Relationships among Bicycle Rider Behaviours, Anger, Aggression, and Crashes in Finland

þÿ O Hern, Steve

2022-03-07

þÿ O Hern , S , Willberg , E , Fink , C & Useche , S 2022 , ' Relationship
Behaviours, Anger, Aggression, and Crashes in Finland ' , Safety , vol. 8 , no. 1 , 18 . https://doi.org/10.3390/safety8

http://hdl.handle.net/10138/342393
https://doi.org/10.3390/safety8010018

safety

MDPI

Article

Relationships among Bicycle Rider Behaviours, Anger, Aggression, and Crashes in Finland

Steve O'Hern [1,2,*], Elias Willberg [3,*], Christoph Fink [3,*] and Sergio Useche [4,5,*]

1 Transport Research Centre Verne, Tampere University, 33014 Tampere, Finland
2 Accident Research Centre, Monash University, Clayton, VIC 3800, Australia
3 Digital Geography Lab, Department of Geosciences and Geography, University of Helsinki, 00100 Helsinki, Finland
4 INTRAS Research Centre, Faculty of Psychology, University of Valencia, 46022 Valencia, Spain
5 Spanish Foundation for Road Safety (FESVIAL), 28004 Madrid, Spain
* Correspondence: steve.ohern@tuni.fi (S.O.); elias.willberg@helsinki.fi (E.W.); christoph.fink@helsinki.fi (C.F.); sergio.useche@uv.es (S.U.)

Abstract: Riding a bicycle is increasingly encouraged as a sustainable transport solution, especially in urban areas. However, safety concerns, both perceived and actual, can significantly lower the willingness to ride among the population. To support cycling planning and policy in the double task of increasing the levels of cycling while mitigating crash risk, there is a need to better understand the behaviours and attitudes of bicycle riders. In this manuscript, we study a cohort of Finnish bicycle riders through four questionnaires, the Cycling Behaviour Questionnaire (CBQ), Cyclist Risk Perception and Regulation Scale (RPRS), Cyclist Anger Scale (CAS), and Cyclist Aggression Expression Inventory (CAX). Our findings show low self-reported errors and violations, and high levels of knowledge regarding traffic rules among Finnish bicycle riders. Most participants report low levels of aggression, which is generally dealt with in constructive ways, while anger was most commonly a result of interactions with motor vehicles and less with other road users such as pedestrians. To further reduce the crash risk in cycling, our results point to the need for further separation between bicycle riders and motorised vehicles, and for the development of risk perception and positive behaviours among riders, particularly those engaging in risky behaviours.

Keywords: road safety; road user behaviour; cyclist; bicycle; behaviour questionnaire

Citation: O'Hern, S.; Willberg, E.; Fink, C.; Useche, S. Relationships among Bicycle Rider Behaviours, Anger, Aggression, and Crashes in Finland. *Safety* **2022**, *8*, 18. https://doi.org/10.3390/safety8010018

Academic Editor: Raphael Grzebieta

Received: 3 December 2021
Accepted: 4 March 2022
Published: 7 March 2022

1. Introduction

Transportation is a major source of global carbon emissions [1]. To meet the carbon reduction targets set in the Paris Agreement [2], society needs to reduce its reliance on private motor vehicles and fossil fuels while increasing the use of public transportation, walking, and cycling [1]. Private vehicles are responsible for many challenges to modern society, including congestion, pollution, and public health issues associated with living a sedentary lifestyle and road traffic crashes [1,3].

Encouraging a mode shift from private motor vehicles to bicycles offers a solution to many of these issues [1,3] with riding a bicycle being widely promoted as a sustainable transport solution [4,5]. However, despite the benefits offered by riding a bicycle, the potential dangers associated with road traffic crashes are often noted as a safety-related deterrent [6,7], particularly for risk-averse people and those with less experience riding a bicycle.

Globally, it is estimated that approximately 41,000 road traffic deaths involve a person riding a bicycle each year [8]. While the number of traffic crashes is decreasing in many OECD nations, the proportion of injuries involving a bicycle rider is increasing together with the growing popularity of cycling [9]. As such, road safety issues must be addressed,

which in turn may encourage more people to ride bicycles and increase participation in active (and healthier) travel modes [7].

In Finland, approximately 8% of trips are by bicycle [10]. On short trips in the range of 1–3 km, and especially in urban areas, the share can be higher, between 13% and 17% [11]. However, of all road users seriously or fatally injured in crashes (MAIS 3+), the share of cyclists is 31% [12]. Analysis of crash characteristics of those injured in single-bicycle crashes in Finland identified infrastructure and especially slippery road surfaces as the key reason (62.9%) for crashes [13]. Other identified causes included cyclist-related reasons such as braking mistakes (15.8%), problematic interactions with other road users (mainly avoidance of other users) (15.5%) and bicycle malfunction (5.2%). These factors are also common internationally and in other Nordic countries [14,15] while some studies also noted the role of latent factors such as travelling while under the influence of alcohol and illicit substances [14,15].

Various studies seek to understand the types of behaviours in which road users engage, and the frequency of engagement using a range of techniques including naturalistic studies, observations, and questionnaires. Much of the research conducted using questionnaires builds on Reason, Manstead, Stradling, Baxter, and Campbell's Driver Behaviour Questionnaire (DBQ) [16]. The DBQ measures two categories of behaviour related to errors (unintentional mistakes) and violations (deliberate behaviours that contravene road rules) [16]. The distinction of these behaviours is that they have unique psychological origins, and the underlying motivations require different road safety countermeasures. Building on the work of Reason et al., Useche et al. [17] initially developed and validated a cycling behaviour questionnaire (CBQ) on the basis of an international cohort of Latin American, European, and North American bicycle riders, both identifying key dimensions of violations and errors that describe risky bicycle riding behaviours, and introducing a third dimension describing "positive" behaviours that represent a range of protective behaviours and habits. In a further outcome, Useche and colleagues [18] investigated the association between behaviours and crashes, identifying increased crash involvement for those who engaged more often in risky behaviours. Conversely, in subsequent studies using the CBQ, positive behaviours were shown to have a protective effect when riding a bicycle, and to be negatively associated with errors and violations [19]. Engagement in positive and risky behaviours is influenced by road user's attitudes and awareness of road traffic rules, their knowledge of traffic norms or their risk perception, which are constructs measured using the Cyclist Risk Perception and Regulation Scale (RPRS) [20].

While many of the factors that increase crash risk, such as the existence, quality, and maintenance of the cycling infrastructure or errors by other road users, are outside of cyclists' own control, research demonstrated that attitudes towards traffic safety can help to mitigate risky behaviours among drivers and cyclists [20,21], and that road safety knowledge can be a protective factor for road traffic crashes. Conversely, road users with negative attitudes towards traffic safety are more likely to have a high propensity for risky behaviours [22]. Differences in risk perception among various cyclists may also play a role in cycling behaviours and attitudes, with females, for example, showing higher discomfort when cycling in mixed traffic [23,24]. However, the strength of these relationships differs by jurisdiction [19], and there is a need to further explore these relationships among different cohorts of bicycle riders.

Similar variations by jurisdictions were identified by Oehl et al. when comparing results from Australia, Singapore, China, and Germany while investigating cyclist anger using the Cycling Anger Scale (CAS) [25], which measures cyclists tendencies to experience situational or context-specific anger when interacting with other road users [26,27]. Oehl identified that interactions with drivers were consistently rated as the most angering when considering the four types of road user interactions measured in the CAS [25]. Thus, while riding a bicycle is promoted as a positive behaviour, interactions with other road users can occasionally make this unpleasant and anger-provoking, with research showing that people sometimes display this anger aggressively [28–30].

To measure bicycle rider aggression, Møller and Haustein (2017) developed the Cycling Anger Expression Inventory (CAX) to understand how people may express their anger and which situations result in aggression when riding a bicycle [28]. The CAX was adapted from an aggression measure used on drivers: the Driving Anger Expression inventory [31], short form [32]. Research using the CAX showed the frequencies of aggression when riding a bicycle, and confirmed differential relationships between anger and aggression. Bicycle riders tend to report most commonly dealing with anger in adaptive constructive ways [28,29]. Personal physical aggression is the least common anger expression; consequently this is reported infrequently by bicycle riders [28,29]. However, to date, the relationship between aggression and crashes has only been investigated among a small number of cohorts of bicycle riders.

In fact, to our knowledge, bicycle rider behaviours, attitudes, anger, and aggression are yet to be investigated in the Finnish population. Given the desire to increase the proportion of people riding bicycles while simultaneously reducing road trauma, understanding these constructs may aid in the development of targeted interventions that can help in reducing crash risks and improving safety while riding a bicycle. As such, the aim of this research was to investigate how factors presented in the CBQ, RPRS, CAS, and CAX (please see Section 2.2) influence crash involvement among a cohort of Finnish bicycle riders.

2. Materials and Methods

2.1. Procedure

A convenience sample of participants were recruited through an online advertisement between 17 and 27 May 2021 through two local urban-planning- and cycling-focused Facebook groups (Lisää kaupunkia Helsinkiin and Helsingin seudun pyöräilijät ry) with over 26,500 members altogether. Given that COVID-19 restrictions were in place during data collection, participants were asked to respond on the basis of their behaviour when national restrictions were not in effect. The survey was hosted on Google Forms and took approximately 20 min for participants to complete. Respondents completed the survey in Finnish. All participants were provided with an explanatory statement before commencing the survey, and they gave their informed consent before proceeding in the survey. Participants did not receive any reimbursement or incentives to complete the survey.

2.2. Materials

The survey comprised a number of previously validated questionnaires addressing aspects of cycling behaviour: the Cycling Behaviour Questionnaire (CBQ) [17], the Cyclist Risk Perception and Regulation Scale (RPRS) [20], the Cyclist Anger Scale (CAS) [25,27], and the Cyclist Aggression Expression Inventory (CAX) [28]. The validated questionnaires were translated into Finnish. Literal translations were used when possible. Transposition was used when English expressions did not exist in Finnish or the translation did not sound natural in Finnish. While the questions were translated to Finnish, they were not adapted to Finnish conditions. Participants were also asked a series of questions regarding their demographics, frequency of riding a bicycle, and number of traffic crashes while riding a bicycle over the past five years.

2.2.1. Cycling Behaviour Questionnaire

A 29-item version of the Cycling Behaviour Questionnaire (CBQ) developed by Useche et al. [17] was utilised to measure self-reported riding behaviours. The CBQ consists of three factors: errors representing unintended risky behaviours, violations representing intentional aberrant behaviours, and positive behaviours that represent protective factors against the occurrence of a crash. Each item is measured on a five-point Likert scale (0 = never, 2 = sometimes, 4 = almost always), where participants report how often they perform each behaviour while riding a bicycle. Previous applications of the CBQ demonstrated good

internal consistency and reliability of factors, with Cronbach's alphas ranging from 0.65 to 0.86 [17,19].

2.2.2. Cyclist Risk Perception and Regulation Scale

The Cyclist Risk Perception and Regulation Scale was used to measure participants risk perception and knowledge of traffic regulations while cycling. The RPRS consists of 12 items, where 7 items measure risk perception, and 5 items measure knowledge of traffic rules for bicycle users. Responses are provided on a five-point Likert scale: 0 = strongly disagree, 2 = neither agree nor disagree, and 4 = strongly agree. Previous applications of the RPRS demonstrated acceptable internal consistency with Cronbach's alphas ranging from 0.62 to 0.72 [19,20].

2.2.3. Cyclist Anger Scale

Participants' anger while riding a bicycle was measured using the Cycling Anger Scale [27]. The CAS includes 14 items, with each presenting a potentially anger-provoking situation while cycling that corresponds to four types of interactions with other road users, namely, car interactions, cyclist interactions, pedestrian interactions, and interactions with the police. Participants indicated the level of anger that would be provoked for each situation on a five-point scale (0 = none at all; 2 = a moderate amount; 4 = very much). Previous applications of the CAS showed acceptable reliability with Cronbach's alphas ranging from 0.67 to 0.87 [25,27].

2.2.4. Cyclist Aggression Expression Inventory

The frequency of an aggressive expression of anger by cyclists was measured using the Cycling Aggression Expression Inventory (CAX) [28]. Items on the CAX are assessed on a five-point scale to measure frequency (0 = never; 2 = about half the time; 4 = always). The CAX measures three broad types of anger expression: adaptive constructive responses, personal physical expressions of anger, and verbal expressions of anger. These three factors demonstrated good reliability with Cronbach's alphas ranging from 0.83 to 0.94 [28,29,33].

2.3. Participants

In total, 213 participants completed the online survey. To be eligible to participate in the study, respondents needed to indicate that they resided in Finland, were aged 18 or over, and rode a bike with some frequency.

Of the respondents, 45.1% identified as female (96), 51.6% identified as male (110), and 3.3% were either nonbinary or did not wish to report their gender identity (7). Participants' age ranged between 19 and 74, with a mean age of 43.7 (SD = 12.0) years. Most respondents were engaged in full-time work (171) and had completed a university degree (149) or studied at a technical school (42). Participants predominately lived in the Helsinki region (83.1%), with the remaining responses distributed throughout Finland.

When asked about their typical cycling habits, when not experiencing COVID restrictions, participants cycled for 6.5 h per week on average (SD = 4.7 h), with the average trip lasting 39.5 min (SD = 31.8 min). Participants commonly used a bicycle to travel to school or work (73.7%), leisure (90.6%), and for exercise and fitness (75.6%). Participants were also asked in how many crashes they had been involved over the past 5 years while cycling, regardless of severity. Over half of the respondents (58.2%) had not been involved in a crash, while a further 26.3% were involved in one crash, and 9.4% were involved in two crashes.

2.4. Analysis

Given that the electronic survey form only allowed for the submission of complete questionnaires, only complete responses were included in the analysis; therefore, there were no missing data, and data imputations were not necessary. After calculating the basic descriptive statistics and factor scores of the used instruments, reliability analysis

was undertaken to assess the Cronbach's alpha for each factor previously reported in the literature. To assess bivariate associations between the age, gender, CBQ, RPRS, CAS, and CAX factors, and the number of self-reported cycling crashes suffered by Finnish riders, Pearson correlations were used. Data were analysed using IBM © SPSS (Version 27; IBM Corp., Armonk, NY, USA) with alpha (α) set to 0.05.

3. Results

3.1. Cycling Behaviour Questionnaire

Table 1 provides a summary of the mean and standard deviation of items for each factor for the CBQ. Regarding risky behaviours, low mean scores were identified for all errors and violations, suggesting that they were rare behaviours among Finnish respondents. The violation with the highest mean score was associated with crossing the road at a crossing point even if the traffic light was red (red-light running), although this was still reported as a rare behaviour. The most common error was not observing a parked car leaving a space and needing to brake to avoid collision. However, this is likely a situation where the bicycle rider has priority over the motor vehicle, but increased awareness of the risk associated with this situation could reduce the likelihood of being involved in a collision, when motor vehicle drivers fail to see an approaching rider.

Table 1. Cycling behaviour questionnaire (CBQ) item scores.

Factor (Cronbach's Alpha)	Item	M (SD)
Errors (0.846)	Failing to notice the presence of pedestrians crossing when turning	0.27 (0.61)
	Not braking at a Stop or Give Way sign and being close to colliding with another vehicle or pedestrian	0.13 (0.44)
	Braking very abruptly on a slippery surface	0.56 (0.71)
	While I am distracted, I do not realise that a pedestrian intends to cross a crosswalk, and therefore I do not stop to let them do so	0.56 (0.67)
	Not realising that a parked vehicle intends to leave and consequently having to brake abruptly to avoid a collision	0.75 (0.94)
	When riding on the left side, not realising that a passenger is getting out of a vehicle or bus, and thus being close to hitting them	0.54 (0.83)
	Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, consequently having to brake	0.20 (0.55)
	Misjudging a turn and hitting something on the road, or being close to losing balance (or falling)	0.28 (0.60)
	Unintentionally hitting a parked vehicle	0.04 (0.39)
	Failing to be aware of the road conditions and falling over a bump, hole or obstacle	0.44 (0.61)
	Confusing one traffic signal with another, manoeuvring according to the latter	0.29 (0.65)
	Trying to brake but not being able to use the brakes properly due to a poor hand positioning	0.23 (0.61)
Violations (0.701)	Cycling under the influence of alcohol and/or other drugs or hallucinogens	0.58 (0.74)
	Riding against the traffic flow (wrong way)	0.56 (0.78)
	Zigzagging between vehicles when using a mixed lane	0.74 (0.96)
	Handling potentially obstructive objects while riding a bicycle (food, packages, etc.)	0.35 (0.67)
	Feeling that sometimes I'm going at a higher speed than what I should be	0.82 (0.93)
	Crossing what appears to be a clear crossing, even if the traffic light is red	1.83 (1.18)
	Carrying a passenger on my bicycle without it being adapted for such a purpose	0.11 (0.48)
	Having a "race" with another cyclist or driver	0.31 (0.71)
	Unintentionally crossing the street without looking properly, thus making another vehicle brake to avoid a crash	0.20 (0.52)
	Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly	0.31 (0.60)
	Braking suddenly and being close to causing an accident	0.22 (0.50)

Table 1. *Cont.*

Factor (Cronbach's Alpha)	Item	M (SD)
Positive behaviours (0.616)	I stop and look at both sides before crossing a corner or intersection	2.80 (1.25)
	I try to move at a prudent speed to avoid sudden mishaps or braking	3.00 (0.99)
	I usually keep a safe distance from other cyclists or vehicles	3.34 (0.73)
	When I use the bike path (or bike lane), I always use the indicated lane	3.70 (0.64)
	I avoid cycling under adverse weather conditions	1.90 (1.30)
	I avoid cycling if I feel very tired or sick	2.72 (1.20)

On the other hand, bicycle riders typically reported high levels of positive behaviours. The lowest mean score was avoiding riding in adverse weather conditions, however given the survey was undertaken in Finland, and adverse weather is common, it seems reasonable that this would not discourage many from riding. The highest mean score was for riding on a dedicated bike path or lane when one is available. Again, this is expected behaviour throughout Finland with many separated walking and cycling facilities that designate space for active modes of transportation. Reliability for the three factors in the CBQ was similar to previously reported scores [17,19], indicating acceptable internal reliability of each factor.

3.2. Cyclist Risk Perception and Regulation Scale

Table 2 summarises the item and reliability scores for the Cyclist Risk Perception and Regulation Scale. Reliability, measured using Cronbach's alpha, for the two items was lower than previously reported scores [19,20], indicating that items included in the scale do not provide a good representation of the underlying factors of knowledge of traffic rules and risk perception for this sample of Finnish participants. When considering knowledge of traffic rules, the lowest score was regarding pedestrian priority, indicating a reduced level of agreement with this statement. This item also had the lowest level of correlation with other items in the factor and when removed the Cronbach's alpha was found to increase, suggesting that the item may not fit well in the context of the Finnish road environment. This finding aligns with how the Finnish road environment operates, with cyclists required to give way to pedestrians at crossings. However, there are also many instances where cyclists and pedestrians share infrastructure, but pedestrians maintain an implicit right of way.

Table 2. Cyclist Risk Perception and Regulation Scale (RPRS) item scores.

Factor (Cronbach's Alpha)	Item	M (SD)
Knowledge of traffic rules (0.543)	I readily recognise traffic signals	3.50 (0.78)
	I know the basic rules governing other types of vehicles	3.57 (0.82)
	I believe that pedestrians should always have the priority, even towards cyclists	2.88 (1.14)
	I easily identify areas prohibited to traffic or bicycle parking	3.00 (1.01)
	Overall, I know the bicycle safety regulations of my city/town	3.54 (0.67)
	I am aware of the potential consequences of being involved in a crash, for example, with another vehicle	3.57 (0.82)
	I perceive potentially higher risks for my integrity when I ride a bicycle than when I am on board of a motorised vehicle	3.39 (0.95)

Table 2. *Cont.*

Factor (Cronbach's Alpha)	Item	M (SD)
Risk perception (0.503)	I am always aware of the other vehicles that surround me on the road	3.35 (0.75)
	I realise that there are signalling and infrastructure problems that can affect my safety	3.77 (0.57)
	I believe that being under the influence of certain substances (alcohol, illegal and/or prescribed drugs) affects my ability to ride well	3.81 (0.54)
	I am aware of the risks involved in using headphones and phones while I ride	3.78 (0.54)
	Riding in urban areas is especially risky, considering the number of vehicles and the complexity of the roads	2.68 (1.21)

For the other items in the scale, participants self-reported good knowledge of traffic rules, with most respondents either agreeing or strongly agreeing with the statements. Similarly, participants reported high levels of risk perception for all items. The lowest score was regarding the statement that riding in urban environments is risky, where there was only moderate agreement. This may be a result of the comparably bicycle friendly urban environment in Helsinki, where most respondents lived, and the large amount of cycling infrastructure, but Helsinki's cycling infrastructure could still be enhanced. As per the previous factor, removing this low-scoring item improved Cronbach's alpha, indicating that the scale may need to be refined when considering Finnish bicycle riders. However, this was beyond the scope of this study, and a larger more representative sample of participants would be beneficial to undertake factor analysis to validate this scale for Finnish cyclists.

3.3. Cyclist Anger Scale

Table 3 presents the item scores for the Cyclist Anger Scale (CAS) across the four factors of car interactions, cyclist interactions, pedestrian interactions, and police interactions. Generally, the results for the CAS aligned with previous international applications of the survey instrument [25,34]. Good reliability was demonstrated for each of the factors, however further research with a larger sample is warranted to confirm the factor structure for Finnish cyclists. The most anger-causing situations were due to interactions with cars, followed by cyclist, pedestrian, and police interactions. When compared to previous applications of the CAS, the Finnish cohort in this sample reported higher overall mean anger, compared to previous studies assessing Australian, Chinese, and Singaporean cyclists, although mean scores were lower than those of German cyclists [25,27,30,34].

Table 3. Cyclist Anger Scale (CAS) item scores.

Factor (Cronbach's Alpha)	Item	M (SD)
Car interactions (0.833)	A fast driving car overtakes you leaving very little space between you	3.53 (0.81)
	A car forces you off your path	3.38 (0.93)
	A car fails to give you the right of way	3.11 (0.98)
	A car overtakes you in a narrow lane	2.89 (1.06)
Cyclist interactions (0.756)	A cyclist overtakes you in a narrow lane	2.03 (1.08)
	A cyclist rides very quickly towards you and thereby obstructs you	2.74 (0.99)
	A cyclist forces you off your path	3.03 (0.97)
Pedestrian interactions (0.815)	A pedestrian blocks the bicycle lane	2.37 (1.02)
	Pedestrians are walking on the bicycle lane	1.78 (1.09)
	A pedestrian unexpectedly crosses the road in front of you	2.16 (1.05)
	A pedestrian is clearly and intentionally blocking the bike lane	3.32 (0.88)
Police interactions (0.835)	You are fined for cycling without lights	1.46 (1.15)
	You are fined for cycling on the wrong side of the road	1.55 (1.20)
	You are fined as your bicycle is considered not fit for the road	1.71 (1.24)

3.4. Cyclist Aggression Expression Inventory

Table 4 presents the results for the Cycling Aggression Expression Inventory (CAX). In line with previous applications of the survey instrument, the lowest mean scores were for personal physical aggressive expression of anger, which respondents rarely reported, while adaptive constructive ways of dealing with anger were the most common. In general, scores for all items were low, indicating low levels of aggression among the sampled cohort. Findings from reliability analysis align with previous applications of the questionnaire, demonstrating good internal consistency [28,29].

Table 4. Cyclist Aggression Expression Inventory.

Factor (Cronbach's Alpha)	Item	M (SD)
Adaptive Constructive ways of dealing with anger (0.793)	I accept there are frustrating situations	1.20 (1.07)
	I tell myself it's not worth getting mad at	1.91 (1.14)
	I tell myself to ignore it	1.18 (1.07)
	I think of positive solutions to deal with the situation	1.73 (1.10)
Verbally aggressive expressions of anger (0.816)	I make negative comments about the road user aloud	1.36 (0.90)
	I swear at the other road user aloud	0.55 (0.82)
	I yell at the other road user	0.83 (0.96)
Personal physical Aggressive expressions of anger (0.757)	I ride a lot faster	0.67 (1.01)
	I ride right up to the other road user	0.13 (0.47)
	I get off the bicycle and tell the other driver off	0.28 (0.69)
	I do to the other road users what they did to me	0.22 (0.62)
	I try to scare the other road user	0.06 (0.33)
	I get off the bicycle to have a physical fight	0.03 (0.31)

3.5. Bivariate (Pearson) Correlations

Bivariate correlations were performed for each factor in the four scales, self-reported crashes over the study period, and participant age and gender, as shown in Table 5. Considering participant age, statistically significant negative correlations were identified for

violations, and anger-provoking interactions with cars, pedestrians, and police, indicating that older cyclists were less likely to be angry when interacting with other road users, and were less likely to perform deliberate aberrant behaviours. At the same time, older participants were increasingly likely to engage in positive behaviours while riding.

Table 5. Bivariate (Pearson) correlations.

Factor	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Age (1)	1													
Gender (2) [1]	0.01	1												
Self-reported cycling behaviours and road safety skills														
Errors (3)	−0.09	−0.02	1											
Violations (4)	−0.30 **	−0.11	0.67 **	1										
Positive Behaviours (5)	0.15 *	0.25 **	−0.33 **	−0.50 **	1									
Knowledge of Traffic Rules (6)	−0.04	−0.04	−0.42 **	−0.36 **	0.18 **	1								
Risk Perception (7)	0.03	0.24 **	−0.43 **	−0.44 **	0.49 **	0.25 **	1							
Cycling anger and aggression subscales														
Car interactions (8)	−0.15 *	−0.06	−0.12	−0.06	0.02	0.13	0.30 **	1						
Cyclist interactions (9)	0.06	0.23 **	0.14 *	0.05	0.08	−0.05	0.05	034 **	1					
Pedestrian interactions (10)	–0.018 **	0.23 **	0.20 **	0.24 **	−0.04	−0.17 *	0.05	0.39 **	0.40 **	1				
Police interactions (11)	−0.14 *	0.03	0.25 **	0.25 **	−0.17 *	−0.17 *	−0.15 *	0.16 *	0.17 *	0.32 **	1			
Adaptive constructive (12)	0.02	−0.06	0.03	0.00	−0.16 *	0.09	0.01	0.09	0.09	0.02	0.02	1		
Verbally (13)	0.05	−0.09	0.32 **	0.29 **	−0.32 **	−0.06	−0.16 *	0.12	0.07	0.09	0.12	0.46 **	1	
Personal physical (14)	−0.07	−0.14 *	0.58 **	0.59 **	−0.43 **	−0.29 **	−0.45 **	−0.02	0.11	0.27 **	0.29 **	0.14 *	0.51 **	1
Cycling safety-related outcomes														
Total Crashes (15)	0.02	−0.09	0.34 **	0.27 **	−0.29 **	−0.18 **	−0.017 *	−0.03	−0.04	0.06	0.14 *	0.07	0.39 **	0.41 **

Notes: ** Correlation is significant at $p < 0.001$ level (2-tailed); * correlation is significant at $p < 0.050$ level (2-tailed). [1] Males as reference group. Due to small sample, responses from nonbinary participants were not included.

Gender differences were identified for risk perception and positive behaviours, with female participants reporting higher rates of positive behaviours. Similarly, there was a negative relationship between female participants and physically aggressive acts.

Both errors and violations were significantly associated with crash involvement. Similarly, participants who were more likely to express anger verbally or physically and be angered by police had a statistically significant correlation with crash involvement. Conversely, positive behaviours, knowledge of traffic rules and risk perception had a statistically significant negative relationship, suggesting a protective factor for these self-reported behaviours.

4. Discussion

The aim of this study was to investigate the association between crash involvement and self-reported bicycle riding behaviour among a cohort of Finnish bicycle riders. The study used previously validated questionnaires specific to riding a bicycle: CBQ, RPRS, CAS, and CAX. Findings indicate that numerous behaviours and attitudes are significantly correlated with crash involvement.

Across the applied questionnaires and cycling-related factors, Finnish riders tend to self-report low levels of negative behaviours and higher levels of positive behaviours. Findings from this cohort align with previous applications of the various survey instruments in Europe, South America, and Australia [18,19].

First, considering the CBQ, Finnish cyclists tended to report low levels of errors and violations when cycling. This was consistent with previous studies utilising the CBQ that demonstrated that people who ride bicycles tend to self-report low levels of risky behaviours [18,19]. The most reported violation was red-light running. This is a potentially

problematic behaviour, especially given correlation between violations and crash risk. This behaviour was observed in a range of observational studies in China, Italy, and Germany, with enforcement and education suggested alongside improvements to cycling infrastructure as potential means to address this behaviour [24,35,36]. There is already evidence that improvements to infrastructure, and particularly traffic light phases, are required in Helsinki, with excessive waiting times of over 200 s identified at some urban intersections [37]. Reductions in waiting times are likely to reduce the prevalence of this behaviour.

Regarding errors, braking abruptly on slippery surfaces and failing to be aware of road conditions were more commonly reported, and there were also low rates of cyclists avoiding riding during adverse weather conditions. These findings combined may highlight the need for increased awareness of the risks of winter riding, which is particularly relevant in Finland where a high proportion of single-bicycle crashes are a result of slipping during winter months [13]. Improved road and path maintenance would also help in reducing this risk, while cyclists can also install winter tyres to improve traction and reduce the risk of falls.

When considering the relationship between errors and violations, and self-reported crashes, significant positive correlations were identified. The third factor in the CBQ, positive behaviours, had negative correlation with crashes, indicating that positive behaviours have a protective effect. This finding supports the outcomes of previous applications of the CBQ, which demonstrated similar patterns for positive behaviours. Analysis of the CBQ indicates that both deliberate and unintentional risky behaviours represent a road safety concern for cyclists and highlighted the need for these behaviours to be addressed. Despite the correlation with crashes, it is noted that overall self-reported errors and violations were rare events for most participants.

This research also demonstrates that previously established relationships between CBQ factors and crashes are also present in Finland, and that avenues to encourage positive cycling behaviours should be promoted, particularly among male respondents who reported lower rates of positive behaviours. The significant relationship between violations and age could be used as an argument for rider training to concentrate on younger age groups. However, it could also be indicative of the general scepticism towards the authority of laws perceived as unjust in young people [38,39]. A common driver for both the rate of errors and violation, and the likelihood of crashes should not be ruled out. For example, poor infrastructure could have a particular impact on both factors. Further research should thus also investigate the potential geographical variation of positive and risky behaviours, and the related crash risk by differentiating the spatial distribution of cyclists and the cycling infrastructure in the analyses.

Like positive behaviours, respondents reported high levels of knowledge of traffic rules and risk perception when answering the RPRS. In fact, both factors were significantly correlated with positive behaviours, and demonstrated significant negative correlations with self-reported errors and violations. These findings align with previous applications of the questionnaire [19,20]. The findings again highlight the benefits of educating cyclists regarding traffic rules and developing risk perception skills.

Interestingly, there were no significant relationships between the factors of the RPRS and respondent age, which may provide an indication that programmes to develop these skills could be effective regardless of the target age group. However, further validation of the RPRS factors is required, and correlations should be cautiously interpreted.

To our knowledge, this study represents the first application of the Cyclist Anger Scale (CAS) and the Cycling Aggression Expression Inventory (CAX) in Finland. Analysis found that each factor demonstrated good internal reliability. When considering the CAS, the lowest scores were reported for interactions with police. This is in line with previous applications of the instrument in Singapore, Germany, China, and Australia [25], and with research conducted using the Driver Anger Scale [31]. There was a significant relationship between police interactions and crash involvement, indicating that those who were more

prone to anger due to police interactions were also more likely to have been involved in a crash over the past 5 years, but the strength of the relationship was low, and participants reported the lowest level of anger from police interactions. Again, it is plausible that the number of crashes and frustration induced by interaction with police are both driven by a common independent factor, such as the quality of infrastructure and the location and overall length of the travelled routes.

Conversely, the most anger-invoking situations involved interactions with car drivers, likely due to the risk of injury to the cyclist when these interactions occur [40], and in the light of the still ongoing fight over urban street space between the proponents of motorised and active modes of transport [41]. Again, findings are in line with previous applications of the survey instrument. Similarly, recent naturalistic studies highlighted that a high proportion of safety critical events involve interactions with motorised vehicle drivers [42], which may explain why they are a greater source of anger.

Analysis highlighted the negative relationships between age and self-reported anger for police, pedestrian, and car interactions. The findings of this research indicate that cyclists prefer to interact with other cyclists and pedestrians compared to motorised vehicles. This provides further justification for expanding the already comprehensive network of cyclist facilities that are present in many cities throughout Finland. For example, Helsinki already has over 1500 kilometres of cycling facilities with plans for further infrastructure development over the coming years. However, the need for further separation of cycling and motorised traffic in infrastructure development should be highlighted as a means to lower the risk of road conflicts in urban space, as well as to increase the attractiveness of cycling among risk-averse and less experienced populations [24,43].

Lastly, analysis of aggression using the CAX demonstrated that adaptive constructive means of dealing with anger were most common among participants, with aggression shown to follow a continuum that was found in applications of the CAX, with the most aggressive acts (physical aggression) being reported the least frequently; however, there were also significant positive relationships between both physical and verbal expressions of anger and crash involvement, suggesting that those riders who engage in these behaviours or feel compelled to engage in these behaviours by, e.g., insufficient infrastructure, may put themselves and others at risk. Further applications of the CAX by Stephens et al. [33] demonstrated that aggression among cyclists is more frequently expressed towards drivers compared to other cyclists or pedestrians, and there is scope to further explore these relationships in Finland.

Results of the CAX suggest that Finnish cyclists tend to deal with anger in constructive ways. Furthermore, the study demonstrates the typically high levels of positive behaviours exhibited among this cohort of cyclist and an associated strong knowledge of traffic rules and risk perception skills. Conversely, aberrant riding behaviours were rarely reported.

Limitations

There are several limitations in this research. The recruitment process for the study required participants to be over the age of 18 years. This excluded younger riders and limits the generalisability of the findings. While the study was available throughout Finland, there was a strong geographic bias towards responses from Helsinki, which was somewhat expected due to the population distribution across Finland. Further research is warranted using the survey instruments to gather a larger and more representative sample from across all of Finland. There is also a need to collect data from other jurisdictions using the survey to allow for cross-cultural validation of the survey instruments.

The study was also conducted as an online survey, which may have limited the ability for certain segments of the population to participate in the study. Again, this issue could be addressed in future applications of the survey instrument by the identification of a representative probabilistic sample, for example, by drawing a sample from the Population Information System by the Digital and Population Data Services Agency in Finland [44]. Collecting a larger sample would also allow for further statistical analysis of the survey

instruments, such as using confirmatory factor analysis to identify the most appropriate factor structures for Finnish population and structural equation modelling to understand the associations and inter-relationships between scales.

As with other previous applications of these survey instruments a noted limitation is that the findings are based on self-report. This is likely to have introduced a self-selection bias in the sample, with those with a strong interest in cycling more likely to participate. Similarly, self-report may introduce social desirability bias when responding. These issues may also be a factor due to the recruitment strategy as the study was advertised using two Facebook groups where participants have an interest in cycling.

The study highlights the relationship between crashes and rider behaviour; further understanding of collision mechanisms and the specifics of crashes by developing more detailed survey questions or through in-depth investigations would provide greater understanding of the crash risk factors. Similarly, behaviours exhibited by riders could be objectively measured and validated using observational or naturalistic study designs.

Lastly, the impact of COVID-19 restrictions that were in place during data collection may have shaped the respondents' perception of the risks they assume while cycling, despite being asked to respond on the basis of their behaviour before the restrictions.

5. Conclusions

Findings from this study represent the first application of various self-reported bicycle rider behaviour questionnaires in Finland. Overall, self-reported errors and violations were rare, and bicycle riders had high levels of knowledge regarding traffic rules. Further, low levels of aggression were identified, and that aggression was generally dealt with in constructive ways, while anger was most commonly a result of interactions with motor vehicles. We also confirmed previous relationships between positive and negative behaviours and crash risk.

Another relevant finding of this research was targeting how promoting positive behaviours among cyclists could be helpful to reduce crash risk. There is a need to gather more in-depth knowledge of crash characteristics and contributing factors to understand the more nuanced relationships between self-reported behaviours and crashes. Furthermore, while behavioural questionnaires are beneficial to understand general behaviours, they are not capable of capturing the subtleties of road user behaviour, and there is a need for complementary observational and naturalistic studies.

This represents an important area for future research where behavioural questionnaires could be coupled with naturalistic or observational studies to confirm the behaviours and frequency of engagement identified in these questionnaires while also developing a richer understanding of cyclist behaviours.

At the same time, this finding should not distract from the fact that all identified negative factors might also coincide with insufficient infrastructure. Improvements in active transport infrastructure and a more equal distribution of urban street space continue to provide the greatest, most effective, and most efficient lever to reduce conflict between road users and improve safety for cyclists and pedestrians.

Author Contributions: Conceptualization, S.O., E.W., C.F. and S.U.; methodology, S.O., E.W., C.F. and S.U.; formal analysis, S.O., E.W., C.F. and S.U.; writing—original draft preparation, S.O., E.W., C.F. and S.U.; writing—review and editing, S.O., E.W., C.F. and S.U. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. E.W. and C.F. received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101004590. E.W. has received support from the Amer Cultural Foundation, Finland [Sporttia Stadiin/Urban Exerciser project].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Banister, D. Cities, mobility and climate change. *J. Transp. Geogr.* **2011**, *19*, 1538–1546. [CrossRef]
2. UNFCCC Paris Agreement. *Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21st Session, 2015: Paris)*; UNFCCC Paris Agreement: Paris, France, 2015; Volume 4, p. 2017.
3. Stevenson, M.; Thompson, J.; de Sá, T.H.; Ewing, R.; Mohan, D.; McClure, R.; Roberts, I.; Tiwari, G.; Giles-Corti, B.; Sun, X. Land use, transport, and population health: Estimating the health benefits of compact cities. *Lancet* **2016**, *388*, 2925–2935. [CrossRef]
4. Pucher, J.; Buehler, R. Making cycling irresistible: Lessons from The Netherlands, Denmark and Germany. *Transp. Rev.* **2008**, *28*, 495–528. [CrossRef]
5. Willberg, E.; Salonen, M.; Toivonen, T. What do trip data reveal about bike-sharing system users? *J. Transp. Geogr.* **2021**, *91*, 102971. [CrossRef]
6. Daley, M.; Rissel, C.; Lloyd, B. All dressed up and nowhere to go?: A qualitative research study of the barriers and enablers to cycling in inner Sydney. *Road Transp. Res.* **2007**, *16*, 42–54.
7. Garrard, J.; Crawford, S.; Hakman, N. *Revolutions for Women: Increasing Womens Participation in Cycling for Recreation and Transport*; Deakin University: Burwood, Australia, 2006.
8. World Health Organization. *WHO Global Status Report on Road Safety 2018*; World Health Organization: Geneva, Switzerland, 2019.
9. Janstrup, K.H. *Road Safety Annual Report 2017*; Technical University of Denmark: Lyngby, Denmark, 2017.
10. Goel, R.; Goodman, A.; Aldred, R.; Nakamura, R.; Tatah, L.; Garcia, L.M.T.; Diomedi-Zapata, B.; de Sa, T.H.; Tiwari, G.; de Nazelle, A. Cycling behaviour in 17 countries across 6 continents: Levels of cycling, who cycles, for what purpose, and how far? *Transp. Rev.* **2021**, *42*, 58–81. [CrossRef]
11. Mannola, M.; Aavajoki, S.; Koramo, M.; Lamuela Orta, C.; Päivänen, J. *Kävelyn ja Pyöräilyn Edistämisen Mahdollisuudet ja Esteet*; Valtioneuvosto Statsrådet: Helsinki, Finland, 2021.
12. Utriainen, R.; Pöllänen, M.; Liimatainen, H. Road safety comparisons with international data on seriously injured. *Transp. Policy* **2018**, *66*, 138–145. [CrossRef]
13. Utriainen, R. Characteristics of commuters' single-bicycle crashes in insurance data. *Safety* **2020**, *6*, 13. [CrossRef]
14. O'Hern, S.; Oxley, J. Fatal cyclist crashes in Australia. *Traffic Inj. Prev.* **2018**, *19*, S27–S31. [CrossRef]
15. Ohlin, M.; Algurén, B.; Lie, A. Analysis of bicycle crashes in Sweden involving injuries with high risk of health loss. *Traffic Inj. Prev.* **2019**, *20*, 613–618. [CrossRef]
16. Reason, J.; Manstead, A.; Stradling, S.; Baxter, J.; Campbell, K. Errors and violations on the roads: A real distinction? *Ergonomics* **1990**, *33*, 1315–1332. [CrossRef]
17. Useche, S.A.; Montoro, L.; Tomas, J.M.; Cendales, B. Validation of the Cycling Behavior Questionnaire: A tool for measuring cyclists' road behaviors. *Transp. Res. Part F Traffic Psychol. Behav.* **2018**, *58*, 1021–1030. [CrossRef]
18. Useche, S.A.; Alonso, F.; Montoro, L.; Esteban, C. Explaining self-reported traffic crashes of cyclists: An empirical study based on age and road risky behaviors. *Saf. Sci.* **2019**, *113*, 105–114. [CrossRef]
19. O'Hern, S.; Estgfaeller, N.; Stephens, A.N.; Useche, S.A. Bicycle rider behavior and crash involvement in Australia. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2378. [CrossRef] [PubMed]
20. Useche, S.A.; Alonso, F.; Sanmartin, J.; Montoro, L.V.; Cendales, B. Well-being, behavioral patterns and cycling crashes of different age groups in Latin America: Are aging adults the safest cyclists? *PLoS ONE* **2019**, *14*, e0221864.
21. Ulleberg, P.; Rundmo, T. Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. *Saf. Sci.* **2003**, *41*, 427–443. [CrossRef]
22. Alonso, F.; Esteban, C.; Useche, S.; Colomer, N. Effect of road safety education on road risky behaviors of Spanish children and adolescents: Findings from a national study. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2828. [CrossRef]
23. Useche, S.A.; Montoro, L.; Alonso, F.; Tortosa, F.M. Does gender really matter? A structural equation model to explain risky and positive cycling behaviors. *Accid. Anal. Prev.* **2018**, *118*, 86–95. [CrossRef]
24. Prati, G.; Fraboni, F.; De Angelis, M.; Pietrantoni, L.; Johnson, D.; Shires, J. Gender differences in cycling patterns and attitudes towards cycling in a sample of European regular cyclists. *J. Transp. Geogr.* **2019**, *78*, 1–7. [CrossRef]
25. Oehl, M.; Becker, T.; Che, M.; Brandenburg, S. Validation of the cycling anger scale in Singapore. *Traffic Inj. Prev.* **2021**, *22*, 32–36. [CrossRef]
26. Deffenbacher, J.L.; Oetting, E.R.; Lynch, R.S. Development of a driving anger scale. *Psychol. Rep.* **1994**, *74*, 83–91. [CrossRef] [PubMed]
27. Oehl, M.; Brandenburg, S.; Huemer, A.K. Cyclists' anger experiences in traffic: The cycling anger scale. *Transp. Res. Part F Traffic Psychol. Behav.* **2019**, *62*, 564–574. [CrossRef]
28. Møller, M.; Haustein, S. Anger expression among Danish cyclists and drivers: A comparison based on mode specific anger expression inventories. *Accid. Anal. Prev.* **2017**, *108*, 354–360. [CrossRef] [PubMed]
29. Stephens, A.N.; O'Hern, S.; Trawley, S.; Young, K.L.; Koppel, S. Self-reported aggression amongst active cyclists. *Accid. Anal. Prev.* **2019**, *128*. [CrossRef] [PubMed]

30. Zheng, Y.; Ma, Y.; Cheng, J. Cycling anger in China: The relationship with gender roles, cycling-related experience, risky and aggressive riding. *Transp. Res. Part F Traffic Psychol. Behav.* **2020**, *68*, 52–66. [CrossRef]
31. Deffenbacher, J.L.; Lynch, R.S.; Oetting, E.R.; Swaim, R.C. The Driving Anger Expression Inventory: A measure of how people express their anger on the road. *Behav. Res. Ther.* **2002**, *40*, 717–737. [CrossRef]
32. Stephens, A.N.; Sullman, M.J.M. Development of a short form of the driving anger expression inventory. *Accid. Anal. Prev.* **2014**, *72*, 169–176. [CrossRef]
33. Stephens, A.N.; O'Hern, S.; Koppel, S. The specificity of cyclists' aggression; Examination of the cycling anger expression inventory across different recipient road user groups. *Accid. Anal. Prev.* **2020**, *146*, 105750. [CrossRef]
34. O'Hern, S.; Stephens, A.N.; Young, K.L.; Koppel, S. What makes cyclists angry? The relationships between trait anger, interest in cycling and self-reported comfort levels. *Transp. Res. Part F Traffic Psychol. Behav.* **2019**, *62*, 672–680. [CrossRef]
35. Gao, X.; Zhao, J.; Gao, H. Red-light running behavior of delivery-service E-cyclists based on survival analysis. *Traffic Inj. Prev.* **2020**, *21*, 558–562. [CrossRef]
36. Schleinitz, K.; Petzoldt, T.; Kröling, S.; Gehlert, T.; Mach, S. (E-) Cyclists running the red light—The influence of bicycle type and infrastructure characteristics on red light violations. *Accid. Anal. Prev.* **2019**, *122*, 99–107. [CrossRef] [PubMed]
37. Pärssinen, T. Pyöräliikenteen liikennevalo-ohjauksen kehittäminen. Master's Thesis, Aalto University, Espoo, Finland, 2020.
38. Marshall, W.E.; Piatkowski, D.; Johnson, A. Scofflaw bicycling: Illegal but rational. *J. Transp. Land Use* **2017**, *10*, 805–836. [CrossRef]
39. Mattheis, N. Unruly kids? Conceptualizing and defending youth disobedience. *Eur. J. Political Theory* **2020**, 1474885120918371. [CrossRef]
40. von Stülpnagel, R.; Lucas, J. Crash risk and subjective risk perception during urban cycling: Evidence for congruent and incongruent sources. *Accid. Anal. Prev.* **2020**, *142*, 105584. [CrossRef] [PubMed]
41. Koglin, T. Urban velomobility and the spatial problems of cycling. In *Experiencing Networked Urban Mobilities: Practices, Flows, methods*; Freudendal-Pedersen, M., Hartmann-Petersen, K., Fjallandm, E.L.P., Eds.; Routledge: London, UK, 2017; pp. 112–118. ISBN 1315200252.
42. Schleinitz, K.; Petzoldt, T.; Franke-Bartholdt, L.; Krems, J.; Gehlert, T. The German Naturalistic Cycling Study—Comparing cycling speed of riders of different e-bikes and conventional bicycles. *Saf. Sci.* **2017**, *92*, 290–297. [CrossRef]
43. Jarry, V.; Apparicio, P. Ride in peace: How cycling infrastructure types affect traffic conflict occurrence in Montréal, Canada. *Safety* **2021**, *7*, 63. [CrossRef]
44. Tiikkaja, H.; O'Hern, S.; Viri, R. Perceptions of trip making and wellbeing. *Transp. Res. Interdiscip. Perspect.* **2021**, *12*, 100464. [CrossRef]