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INSIGHTS INTO EXPERIENCES AND RISK PERCEPTION OF RIDERS OF FAST E-BIKES

Abstract

In Switzerland, e-bikes are becoming increasingly an issue for road safety. The aim of this study was to investigate the cognitive components associated with riding behaviour among riders of fast e-bikes. For this purpose, a model with seven predictors for (self-reported) riding behaviour was developed. In addition, the influence of various control variables was examined. All variables were collected using a questionnaire. 2,158 riders of fast e-bikes participated in the study. With risk perception regarding the higher speed of e-bikes, feeling of invulnerability and perceived behavioural control in general and in regard to speed, four factors turned out to be significantly associated with riding behaviour. Other than expected the directions identified in these associations indicated, that the cognitions tended to reflect the behaviour shown rather than to influence behaviour. Respondents seemed to have inferred their invulnerability, their behavioural control and the risk associated with speed from their riding behaviour. Significant control variables to predict riding behaviour were age, gender, frequency of e-bike use and riding experience with a conventional bicycle. Recommendations for further research are discussed.

Keywords and topics: E-bike, speed, traffic safety, survey, risk perception

Research domain: Transport safety

I. Introduction

1. Background

E-Bikes are vehicles similar to bicycles, but equipped with an electric motor that assists the rider's pedalling up to a certain speed. Higher speeds can only be achieved by muscle strength. In Switzerland, two classes of e-bikes with pedal-assist are available. So-called "slow" e-bikes support pedalling up to 25 kph and have an engine power up to 500 W. "Fast" e-bikes provide assistance up to 45 kph and have a maximum power of 1000 W. Both types are legally classified mopeds. In recent years, the e-bike market in Switzerland has increased strongly. From 2007 to 2013, annual sales of e-bikes grew from below 10,000 to 50,000. In 2013, nearly one-third of the sales were fast e-bikes. E-bikes are primarily bought by middle-aged customers (average age of purchaser between 47 and 51) (Buffat, Herzog, Neuenschwander, Nyffenegger, and Bischof, 2014; Haefeli, Walker, and Arnold, 2012). In an online survey, e-bike owners stated that they travelled an average of around 2,600 km a year on their bikes. For the most part, e-bike trips seem to be a substitution for car trips (on average, almost 1,000 km per person), for public transport (570 km) and for conventional bikes (420km) (Buffat et al., 2014).

While e-bikes have many advantages such as flexibility or ecological and economic benefits, they also pose some dangers. Compared to conventional bicycles, e-bikes are capable of higher speeds, which lead to longer braking distances, errors of judgement by other road users and more serious injuries in the event of an accident. Not surprisingly, as sales of e-bikes have increased, the involvement of e-bikes in crashes has also increased. Between 2011 and 2013 the number of e-bike riders severly injured or killed on Swiss roads has risen by more than 70 %. In comparison to conventional bicycles, there are more serious accidents registered due to loss of control of the e-bike (single accidents) than due to collisions. This suggests that not only do other road users underestimate the speed of e-bike riders, but e-bike riders themselves also misjudge the risk factor speed and fail to ride defensively enough.

Road user behaviour is considered to be an important determinant for road safety (Horswill and Helman, 2003; Näätänen and Summala, 1976). Significant correlations were found between risky driving behaviour and involvement in accidents or near misses (Iversen and Rundmo, 2004). For the purpose of accident prevention, it is therefore important to know which psychological factors influence driving behaviour and which factors contribute to a safety-oriented driving style. In this regard, various theories emphasize the influence of cognitive components. One factor to which important significance is often attributed is the perception of risk (an overview is given in Ranney, 1994). Another factor being discussed is perceived behavioural control (Paris and Broucke, 2008; Wallén Warner and Åberg, 2008), a component of the theory of planned behaviour (Ajzen, 1991). So far, the effects of cognitive factors on driver behaviour have primarily been studied in road safety research on car drivers. The only studies that specifically relate to e-bike riders were found in China with much younger samples than the average age of e-bike riders in Switzerland (Bai, Liu, Guo, and Yu, 2015; Weinert, Ma, Yang, and Cherry, 2007; Yao and Wu, 2012; Zhang, Zhang, and Qi, 2013).

Accordingly, the present study aims to investigate which cognitive components are associated with riding behaviour among e-bike riders in Switzerland.

2. Research Questions

A model for predicting (self-reported) riding behaviour was developed based on a literature review on the topics of e-bikes, riding behaviour and risk competence as well as based on theoretical considerations. The model is shown in Figure 1. The assumed influential factors are on the right. In addition to risk perception and perceived behavioural control, the following factors were included in the model: knowledge of accident occurrence of e-bikes, perspective taking (the ability to take others' perspective) and feeling of invulnerability.

Various control variables whose possible influence should also be checked are listed on the left. The aim of this study is to examine whether the influential factors assumed are indeed significantly associated with riding behaviour and to determine the direction of the association. In addition, the goal is to investigate whether a correlation can be demonstrated between (self-reported) riding behaviour and accident rates. Beside these theoretical questions, knowledge of legal regulations, helmet usage, rate of riding with lights and the most common travel purpose are of interest at a descriptive level.

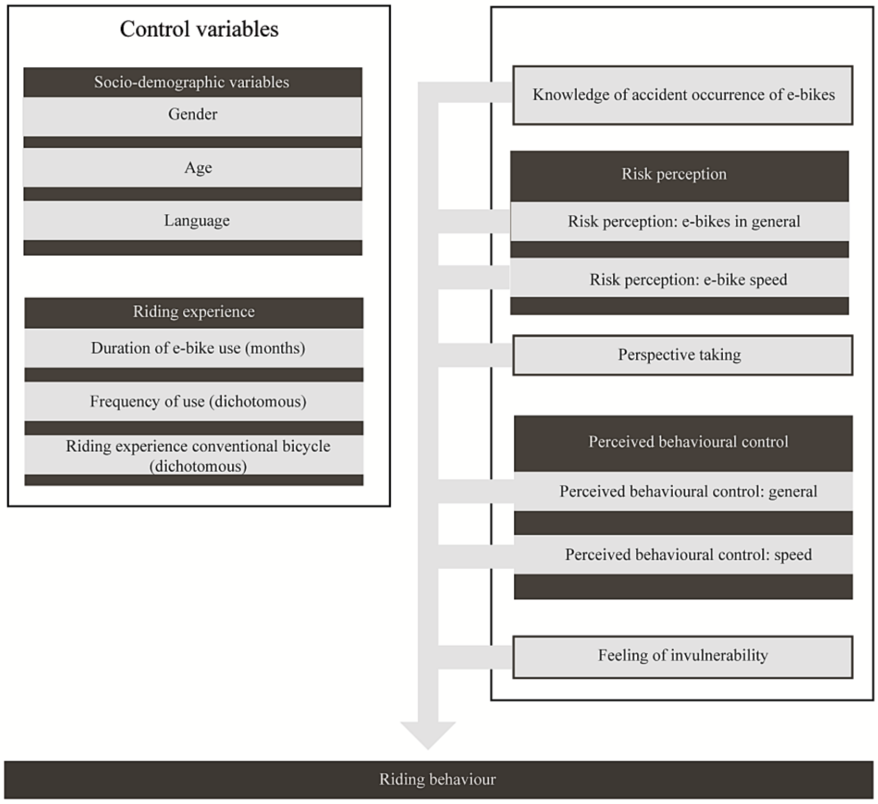

Fig. 1: Model with assumed influential factors

II. Methods

1. Data

The information of interest was collected by means of a paper questionnaire. The survey period covered was one month (June 2014). In order to obtain the addresses of e-bike riders, all of Switzerland's 26 road traffic authorities were approached. All owners of fast e-bikes (pedal assistance up to 45 kph) are registered with these authorities because they are classified as mopeds and require a driving licence and a number plate. The request guaranteed that the data would be used only once and in anonymous form. Six road traffic authorities expressed their willingness to participate and supplied a total of 9,894 addresses. A random sample of 40% was drawn from these, which resulted in 3,957 people being contacted. As an incentive, a postcard for participation in a prize draw for two iPads was enclosed with the questionnaire. 2,247 people returned the completed questionnaire. This corresponds to a response rate of 56.8%.

2. Questionnaire

The questionnaire collected the influential factors assumed in the theoretical model (see section I) and the control variables. Because no existing scales could be found, new scales to measure the assumed influential factors had to be developed. The verification using factor analysis led to perceived behavioural control and risk perception being divided into two factors (both general and speed).

In the final version of the questionnaire, each of the seven factors contained 2-5 items. With the exception of knowledge of accident occurrence of e-bikes, for each factor the scores of the single items were summed into a single index. The single item scores ranged from 1 = strongly disagree to 4 = strongly agree. The internal consistencies of the different scales have to be considered as low. The highest Cronbach's alpha was $\alpha = .656$, the lowest $\alpha = .328$.

Knowledge of Accident Occurrence of E-bikes. To measure respondents' knowledge of accident occurrence of e-bikes, the frequency of four types of e-bike accidents had to be estimated (*single accident, collision in a roundabout, collision when overtaking, collision at a junction*). The scores ranged from 1 = very rarely to 5 = very frequently. The responses to collisions were compared with the response to single accidents. If the single accident was identified as "more frequent", 1 point was awarded, if it was rated as "equally frequent", 0 points were awarded and "less frequent" received -1 point. In the end, all the points were added ($\alpha = .789$).

Risk Perception: E-bikes in general. Perception of risks of e-bikes in general was determined by three questions: *"If you can ride a regular bike safely, then you can also ride an e-bike safely (recoded)", "Accidents are more likely with an e-bike than with a regular bike", "Riding an e-bike is more dangerous than riding a regular bike"* (α = .650).

Risk Perception: E-bike Speed. Awareness of risks relating to the higher speed of e-bikes was measured by means of the following items: *"e-bikes entice people to go fast, even where it's dangerous".* What particular hazards are e-bike riders exposed to? *"Higher speeds in comparison to regular bikes", "Longer stopping/braking distances in comparison to regular bikes"* (α = .557).

Perspective Taking. To measure people's ability to take others' perspective, respondents were presented with questions on other road users' problems with e-bike riders: "*I don't think it matters to other road users whether I'm riding an e-bike or a regular bike (recoded)", "I think that other road users sometimes find it difficult to spot me in traffic", "Other road users overlook e-bike riders", "Other road users underestimate the speed of e-bike riders"* (α = .619).

Perceived Behavioural Control: general. Respondents' subjective conviction of having the e-bike under control in general was ascertained with the following items: *"I feel that I can safely master my e-bike in all situations", "In certain traffic situations, riding an e-bike becomes an event beyond my control (recoded)"* (α = .328).

Perceived Behavioural Control: Speed. Two questions were used to ascertain whether e-bike riders believed they had their speed under control: *"I find it difficult to judge how fast I'm going on my e-bike (recoded)", "I don't always manage to ride at an appropriate speed (recoded)"* (α = .514).

Feeling of Invulnerability. Two items measured people's belief of being invulnerable on an e-bike: *"When I ride my e-bike, mastering road traffic without an accident is my responsibility", "I don't think that much can happen to me while riding my e-bike"* (α = .390).

Riding Behaviour. Five items were used to ascertain whether e-bike riders had a safety-oriented riding style: *"Even if I have right of way, I always check very carefully to make sure that other road users have seen me before I continue", "I always comply with the traffic rules", "My most important principle when riding my e-bike is to ride very carefully and deliberately".* The scores for these three items ranged from 1 = strongly disagree to 4 = strongly agree. In addition, riding style had to be assessed in two ways: *riding style: restrained – racy (recoded). Riding style: careful – brisk (recoded).* The scores ranged from von 1 = restrained or careful to 5 = racy or brisk (α = .656).

In addition to the variables listed in the model, the following were also investigated: riders' knowledge of legal regulations, riding with lights, helmet usage, the most frequent trip purpose, riding experience with a conventional bicycle and accident experience. The questionnaire contained a total of 45 questions.

3. Sample

To ensure that respondents had had some experience with e-bikes, all those participants who, according to their own statements, did not yet have a minimum of one month's riding experience or did not own an e-bike themselves were excluded. Although only fast e-bikes are registered with the road traffic authorities, some people reported that they rode a slow e-bike. These were also excluded from the sample, since the difference between fast e-bikes and conventional bicycles is more distinct than with slow e-bikes. People with too many missing values were also excluded.

The sample finally comprised 2,158 people. 50.3% were men, 49.7% women. The mean age was 50.13 years (SD = 11.4). The youngest person was 14, the oldest 87 years old. 87.9% completed the questionnaire in German, 12.1% in French. On average, participants had used their e-bikes for 36.59 months (SD = 32.8).

4. Data Analysis

The statistical analyses were carried out using SPSS 22. To verify the associations assumed in the model, a multiple linear regression analysis (enter method) was calculated. The comparison of the model variables between people with and without accident experience was determined by a t-test for independent samples, while the relationship between riding behaviour and accident rate was determined by means of correlation (Spearman).

III. Results

1. Descriptive Statistics

Riding Experience Conventional Bicycle, Rate of Riding with Lights, Helmet Usage, Main Trip Purpose. Most of the respondents (60.8%) indicated to have regularly ridden a conventional bicycle prior to using an e-bike. Only 9.5% had virtually no experience with a regular bike. 92.0% stated that they complied with mandatory helmet-wearing legislation and always wore one when riding their e-bike; only 2% rarely or never wore one. During the day, 23.3% of the participants always switched on their e-bike light, 40.1% never rode with a light in the daytime. During the warm months, the majority of respondents rode their e-bike several times a week: 35.3% rode almost daily, 40.4% several times a week. The e-bike was most commonly used to travel to and from work or school (60.3%), followed by leisure-time trips (26.0%).

Trip Duration and Frequency of Use. According to the respondents, an average e-bike ride lasted 42.14 minutes (SD = 39.2). This average length of time depended on how often people used their e-bike. People who rode their e-bike almost every day made average trips of 26.18 minutes (SD = 19.1), while those who only rode several times a month took far longer trips (66.73 minutes, SD = 51.7).

Single Items to measure Predictors. The majority of respondents felt it was important to ride safely and cautiously (90.4%). Most participants (74.5%) knew that the stopping distance for e-bikes was longer and that their speed was higher than for conventional bicycles. 96% of the participants even agreed with the statement that other road users underestimated the speed of e-bike riders. However, many might have overestimated their ability to control their e-bike and its speed at all times. There were only a few extreme manifestations in the assessment of one's own riding style. Most of the respondents allocated their riding style accordingly to one of the middle categories. Between the two poles of restrained – racy, the tendency was towards racy; between the two poles of careful - brisk, the tendency was towards “careful”.
When asked to estimate the most frequent accident causes among e-bike riders, participants identified the greatest danger of collisions happening at intersections due to other road users' failure to give way. Collisions at roundabouts due to right of way violations were also assessed as frequent. In contrast, single accidents / falls, were somewhat underrated and assessed as less frequent.

Knowledge of Legal Regulations. Respondents were well-informed about mandatory helmet use law for fast e-bikes (97.7%). In contrast, the minimum age of 14 for riding e-bikes was less well known (56.3%). 67.6% were aware of compulsory use of the bike lane. 75.7% knew that riders of slow e-bikes don't have to wear helmets.

Accident Experience. Most participants had not yet had an accident with their e-bike up to the time of the survey. If there had been an accident, it was more often a single accident / fall than a collision. About 16% of respondents had had at least one single accident while nearly 5% had experienced a collision. The distribution of the number of accidents experienced is shown in Figure 2. Taking riding experience into account, single accidents amounted to an average accident rate of .09 (SD = .27) per year and collisions to a rate of .02 (SD = .16). This means that, each year, around four out of fifty e-bike riders experienced a single accident and one was involved in a collision.

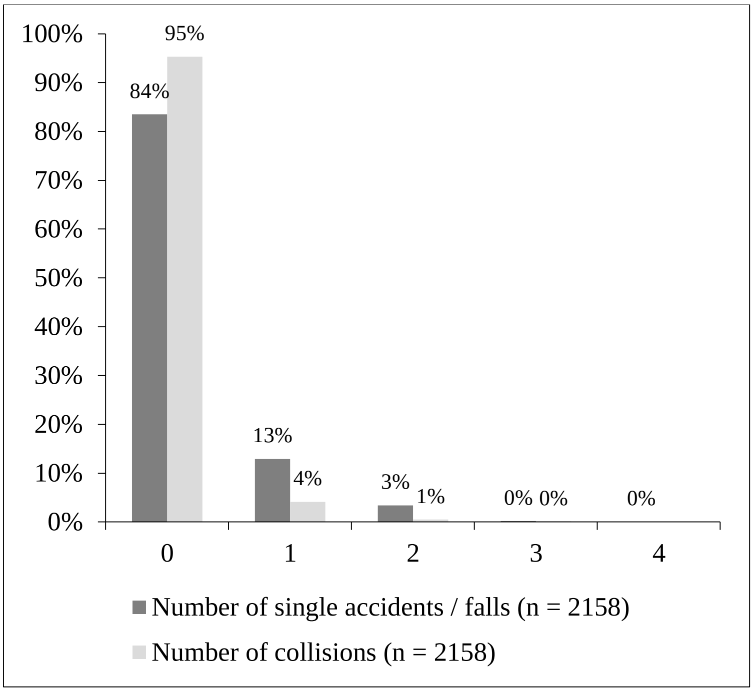

Fig. 2: Accident experience. Number of single accidents and collisions

Overview of Scales. The means, standard deviations, minimum and maximum of all scales are shown in Table 1. The riding behaviour scale served as the dependent variable, the other 7 scales as predictors (see model in section I).

Table 1. Means, standard deviations, minimum, maximum of all scales

Scales	M	SD	Min	Max
Knowledge of accident occurrence of e-bikes	-0.18	2.15	-3.00	3.00
Risk perception: e-bikes in general	7.43	2.00	3.00	12.00
Risk perception: e-bike speed	8.76	1.82	3.00	12.00
Perspective taking	12.28	2.26	4.00	16.00
Perceived behavioural control: general	5.38	0.87	2.00	8.00
Perceived behavioural control: speed	5.56	1.32	1.00	7.00
Feeling of invulnerability	4.93	1.32	2.00	8.00
Riding behaviour	16.59	2.43	8.00	22.00

2. Model Verification: Predictors of Riding Behaviour

The multiple regression showed that self-reported riding behaviour is significantly associated with some of the variables collected. The results are shown in Table 2. The regression could explain 17% of the variance in self-reported riding behaviour. Effect size for the overall model was f^2 = .20, which corresponds to a small to medium effect according to Cohen (1992).

Table 2. Summary of multiple regression analysis for variables predicting riding behaviour

Scales	B	SE B	β
Knowledge of accident occurrence of e-bikes	.03	.02	.03
Risk perception: e-bikes in general	-.04	.03	-.03
Risk perception: e-bike speed	-.07	.03	-.06*
Perspective taking	-.02	.03	-.02
Perceived behavioural control: general	.14	.06	.05*
Perceived behavioural control: speed	.28	.04	.15***
Feeling of invulnerability	.12	.04	.07**
Control variables	**B**	**SE B**	**β**
Gender	-1.30	.10	-.27***
Age	.04	.01	.17***
Language	-.25	.16	-.03
Duration of e-bike use (years)	-.06	.03	-.04
Frequency of use (dichotomous)	.46	.12	.08***
Riding experience conventional bicycle (dichotomous)	.38	.11	.08***

Note: $F(13,1898) = 29.20$, $p = .00$, $R^2 = .17$, $f^2 = .20$. * p ≤ .05, **p ≤ .01, *** p ≤ .001

The strongest correlations were found between two control variables - gender and age. Women ($\beta = -.27$) and older people ($\beta = .17$) reported to ride their e-bikes in a more security-oriented manner than did men or younger people.

Of the assumed factors, only four were significantly related to riding behaviour. People who thought they had the speed of their e-bike (perceived behavioural control: speed, $\beta = .15$) and the e-bike in general (perceived behavioural control: general, $\beta = .05$) well under control, were more likely to ride in a safety-oriented way. According to their self-report, people who tended to feel more invulnerable rode more cautiously as well (feeling of invulnerability, $\beta = .07$). An inverse relationship was found between risk perception regarding e-bike speed and riding behaviour ($\beta = -.05$). Respondents who were more aware of the risk factor speed stated that they rode their e-bikes less cautiously. Knowledge of accident occurrence of e-bikes, general risk perception regarding e-bikes (risk perception in general) and the ability to take others' perspective, however, were not associated with self-reported riding behaviour.

In addition to gender and age, two other significant predictors were found in the control variables. People who rode e-bikes less frequently (frequency of use, $\beta = .08$) and those who had less riding experience with conventional bicycles ($\beta = .08$), reported to ride e-bikes more cautiously.

To check whether accident experience had an impact on cognitive variables and riding experience, the same regression was calculated a second time, but this time only included those people who had already experienced an accident (single accident or collision). The effect of gender was even stronger ($\beta = -.32$, $p < .001$). While various scales no longer showed any significant betas (frequency of exposure, riding experience conventional bicycle, perceived behavioural control: general, feeling of invulnerability), the knowledge of accident occurrence scale was now significantly associated with riding behaviour ($\beta = 112$, $p < .05$). People who were more aware of the risk of single accidents accordingly rode more cautiously.

3. Comparison of Model Variables and Single Items between People with and without Accident Experience

T-tests for independent samples were performed (bilateral testing) for the comparison of the model variables between people with and without accident experience. Table 3 shows means and standard deviations for those model variables in which the two groups differed significantly.

Table 3. Means and standard deviations of the model variables with significant differences between groups with and without accident experience

	No accident experience		**Accident experience**	
Riding behaviour	16.70 (2.37)	*N* = 1678	16.19 (2.62)	*N* = 419
Knowledge of accident occurrence of e-bikes	-.26 (2.1)	*N* = 1691	.15 (2.13)	*N* = 424
Risk perception: e-bikes in general	7.37 (2.01)	*N* = 1699	7.66 (1.91)	*N* = 423
Perceived behavioural control: general	5.40 (.86)	*N* = 1693	5.29 (.87)	*N* = 418
Feeling of invulnerability	4.99 (1.33)	*N* = 1702	4.67 (1.26)	*N* = 421
	Control variables			
Age	50.50 (11.22)	*N* = 1711	48.66 (12.04)	*N* = 425
Duration of e-bike use (years)	2.91 (1.63)	*N* = 1712	3.59 (1.73)	*N* = 422
Frequency of use (dichotomous)	1.26 (.44)	*N* = 1721	1.18 (.38)	*N* = 423

People without accident experience claimed to exhibit safer riding behaviour than those with accident experience ($t(600) = 3.62$, $p < .001$). They also felt more that they had their e-bike under control (perceived behavioural control, $t(2109) = 2.252$, $p < .05$) and they were invulnerable (feeling of invulnerability $t(2121) = 4.50$, $p < .001$). Accident experience, however, was associated with higher risk awareness for e-bikes in general ($t(2120) = -2.722$, $p <.01$) and greater knowledge of accident occurrence of e-bikes ($t(2113) = -3.466$, $p < .01$). With regard to the duration of e-bike use, those who already had experienced an accident had been riding for about half a year longer than those without accident experience ($t(618) = -7.29$, $p < .001$).

Differences in perceived behavioural control and feeling of invulnerability were mainly attributable to two items: 66% of people with no accident experience claimed they felt they mastered their e-bike safely in all situations. The figure for those with accident experience was only 52%. Of the former, 34% thought that it was always their own responsibility to mastering road traffic without any accidents. Among the latter, only 24% were of that opinion. Those who had never experienced an accident were also inclined to think that you can safely ride an e-bike if you can safely ride a regular bike. 27% were absolutely of this opinion. The figure was only 17% for those with accident experience.

4. Relationship between Riding Behaviour and Accident Rate

In order to check whether riding behaviour is associated with accident rate, two bivariate correlations were calculated, one for single accidents and one for collisions. No significant association was found with riding behaviour ($r = -.032$, $p > .05$) for the accident rate for single accidents per year. However, a significance was found ($r = -.078$, $p < .001$) for the accident rate for collisions per year.

IV. Discussion

The aim of this study was to investigate the cognitive components associated with riding behaviour among riders of fast e-bikes in Switzerland. For this purpose, a model with seven predictors for predicting (self-reported) riding behaviour was developed. In addition, the influence of various control variables was examined. All variables were collected using a questionnaire.

The assumption that e-bike riders themselves misjudge the risk factor speed was not confirmed. The majority of respondents was well aware that the stopping distance for e-bikes was longer and the speed was higher than with conventional bicycles. That other road users underestimate the speed of e-bikers was affirmed by as many as 96% of the participants. However, in the regression analysis to predict riding behaviour, risk perception regarding the higher speed of e-bikes turned out to be secondary. The association with self-reported riding behaviour was only weak. It also went in the other direction, as would be expected at first sight. Those who were more aware of the dangers of speed rode their e-bikes less cautiously, according to their own statements.

The directions of the associations with the three other significant predictors also tended to be somewhat surprising at first glance. The feeling of being invulnerable related positively to riding behaviour. Those who felt more invulnerable, thus rode more cautiously. This finding is contrary to the theory that people who feel they are invulnerable, tend to behave rather riskily (i.e. (Chan, Wu, and Hung, 2010)). The two factors of perceived behavioural control (general and speed) were also positively related to riding behaviour. The more someone believed to have their e-bike in general and speed well under control, the more likely the person was to also state they rode in a safety-oriented manner.

The directions identified in the associations between these cognitive variables and riding behaviour indicate that the cognitions tend to reflect the behaviour shown rather than to influence behaviour. Respondents might have inferred their invulnerability, their behavioural control and the risks associated with speed from their riding behaviour: just because they always ride their e-bike cautiously, they always have control of the vehicle and think that they can hardly endanger themselves. People who ride more riskily, however, experience the dangers of e-bikes firsthand and develop a greater awareness of these dangers.

The other assumed influential factors - the risk perception regarding e-bikes in general, the ability to take others' perspective and knowledge of accident occurrence of e-bikes - were not associated with self-reported riding behaviour. Of the significant cognitive variables, the subjective belief of having speed under control (perceived behavioural control: speed) had the strongest association, followed by the perceived behavioural control in general and the feeling of being invulnerable.

However, self-reported riding behaviour was best predicted by two characteristics of the rider - age and gender. Compared with men and younger people, women and older people reported that they rode their e-bike in a more safety-conscious manner. With frequency of use and riding experience with a conventional bicycle, two other control variables were found to be significant predictors. People who rode an e-bike less frequently and people who had had less riding experience with a conventional bicycle before using their e-bike, stated that they ride their e-bike more cautiously.

Contrary to other research findings, the present study resulted in no significant relationship between riding behaviour and single accidents. In collisions, however, a significant but weak correlation was found. People who reported riding their e-bike less cautiously had a higher collision rate than people who reported riding in a more safety-oriented manner. The fact that no significant association could be found between riding behaviour and single accidents and the association was only weak with collisions, could be related to the fact that accidents are rare events and often result from a combination of factors.

All in all, this study offered an initial insight into how riders of fast e-bikes in Switzerland perceive the particular dangers of e-bikes and how they deal with them. Various cognitive factors related to riding behaviour were identified. Since there is a more likely tendency for the results to be interpreted in the sense that awareness of the risk factor speed and the feeling of invulnerability are derived from riding behaviour, no statements on any interventions can be made. It remains unclear whether a safety-oriented riding style could be achieved, for example, by increasing risk perception. Whether users’ riding style can be changed by means of appropriate measures would be another interesting research question in any case.

One important limitation of this study is the fact that users’ riding style was measured by means of self-reporting. Firstly, there is a risk of socially desirable responses, so that riding style appears to be safer than it actually is. Since the setting was anonymous, however, the effect should not have been too strong (Lajunen and Summala, 2003). Secondly, respondents might display response tendencies that pervade all the scales, the predictors as well as the scale on riding behaviour. This might have led to statistically significant associations that do not exist in reality. To verify the results of this study, the findings should therefore be validated by objective measurements of riding behaviour.

Further research is needed into which factors are associated with accident experience. For this purpose, the interplay of various factors should be taken into account and both cognitive variables as well as riding behaviour be included. Using longitudinal studies, the directions of the relationships might be examined more closely and assumptions about causality checked. Given the rarity of accidents, it appears meaningful to include near misses as well.

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