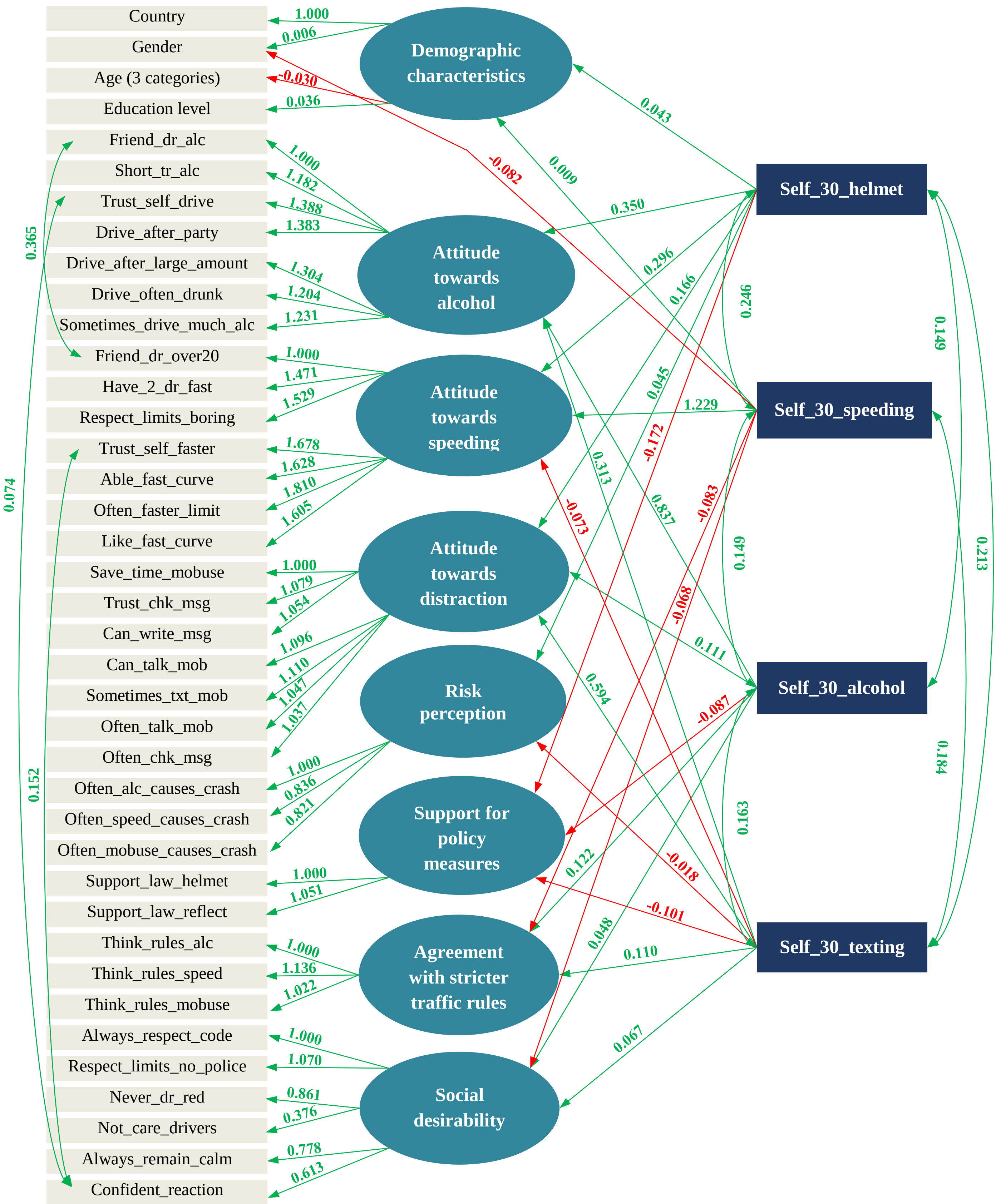

Figure 8: Path diagram of the ESRA2 SEM model for PTW behavior

Risk perception is a latent construct based on participant beliefs of whether the previous attitudes, i.e. alcohol, speeding and distraction constitute crash causes. As such, it is reasonably formulated with positive correlations with these dependent variables. Higher risk perception was found to be correlated with fewer instances of texting while riding a PTW, but also with more frequent instances of riding without a helmet. This result indicates that riders recognize texting as a higher risk than riding without helmet. Riders are considering that handheld mobile use while texting will hinder their riding performance and perception and will lead to more unsafe events rather than riding without safety equipment. It has been reported in a study related to the first version of ESRA that cyclists who feel very unsafe in traffic wear a helmet more often (Torfs & Meesmann, 2019). Conversely, the present finding is possibly a hint of overconfidence by riders, as they may believe they will not be needing their helmets.

Support with policy measures is a latent construct based on participant support for legal obligations for riders to use protective equipment such as helmet and reflective materials while riding. As such, it was reasonably correlated with fewer instances of riding without a helmet, riding while under the influence of alcohol and riding while texting. In other words, support with policy measures reflects safer riding attitudes of PTW riders overall.

Agreement with stricter traffic rules is a latent construct based on participant agreement on whether current penalties should be stricter. It is noteworthy that belief in stricter traffic rules was found to be correlated with fewer instances of rider speeding, but more frequent instances of riding while under the influence of alcohol. Riders may think that they could adjust their behavior if legal obligations are stricter, or do not believe they are personally affecting road safety by their choices, including alcohol consumption.

The final latent construct is that of social desirability, created based on the degree to which riders act in relation to whether these actions will be witnessed and evaluated by other road users. It reflects a separation of rider actions from the perception of others, or, in similar terms, the consistency of driver actions regardless to any other road users witnessing them. This awareness to appear socially desirable appears to be correlated with fewer instances of riding without a helmet but more instances of riding while under the influence of alcohol and texting while riding. There is a possibility that for riders, social desirability is connected with peer pressure, thus they engage in riding under the influence from a desire of acceptance. A similar desire can be the explanation of texting while riding, which could also denote that the rider is pursuing more social activities.

Several covariances are also quantified in the SEM framework. If respondent riders have friends who are more likely to drive after alcohol consumption in their respective social circles, then these friends are more likely to also exceed speed limits in residential areas by over 20km/h. Another, perhaps intuitive, finding is that riders that trust themselves to drive after alcohol consumption or riders who trust themselves while riding significantly faster than the speed limit, have more confidence in their overall driving abilities and the manner in which they react in different situations. It should also be mentioned that the majority of covariances modeled between the latent variables is reasonable and anticipated (e.g. higher risk perception increases the support for policy measures). The few isolated instances of unexpected results may be considered corrections of the SEM model for the existing positive relationships that might have been overestimated.

Equally importantly, the dependent variable covariances are all positive and statistically significant. This indicates that a rider who will engage more frequently in every single one of the four examined unsafe riding behaviors is more likely to also engage in all the others as well.

6. Conclusions

The present research aimed to provide a thorough, overarching structure of relationships correlating four unsafe PTW rider stated behaviors (riding after alcohol consumption, speeding, helmet use and texting) with several self-reported attitude parameters and factors regarding rider perspectives on traffic rule strictness and social desirability. To that end, data from the second version of the E-Survey of Road users' safety Attitudes (ESRA2) were utilized, which provided a broad sample encompassing 5,958 respondent riders from 32 countries. A SEM was fitted as the most appropriate tool that could incorporate theoretical latent variables in a multiple-input, multiple-output framework.

The contribution of this research is the examination of a multitude of beliefs and attitudes and their correlation with four unsafe rider behaviors using the broad ESRA2 participant sample. Numerous statistical relationships were discovered and quantified correlating the four examined unsafe rider behaviors with eight latent variables. These latent variables served to meaningfully represent unobserved theoretical constructs expressing (i) demographic profiles, (ii) attitudes towards risk factors, such as alcohol, speeding and distraction while riding, (iii) positive attributes towards road safety, such as risk perception, support for policy measures, agreement with stricter traffic rules and (iv) social desirability, based on the degree to which rider behaviors are affected by witnesses.

The entire scientific process conducted within this research provided answers to the scientific questions set in the Introduction. Specifically:

1. The overarching structure of relationships correlating various unsafe stated PTW rider behaviors can be appropriately captured by SEM.
2. PTW self-declared inputs be converted to meaningfully represent unobserved theoretical constructs expressing the four aforementioned theoretical constructs.
3. Several statistical influences of self-reported attitude parameters, rider perspectives on traffic rule strictness and social desirability on unsafe PTW behaviors were detected and quantified.

The SEM output also confirmed the initially set a-priori hypotheses: stated PTW rider behaviors are indeed simultaneously correlated with the examined unobserved theoretical constructs in the majority of cases, with minor exceptions as shown by the path diagram of Figure 8. Furthermore, unsafe PTW rider behaviors were found to be positively correlated with each other, meaning that a driver who engages in one unsafe behavior is more likely to engage in the other behaviors as well.

Overall, reasonable and intuitive relationships were obtained both for the creation of latent variables from the predictors (i.e. the ESRA2 questionnaire responses) and from the correlations of the unsafe behaviors on the latent variables. For instance, the support for legal obligations for riders to wear a helmet (ESRA2 question) is positively correlated with support for policy measures, a latent variable negatively correlated with three out of four unsafe behaviors (i.e. riding under the influence of alcohol, riding without a helmet and texting while riding) in turn. Additional discovered relationships describing intercorrelation between unsafe behaviors indicate that road safety strategies may be successful if they adopt a more aggregated approach to target unsafe behavior overall, rather than targeting only speeding while riding, for instance.

Naturally, the present research is not without limitations. The ESRA2 questionnaire yields self-reported data on behaviors or attitudes on various road safety aspects. Self-reported data from questionnaire replies have known deficiencies in terms of accuracy and lack of direct observation capabilities (Kelley et al., 2003) and response bias (Rosenman et al, 2011). Response bias may manifest as desirability bias, misunderstanding of the questions and recall error (Choi & Pak, 2005). However, in the framework of this study, the four main questions about PTW riders' self-declared behavior provide a clear behavioral criterion and the answers are drawn from a recent time period. It can therefore be reasonably expected that misunderstanding problems and recall errors may be limited. The inclusion of countries with different characteristics in the same model could be considered an additional limitation of the present research. In this study, countries were grouped together; however any variations of the included variables across the studied countries remained uncaptured by the aggregate-level SEM of the present study. The different purposes and patterns of PTW use between countries are not taken into account within the present framework, and would require additional data to be mathematically represented in the models.

These limitations can provide impetus for future research efforts. The literature appears to be lacking a thorough comparative review dedicated on the fluctuations of the PTW rider behaviors examined in the present research, namely alcohol use, helmet use, mobile phone use and protective clothing use. Such an analysis could comparatively examine how these behaviors are influenced by regional variations of relevant rules, requirements, enforcement level, social and cultural norms, rider education, environmental and economic conditions and any other relevant factors. It would also be quite interesting for future research examining risky PTW rider behaviors to group the countries or regions based on specific characteristics such as common features in legislation, level of enforcement, or road safety key performance indicators. Subsequently, separate models can be developed for each group which will allow for additional comparisons between groups, based on the coefficient/significance of variables, for instance. Alternatively, regional variations of factors can be controlled for using appropriate model structures. For instance, spatial analysis of rider behaviors could incorporate local or regional variations as spatially structured and unstructured random effects. Another example is mixed-effect modelling allowing for random intercepts/variable coefficients on a regional level.

Despite the aforementioned limitations, the authors believe that present results are valid and informative on an aggregate level, given the broad multi-country study sample of ESRA2. Overall, the present study provides an overarching snapshot of and as such is useful to plan and support road safety policies with considerable impacts and benefits, especially for global or high-level road safety initiatives.

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