Identifying Psychological Factors of E-Bike Riders' Traffic Rule Violating Intention and Accident Proneness in China

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Abstract

This paper aims to understand and predict electric bike (e-bike) riders' traffic rule violating intention and accident proneness using self-report survey data of over 2,000 e-bike riders in Shanghai. An extension of the theory of planned behavior (TPB) is proposed for this purpose which integrated seven new psychological factors (moral norm, perceived risk, conformity tendency, self-identify, descriptive norm, legal norm, and past behavior) alone with three basic variables (attitude, subjective norm, and perceived behavioral control) in the original TPB. Structural equation models were estimated to understand the impacts of different TPB variables on traffic rule violating intention and accident proneness. Model estimation results show that the proposed model framework can better explain e-bike riders' traffic rule violating intention and accident proneness compared to the original TPB. These findings can be used by policy-makers to design traffic safety management countermeasures that target identified psychological variables for reducing e-bike riders' traffic rule violating intention and accident proneness.

INTRODUCTION

Electric bike (e-bike) ownership and usage have skyrocketed over the past decade. In 2016, over 200 million e-bikes were on China's road and 3 million more were sold in the same year compared to just a few thousand in 1998 (Cherry and Cervero, 2007; Zuev Zuev, 2019). E-bike has become a popular mode choice for many travelers, especially for those who live in small-to-medium-sized cities such as Nantong, Jiangsu province, where the average income is relatively low and the public transit system is underdeveloped. According to Nantong Urban Transport Development Annual Report, over 40% of trips in the downtown area of Nantong in

2017 were made using e-bikes (NUTDAR). E-bike represents a relatively cheap, convenient, flexible, and dependable transportation mode for door-to-door travel compared to using transit and car. It can also travel faster than most modes of transportation for short-distance travel when the road is relatively congested during peak hours.

Despite the benefits of using e-bikes, the total number of accidents and fatalities involving e-bike riders have also increased drastically in the past decade. Between 2013 and 2017, around 56,200 traffic accidents were caused by e-bike riders resulting in 8,431 fatalities, 63,400 injuries, and direct property losses of 111 million-yuan in China. In Jiangsu province, more than 50% of e-bike-involved traffic accidents and over 40% of e-bike-involved fatalities were caused by e-bike riders' traffic rule violating behavior (RTAASR). Such behavior includes red-light running, speeding, riding on motor vehicle lanes, riding against the direction of traffic, and unsafe lane changing behavior, etc.

Great efforts have been made on combating increasing e-bike-involved accidents. Several recent studies aimed to understand the factors that contribute to e-bike riders' traffic rule violating intention and behavior. Most of such studies focused on one of the traffic rule violating intention or behavior, among which red-light running behavior received noticeable attention. Gender and age are two sociodemographic factors that were found to statistically significantly affect e-bike riders' traffic rule violating intention or behavior. Most of the studies found that male e-bike riders are more likely to perform red-light running behavior (Yao and Wu, 2012; Yang et al., 2018). Some of the previous studies attempted to identify psychological factors contributing to e-bike riders' traffic rule violating behavior. Yao and Wu (2012) showed that e-bike riders' risk perception has a statistically significant impact on the "aberrant riding behavior" (i.e., give a sudden beak, weave through traffic), and they suggested implementing behavioral interventions that influence risk perception can be beneficial to reduce such behavior. Yang et al. (2018) proposed an extension to the theory of planned behavior (TPB) to identify psychological factors that affect e-bike riders' intention to run against red light using hierarchical regression models and proposed some intervention strategies that targeted at the identified factors. However, their study only considered the intention to perform one of the e-bike riders' traffic rule violating behavior, and the types of psychological factors included in the study were also limited.

Apart from studies that focused on understanding factors that affect traffic rule violating intention and/or behavior, another category of studies aims at understanding factors affecting the likelihood of having accidents. Sociodemographic factors such as gender, age, education level and years of active driving have been identified to statistically significantly affect the likelihood of having accidents (Mohammadi 2009). Several studies also delved into the effect of high-risk behaviors on the frequency and severity of accident-involved drivers, in which high-risk behaviors including aberrant driving behaviors and alcohol or drug use (Parker et al., 1995; Özkan et al., 2006). However, few studies aimed at understanding factors that affect accident proneness which can be defined as drivers who have the tendency to experience more accidents than otherwise identical individuals. To the best of our knowledge, none of the previous studies

have investigated psychological factors that affect e-bike riders' accident proneness, or have explored the relationship between e-bike riders' traffic rule violating intention and accident proneness.

This paper aims to examine the impacts of psychological factors on e-bike riders' traffic rule violating intention (VI) and accident proneness (AP) using a proposed extension of TPB (see Figure 1). The theory of planned behavior (TPB) is a social psychological model developed by Ajzen (1991), which has been widely used to study drivers' traffic rule violating intention and other related behaviors, including speeding (Chan et al., 2010; Chorlton et al., 2012) and drinking -driving (Moan and Rise 2011; Zhou et al., 2012).

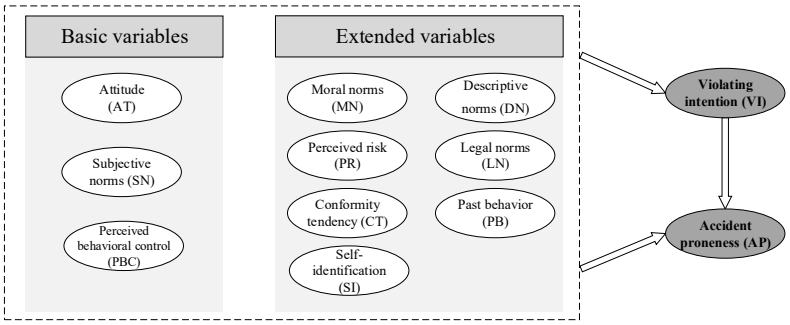

Figure 1 The proposed TPB framework extension for e-bike riders' traffic rule violating intention and accident proneness

In the proposed TPB extension, three variables (attitude (AT), subjective norms (SN), and perceived behavioral control (PBC)) existed in the original TPB are defined as follows. Attitude represents an e-bike rider's favorable/unfavorable view of traffic rule violating behavior. Subjective norms refer to the perceived view of his/her important referents (e.g., family members and friends) on approving/disapproving traffic rule violating behavior. Perceived behavior control is an e-bike rider's perceived ability to perform or not to perform traffic rule violating behavior. Seven new variables integrated in the proposed extension are variables that have been identified in various studies which contribute to e-bike riders' red-light running behavior, pedestrians' road crossing behavior, drivers' fatigued driving behavior, texting behavior while driving, and driving under influence of alcohol, which are similar to e-bike riders' traffic rule violating behavior. Moral norms (MN) presents an e-bike rider's belief that traffic rule violating behavior is inherently right or wrong. Perceived risk (PR) is the perceived risk of traffic rule violating behavior. Conformity tendency (CT) and self-identification (SI) present the easiness that an e-bike rider can be influenced by ambient riders (e-bikers or cyclists) to change his/her behavior and his/her self-identified rider type (an aggressive rider or a cautious rider), respectively. Descriptive norms (DN) and legal norms (LN) are defined as the degree of an e-bike rider's resembling traffic rule violating the behavior of his/her important referents and perceived legal consequence (e.g., punishment) of traffic rule violating behavior. Past behavior (PB) reflects the number of times an e-bike rider performed traffic rule violating behavior in the past given period.

To capture the impacts of psychological factors on e-bike riders' traffic rule violating intention and accident proneness, a survey for self-identified e-bike riders in China is designed. Participants were asked to report their traffic rule violating intention in a designed scenario and accident proneness in terms of the number of e-bike accidents they had and injury severity in the past three years. Questions were also asked to capture ten psychological factors in the proposed framework (Figure 1). Using structural equation models (SEMs) to obtain an optimal model for predicting traffic rule violating intention and accident proneness, also investigate the direct/indirect effects and mediating effects of TPB variables in this optimal model. Based on model estimation results, safety countermeasures are proposed to target different psychological factors that affect e-bike riders' traffic rule violating intention and accident proneness to reduce e-bike related accidents and promote road safety.

METHODS

Variables and measures

To understand psychological factors that affect e-bike riders' traffic rule violating intention and accident proneness, an experiment is designed using self-reported on-site and online questionnaires. In the survey, participants who often use e-bikes were asked to answer a wide range of questions related to each component of the proposed model framework (Figure 1) under a designed scenario. Under this scenario, participants were "riding an e-bike to work/school or need to be at a place on time" and they are "running late". They were asked about their intention to violate traffic rules (e.g., running red lights, speeding riding, riding in a motor vehicle lane, riding in opposite directions, or changing lane randomly). Their accident proneness was measured based on the number of times they suffered accidents and injury severity in the past three years. The questions related to various psychological factors in the proposed model framework are designed by previous studies (Evans and Norman, 2003; Zhou et al., 2009; Zhou et al., 2010; Kim, 2018; Yang et al., 2018; Potard et al., 2018; Shi et al., 2018). The finalized questionnaire is a 27-item scale using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree".

Procedures and Participants

The formal survey was conducted in on-site and online questionnaires. Moreover, only participants with more than 3 years of e-bike riding experience are screened out to finish the self-report questionnaires. According to the Regulation on the Implementation of the Road Traffic Safety Law of the People's Republic of China in 2017, people who are 16 years old or above can ride e-bikes in China. Thus, the participants must be e-bike riders who are 19 years old or more.

Prior to the formal survey for this study, a pilot survey with a small total of 54 participants was performed in on-site questionnaires to make sure that each item in the questionnaire was easily comprehensive and assess the average time of completing one survey. We conducted Cronbach's alpha (α) correlation test and principle component analysis (PCA) to retain those reliable and valid items which were through the tests.

After the pilot survey, the formal survey was carried out in Shanghai, China in May 2018. One for on-site questionnaires, to ensure the participants were e-bike riders and had enough time to complete the questionnaires, we selected the non-motorized parking lots of superstores and shopping malls to conduct the face-to-face surveys by professional surveyors and provided some small gifts to compensate for participants' time occupied. The face-to-face survey takes approximately 8-10 min to complete. One for online questionnaires, we published the online questionnaires and collected the survey data using an online survey application (www.wjx.cn). To ensure the validity of the online data obtained, the participants who set the same IP-address were forbidden to repeat the questionnaires. The online survey can be finished about in 10 min. In this survey, the total number of on-site and online questionnaires collected weas 896 and 1532 respectively. The complete and valid questionnaires were 2326 after excluding 102 invalid questionnaires.

Data analysis

Preliminary data analysis of the TPB variables were conducted by using descriptive statistics and Pearson correlations. Next, SEMs were utilized to predict e-bike riders' violating behavioral intention and accident proneness regarding the basic TPB variables and extended TPB variables, and understand the direct effects and mediating effects of the TPB variables on violating behavioral intention and accident proneness.

RESULTS

Data reliability and validity

For each construct, Cronbach's alpha (α) correlation test was used to compute the internal consistency of the items for evaluating the reliability of the survey data. The closer a Cronbach's alpha (α) is to 1, the stronger the internal consistency of the items in the construct. Cronbach's alpha (α) ranged from 0.72 to 0.88, which were more than 0.70, indicating the internal consistency of each construct was strong. Principle component analysis (PCA) was utilized to calculate the confirmatory factor analysis (CFA) which assesses a priori hypothesis on what items should be associated with what factors for evaluating the validity of the collected data. PCA identified every single component accounting for 75%-95% of the variance, suggesting acceptable validity of the data. Table 1 presents the descriptive statistics of the psychological variables.

TABLE 1 Mean and S.D. of the score for each item

Variable	Item	Mean (S.D.)	Variable	Item	Mean (S.D.)
	AP 1	3.87 (1.53)		PBC 1	3.81 (1.24)
AP	AP 2	3.42 (1.76)	PBC	PBC 2	4.35 (1.31)
	Mean	3.65		Mean	4.08
VI	VI 1	1.85 (1.20)	MN	MN 1	4.32 (1.25)

	VI 2	2.01 (1.51)		MN 2	4.11 (1.19)
	Mean	1.93		Mean	4.22
	AT 11	-1.34 (1.33)		PR 1	4.76 (1.42)
	AT 12	3.76 (1.27)	PR	PR 2	4.55 (1.33)
	AT 21	-0.87 (1.38)		Mean	4.66
AT	AT 22	4.01 (1.41)		CT 1	3.84 (1.18)
	AT 1= AT 11×AT 12	-5.16 (4.81)	CT	CT 2	4.50 (1.22)
	AT 2= AT 21×AT 22	-3.42 (4.39)		Mean	4.17
	Mean (AT 1 and AT 2)	-4.29		SI 1	4.59 (1.06)
	SN 11	-1.08 (1.01)	SI	SI 2	4.37 (1.26)
	SN 12	4.21 (1.37)		Mean	4.48
	SN 21	-0.86 (1.15)		DN 1	4.36 (1.39)
SN	SN 22	3.98 (1.52)	DN	DN 2	4.19 (1.12)
	SN 1= SN 11×SN 12	-4.58 (3.26)		Mean	4.28
	SN 2= SN 21×SN 22	-3.53 (3.87)		LN 1	2.28 (1.33)
	Mean (SN 1 and SN 2)	-4.06	LN	LN 2	2.01 (1.07)
PB	PB 1	4.61 (1.27)		Mean	2.15

Results of the structural equation modeling

To evaluate the predictive power of the proposed E-TPB framework and two model frameworks in the literature (i.e., the original TPB framework (O-TPB) and an extension TPB proposed by Yang et al. (2018) with the addition of accident proneness (Y-TPB)), were used as the baseline comparators. Path analysis was conducted to test the degree of fit of these models proposed to the obtained data using the Lagrange Multiplier Test. Modification indices consist of CMIN/df, RMSEA, GFI, NFI, IFI, CFI, and TLI. Furthermore, path analysis was performed to evaluate the significance of the direct effects of the TPB variables on behavioral intention, as well as of the mediating effects on accident proneness using maximum likelihood estimation. The goodness-of-fit and predictive power indexes for the three models are shown in Table 2. The final model (E-TPB model) is presented in Figure 2.

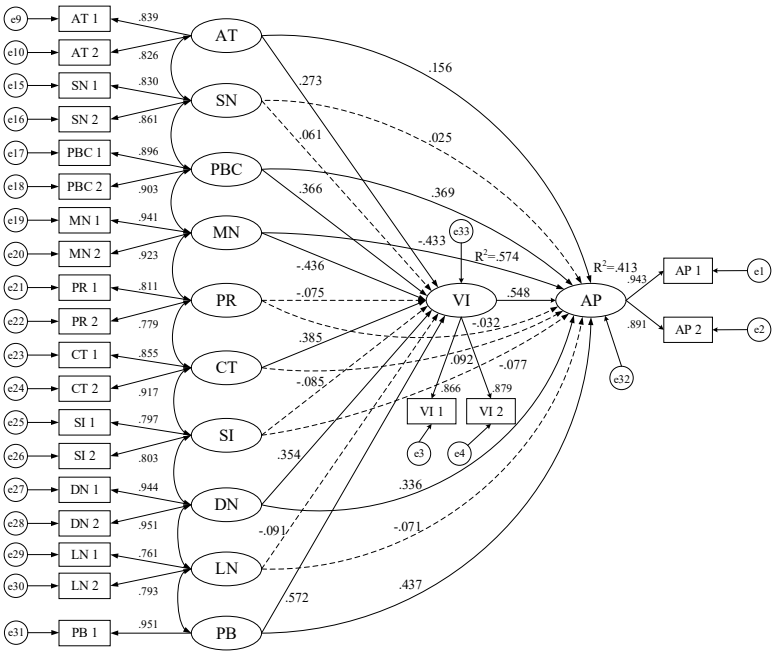

Figure 2 Path analysis with standardized coefficients for the proposed framework

TABLE 2 The goodness-of-fit and predictive power indexes for three models

Index	O-TPB model	Y-TPB model	E-TPB model
CMIN/df	2.154	1.726	1.542
RMESA	0.073	0.051	0.042
GFI	0.945	0.964	0.973
NFI	0.924	0.955	0.961
IFI	0.933	0.950	0.957
CFI	0.927	0.958	0.965
TLI	0.915	0.931	0.944
R^2 (VI)	0.292	0.436	0.574
R^2 (AP)	0.195	0.327	0.413

DISCUSSION

Predictors of traffic rule violating behavior and accident proneness

The path analysis results showed that subjective norms on the three basic variables had no significant effect on traffic rule violating intention, which was consistent with the results related to driving behavior and red-light running (Yang et al., 2018; Zhou et al., 2012; Shi et al., 2018). This is mainly because e-bike riders' families and friends generally approve of legal or right riding behavior and struggle against illegal or wrong riding behavior, which caused a low standardized coefficient of subjective norms. The other two basic variables of attitude and perceived behavior control were positively correlated with traffic rule violating intention. In terms of attitude, e-bike riders intended to take a risk to commit traffic rule violating if the behavior can save time or raise efficiency, in line with some studied results (Yang et al., 2018;

Shi et al., 2018). With respect to perceived behavior control, under the current traffic conditions in China, since it is easy and pervasive to perform traffic rule violating, resulting in the stronger behavioral intention, which was in line with some studied results (Moan and Rise 2011; Zhou et al., 2012). In light of the mediation analysis, subjective norms had no indirect effect on accident proneness, while traffic rule violating intention had mediated the positive effects of attitude and perceived behavior control on accident proneness.

Among the seven extended variables, moral norm, conformity tendency, self-identify, descriptive norm and past behavior exerted a significant impact on traffic rule violating intention, and these variables indirectly influenced accident proneness by promoting traffic rule violating intention. Moral norms had a significantly negative impact on behavioral intention. The finding was consistent with previous researches on driver speed behavior and e-bike riding behavior (Sutton 1998; Özkan et al., 2006). Also, a higher level of the moral norm could lead to weaker accident proneness.

E-bike riders who showed a higher tendency toward social conformity had stronger traffic rule violating intention, as well as had greater accident proneness, due to that they were more easily to be influenced by the surrounding riding behavior. Some related studies found similar conclusions, indicating that pedestrians with higher conformity tendency had greater intention to cross against the red light while others were crossing against the red light (Shi et al., 2018). The main reason could be that following the crowd with running a red light would make the individual pedestrian feel much safer, including life safety and security without punishment. E-bike riders have homologous psychological traits. Following the riding crowd to perform traffic rule violating behavior, including running red lights, speeding riding, riding in a motor vehicle lane, riding in a opposite directions and changing lane randomly, etc., make the individual rider feel safer because drivers would slow down for a riding crowd rather as compared to one single rider, and feel that they are not easily punished by traffic police. The findings were inconsistent with Yang et al. (2018). Yang et al. (2018) proposed that conformity tendency had no significant impact on e-bike riders' red-light running. The reason why e-bike riders were less likely to run the red light in groups could be that e-bike can cross the intersection against the red light in a high speed when there was a traversable space-time gap in traffic flow, instead of following the others to do so (Yang et al., 2018).

Descriptive norm contributed a positive influence on traffic rule violating intention and accident proneness, revealing that e-bike riders' families and friends who often conducted legal or right riding could reduce the likelihood of riders' traffic rule violating behavior and accident proneness. In the Y-TPB model and E-TPB model, subjective norms exerted no significant effect on traffic rule violating intention and accident proneness as compared with the O-TPB model. In other words, riding behavior of riders' families and friends is more influential on riders' intention than whether or not they approve of the behavior. A descriptive norm was always a significant predictor of pedestrians' illegal traffic behavior. For example, the individual pedestrian had a higher intention to imitate families' and friends' traffic behavior (Sutton 1998).

Nevertheless, Yang et al. (2018) investigated that e-bike riders' red-light running behavioral intention was not influenced by their families' and friends' behavior.

As expected, past behavior had a positive impact on the behavioral intention and accounted for an additional 13.8%, 8.6% to the explained variance for behavioral intention and accident proneness respectively in the E-TPB model. Compared with Yang et al. (2018)'s study, the present study integrated some extended variables, including legal norm and past behavior, into the TPB model, in which past behavior significantly improved the predictive power and interpretability for e-bike riders' traffic rule violating intention. The finding indicated that e-bike riders with more traffic rule violating behavior in the past had greater accident proneness, and were expected to commit traffic rule violating more often than others with fewer past behaviors.

It is logical to believe that individuals perceive the risk of what they are doing they will avoid doing so. In the current study, perceived risk had no significant impact on traffic rule violating intention and accident proneness, which was inconsistent with previous studies (Mohammadi 2009; Chan et al., 2010). Zhou et al. (2009) summarized studies on pedestrians' violating crossing and revealed that perceived risk was a significant predictor of low magnitude. Whereas, Zhou et al. (2016) found that perceived risk was not a significant variable in predicting pedestrians' violating crossing. Therefore, the impact of perceived risk on illegal traffic behavior was not clear (Shi et al., 2018). Chorlton et al. (2012) investigated that individuals generally had unrealistic optimism towards risk or disease, resulting in that perceived risk contributed a weak impact on some behaviors or intentions. In our study, the means of perceived risk was 4.66 (value range is 1-5), and about 72% of the participants assessed perceived risk as 4 or 5, indicating that most e-bike riders usually regarded traffic rule violating behavior as unsafe or easily injured traffic behavior. However, there were still a large number of e-bike riders who performed traffic rule violating behavior, indicating that we did not need to further emphasize the danger or risk of traffic rule violating behavior in the intervention strategies.

No evidence was found for the significant effect of self-identify on traffic rule violating intention and accident proneness. Among several studies on riding speed behavior, the results revealed that the motorcyclists who regarded themselves as "speeder" had a stronger intention to ride at a high speed (Chorlton et al., 2012). It's worth mentioning that the impact of self-identify on predicting pedestrians' violating crossing behavior was still unclear. Evans and Norman (2003) highlighted that self-identify was significantly correlated with pedestrians' road crossing decision. On the contrary, Zhou et al. (2009) found self-identify was not a significant predictor of pedestrians' road crossing intention. A plausible reason is that non-motorized vehicle or motorized vehicle users self-identify are greatly influenced by social desirability and external conditions, causing that self-identify always is inaccuracy and bias and has an unstable impact on some traffic behaviors.

The legal norm was also not significant. Kim (2018) revealed that legal norms had no significant impact on the behavior of texting while driving, and found that a banning law of texting-while-driving behavior could not change drivers to consciously and actively avoid such dangerous behavior in a short-term effect. Legal norm was not a significant predictor, which did

not mean that legal norms had no effect on traffic rule violating behavior and accident proneness, whereas revealed that laws could not only focus on formulating traffic laws, but also on the strict implementation and efficient management. To reduce e-bike riders' traffic rule violating ratio and accident proneness, it is necessary to improve the on-site enforcement frequency and punishment severity for such behavior.

Implications of developing safety countermeasures

Understanding the effects of the psychological factors on e-bike riders' traffic rule violating intention and accident proneness, were able to facilitate more effective traffic safety interventions, and support countermeasures to be tailored for a specific e-bike rider group. The results demonstrated that attitude, perceived behavior control, moral norm, conformity tendency, descriptive norm and past behavior exerted significant influence on traffic rule violating intention and accident proneness. Therefore, we developed some traffic safety management countermeasures and psychological interventions targeted at the predictors.

In this study, since attitude significantly affected e-bike riders' intention and accident proneness, the safety education should emphasize the benefits of traffic rule violating behavior (e.g., saving time or reaching destination quickly) was not worth the risk. With respect to perceived behavior control, we could take some traffic safety management countermeasures. More specifically, we can integrate Radio Frequency Identification (RFID) into e-bike license plates, combined with traffic cameras, to achieve dynamic monitoring and automatic capture of e-bike riders' traffic rule violating behaviors along with the whole road segments and intersections. These countermeasures would strengthen off-site law enforcement and exposure of illegal riding, and improved the perception of the difficult to commit traffic rule violating behavior. Moral norms and conformity tendency could be corrected by means of safety education as well. With respect to conformity tendencies, we can enhance the off-site law enforcement against the conformity groups of traffic rule violating by using the RFID technology; Furthermore, taking riding in opposite directions as an example, the continuous arrow marking were suggested to set on the non-motorized vehicle lanes for strengthening the riding direction, which may reduce the phenomenon of riding in opposite directions in groups. The aforementioned results revealed that e-bike riders' behavior was easily influenced by their important referents' (e.g. family members and friends) behaviors, so the safety education should inform the e-bike riders that if they riding legally or properly, others, as well as their family members and friends would follow or imitate their behaviors, which means they are protecting themselves while protecting their families and friends. Younger e-bike riders had a more positive attitude towards traffic rule violating behavior, so safety publicity and education for them could be an effective means to reduce the behavior intention and accident proneness. In fact, school-based education is an essential means to change or correct individual attitudes, especially to correct children's and younger people's attitudes. Another finding of this study was that e-bike riders who had the professional driving training and passed the driving tests committed less traffic rule violating behavior in the past. It gives us a revelation that if e-bike riders are required

to attend e-bike riding training and pass some riding tests, riders' traffic rule violating intention and accident proneness could be reduced.

CONCLUSIONS

The current study aims to understand and predict e-bike riders' traffic rule violating intention and accident proneness within the extended TPB. We conducted SEMs to uncover the impacts of the basic TPB variables and the extended TPB variables on traffic rule violating intention and accident proneness. In the basic TPB model, attitude, subjective norm, and perceived behavioral control were significant predictors. After adding the extended TPB variables into the model, the subjective norm was no more significant, whereas moral norm, conformity tendency, descriptive norm and past behavior among the new variables showed a significant influence on the behavior intention and accident proneness. The final model explained 57.4% of the variance for behavioral intention, and 41.3% of the variance of accident proneness. In particular, a newly added factor named past behavior enhanced the additional 13.8%, 8.6% to the explained variance for behavioral intention and accident proneness respectively. The predictive power and interpretability for e-bike riders' traffic rule violating intention in this study was higher than previous study on e-bike riders' red-light running intention (Yang et al., 2018). Compared with the other studies, this study was first to investigate e-bike riders' accident proneness. The mediation analysis results pointed out that these six identified psychological variables exerted significantly indirect effects on accident proneness expressed in a mediator of traffic rule violating intention, which means that e-bike riders' accident proneness could be explained and predicted by these variables. The final findings could support to develop some traffic safety countermeasures, such as off-site law enforcement based on the RFID technology, safety psychological education, e-bike riding training and tests, etc., to correct e-bike riders' behavior and reduce the incidence of these road traffic casualties involving e-bikes.

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