Self-reported aggression amongst active cyclists

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ABSTRACT

There is a paucity of research regarding aggressive behaviours of on-road cyclists and the consequences that aggression may have on their safety. To address this, we examined self-reported anger-based aggression in a sample of "active" cyclists (N = 623: males = 69%) defined as those who regularly ride a bicycle on-road (all rode at least once a week, 64% rode between 4–7 days per week). Using the Cyclist Anger Expression Inventory (CAX) three broad types of anger-based aggression were identified: 1) constructive ways of dealing with anger, 2) verbal aggression and 3) personal physical aggression. Cyclists reported that most to almost all of the time they deal with anger in adaptive constructive ways. When they were aggressive, they were most likely to express this through verbal types of aggression such as shouting or swearing aloud. Personal physical types of aggression were infrequent and these were the only type of behaviour found to be related to crashes. Regression analyses showed that factors associated with personal physical aggression included anger propensities, distance travelled, being male and younger. Interestingly, personal physical aggression was also more frequently expressed by cyclists classified as "strong and fearless" (Geller, 2009), that is avid cyclists who feel comfortable in all riding environments. Therefore, although the expressions of extreme aggression are rare, they are expressed in a group of riders who regularly ride on the road, making them particularly vulnerable. Effective strategies need to be developed to lessen cyclist aggression and mitigate the potential risks associated with these behaviours, for both cyclists and other vulnerable road users.

1. Introduction

Very little research has been conducted investigating aggressive behaviours of on-road cyclists and the potential consequences these behaviours have on their safety. Recent research identified that certain situations can provoke anger in cyclists and this is dependent upon both the cyclist's level of comfort while riding, as well as the type of road user the provocation is from (O'hern et al., 2019). While it is important to understand what road environments, situations and interactions provoke anger while cycling, there is a further need to understand how anger is dealt with and if it manifests into aggression.

In contrast to the cycling domain, a large amount of research has been undertaken regarding the aggressive behaviours of drivers. This research has shown that aggression can manifest in behaviours that increase crash risk for the aggressor. These include tailgating (Stephens and Groeger, 2014; Stephens and Fitzharris, 2017), faster driving speeds (Mesken et al., 2002; Stephens and Groeger, 2011) and dangerous overtaking (Stephens and Groeger, 2011). Indeed, naturalistic driving studies have found that when aggressive, drivers have 35 times the odds of crash involvement compared to when they are driving

under a normal state (i.e. not aggressive) (Dingus et al., 2016). It is therefore likely that aggression in cyclists may also be associated with increased crash risk, depending upon the type of aggression. This has important road safety implications given that cyclists are already a vulnerable road user group who are disproportionally over-represented in injury statistics (O'hern and Oxley, 2018).

There has been little empirical research conducted in this field, particularly to understand cyclist aggression and its relationship with crash involvement. Given that cycling conditions are different to driving conditions, it is likely that cyclists do not exhibit the same types or levels of aggression as drivers do. According to the General Aggression Model (Anderson and Bushman, 2002) aggression is determined by a unique combination of individual and situational factors. Key to this is the appraisal of the appropriateness of response for the situation and predicted outcomes of the aggressive behaviour. Cyclists by nature are more vulnerable than drivers due to their lack of physical protection and reduced tolerance to biomechanical forces (O'hern and Oxley, 2018). This is particularly evident for those who ride on-road. As such on-road cyclists may be less likely to display aggression towards motorists, than other road users.

Indeed, Rowden et al. (2016) explored aggression within motorcycle riders who are also more vulnerable than the motor-vehicle drivers they share the road with. In their study, clear differences emerged between aggression while riding and aggression while driving for the same individuals. Further, perceptions of own skill were important predictors of aggressive riding; but less so for aggressive driving, suggesting that assessments of the situation and the individual's role within it underlie aggression. In the same manner that anger propensities differed according to the comfort levels of cyclists, as mentioned above (O'hern et al., 2019), aggression, if displayed, might be restricted to those who feel confident in doing so under certain conditions.

A commonly utilised typology of cyclists, developed by Geller (2009), classifies people into four categories based on their interest in cycling and self-reported comfort levels when cycling (Dill and McNeil, 2013). These range from very little interest and no intention to cycle to avid cyclists who are confident to ride in all types of road environments. It is therefore hypothesised that aggressive expressions of anger may differ based on classification across this typology.

One previously published study investigating aggression in cyclists considered attitudes toward cycling as a predictor of aggression (Møller and Haustein, 2017). Møller and Haustein (2017) examined aggression as a response to anger in a large sample of Danish cyclists. To measure aggression, they adapted a scale designed to measure aggressive expressions of anger in drivers (Driving Anger Expression Inventory; DAX-short: Deffenbacher et al., 2002; Stephens and Sullman, 2014). The DAX-short asks drivers to rate the frequency of 15-types of aggressive behaviours that are a response to being angered while driving. These combine into four broad categories of aggression: adaptive constructive aggression, verbal aggression; personal physical aggression; and using the vehicle to express anger. Individuals are asked to consider when they are driving and rate the frequency they would engage in each type of behaviour when angered while driving.

The adapted scale, named the cycling anger expression inventory (CAX) uses 13 of the original 15 items. Individuals are asked to imagine they are cycling and rate the frequency they would engage in each type of behaviour when angered while cycling. The CAX items combine to form three broad categories: adaptive constructive aggression, verbal aggression; personal physical aggression. Adaptive constructive responses to anger include items describing positive ways of dealing with anger, such as telling oneself not to worry about it. Verbal aggressive expressions of anger involve behaviours such as yelling or swearing at the other road user. Personal physical ways of dealing with anger involve behaviours where the rider uses their body to express anger, such as riding up to another road user. While, Møller and Haustein (2017) initially found support for a fourth factor: use of vehicle to express anger, this contained only one item and so was excluded in favour of the 13-item three factor model.

Møller and Haustein (2017) found that the preferences for different expressions of anger-based aggression did not differ across mode of transport, but the frequencies did. Whether driving or riding, individuals more commonly dealt with anger constructively. They also noted that verbal aggressive responses were more common than personal physical responses, however both types of responses were infrequent. This pattern aligns with previous research in driving (Stephens and Sullman, 2014, 2015) and highlights the trait nature of general anger response tendencies. Interestingly, Møller and Haustein (2017) reported that individuals were more likely to report verbal aggression when driving compared to cycling; while individuals were more likely to report personal physical aggression when cycling compared to driving. These results suggest that, while the tendencies for a certain type of response may be inherent (i.e. constructive methods), aggression is somewhat regulated according to the situation, and consequently may differ when cycling.

The factors that predicted cyclist aggression were also similar to those found in aggressive driving (Deffenbacher et al., 2002; Stephens and Sullman, 2014, 2015, Møller and Haustein, 2017; Stephens and

Fitzharris, 2017). For example, younger riders, male riders and those who rode more frequently were all more likely to be aggressive while cycling. Interestingly, positive attitudes towards cycling were not associated with aggression while cycling. It is therefore likely that extrapolating the findings from driving, where aggression is related to crash involvement, indicates that aggression in cyclists will also be associated with crash involvement. Crash involvement was not explored by Moller and Haustein (2017), or reported anywhere else. Therefore, one aim of this study was to explore whether aggressive cycling is related to crashes.

While the findings from Møller and Haustein (2017) provide valuable insight into cyclist behaviours it should be noted that Møller and Haustein (2017) conducted their research utilising a cohort of Danish cyclists. With Denmark having some of the highest cycling participation rates in the world (Pucher and Buehler, 2008), it is likely that there was an overall higher level of cycling skill amongst the study participants, than would be identified in other countries. Indeed, there are noted differences between cycling participation rates and culture in European countries compared to Australia (Bassett et al., 2008; Pucher et al., 2010). In addition, further examination of the CAX is warranted to confirm the structure of the model, assess its generalisability to different cohorts of cyclists and strengthen our understanding of the issue of aggression amongst cyclists. As such, the primary aim of the current study was to identify the frequency of self-reported anger-based aggression amongst a cohort of Australian cyclists and to identify factors that predict these expressions of anger. The association between cyclist aggression and crashes was also explored.

2. Method

2.1. Participants and procedure

A total of 623 respondents (69% males) completed an online questionnaire regarding their cycling experiences, as well as their self-reported anger and aggression while cycling. Participants ranged in age from 18 to 75 years (M = 42.6 ± 11.7) and all rode on-road at least once per week, with the majority (64%) riding daily or 4–6 days per week.

Participants were recruited though social media advertisements and flyers placed at bicycle parking facilities. Participants were eligible to take part in the study if they: were 18 years of age or older; identified as a 'regular' on-road cyclist, (i.e., rode a bicycle on-road once per week on average); were proficient in English, and were currently living in Australia. The online survey was hosted using the Qualtrics online survey platform. On completion of the survey, participants had the opportunity to provide their email address via a separate link to enter the draw to win an iPad. The survey took approximately 15 min to complete and the study methodology was approved by the University ethics committee.

2.2. Materials

2.2.1. Demographics and crash history

Participants provided information on their typical cycling habits, the number of trips made by bicycle per week and average weekly kilometres travelled by bicycle. Participants were also asked to report any crash involvement while cycling over the past two years, if they were at-fault in these crashes and if they had received an infringement while cycling over the past two years.

2.2.2. Cycling interest and comfort level

The "Four Types of Cyclists" scale adapted from Dill and McNeil (2013) and based on Geller (2009) was used to classify cyclists according to their self-reported interest in cycling and comfort levels across different cycling environments. To classify cyclists, participants respond to a set of modified scenarios depicting cycling environments

Table 1
Model fit for the CAX.

Model	Description	χ^2 (df)	p	CFI	RMSEA	90% CI	p close	CAIC
1	13-item, 3 factor (no item 9)	4.20 (62)	0.005	0.93	0.07	0.06-0.08	< 0.001	475.81
2	14-item, 3 factor	3.85 (74)	0.005	0.92	0.07	0.06-0.08	< 0.001	515.03
3	13-item, 3 factor (no item 12)	3.30 (62)	0.005	0.94	0.06	0.05-0.07	0.026	420.22
4	13-item, 3 factor (items 8 & 9 co-varied)	3.15	0.004	0.94	0.06	0.05-0.07	0.06	415.33

CFI = Comparative Fit Index; RMSEA = Root Mean Square of Approximation; CI = Confidence interval; CAIC = consistent Akaike's information criterion.

common to Australian infrastructure, with participants rating their level of comfort across each of the scenarios.

The four classifications of cyclists include: 1) "Strong and fearless"; 2) "Enthused and confident"; 3) "Interested but concerned", and 4) "No way, no how". "Strong and fearless" are avid cyclists who are comfortable riding on a variety of road environments, including on roads with or without marked bicycle lanes. "Enthused but confident" cyclists are also comfortable on-road but prefer bicycle specific infrastructure. "Interested and concerned" riders do not regularly ride and are not comfortable with on road riding. "No way, no how" cyclists either have no interest in cycling or are unable to ride for some reason. Due to the study exclusion criteria, no cyclists in the sample were classified as "No way, no how".

2.2.3. Cyclist aggression expression inventory (CAX)

The CAX is a 14-item scale developed to measure the frequency of aggressive expression of anger toward other road users by cyclists (Møller and Haustein, 2017). Items on the CAX are assessed on a five-point scale to measure the frequency (1 = never; 3 = about half the time; 5 = always) that cyclists engage in each behaviour. As mentioned above, 13 items of the CAX can be considered across three broad types of anger expression: adaptive constructive responses, verbal expressions of anger, and personal physical expressions of anger. These three factors have demonstrated good reliability with Cronbach alphas ranging from 0.86 (verbal) to 0.94 (physical) and 0.89 for the total CAX (which does not include adaptive constructive items). Cyclist Anger Scale (CAS)

Cyclist's propensity to become angry while riding was measured using the CAS. The CAS is a 12-item scale that each describe a type of interaction with various road user groups, including pedestrians, vehicles, police and other cyclists (Oehl et al., 2016). For each item, participants report how much anger they would experience on a five-point scale (1 = none; 3 = a moderate amount; 5 = very much). For this study, total anger (the summation of scores for each item) was utilised in the analyses. The CAS has good reliability with the Cronbach's alpha on the total scale for the current sample of 0.83.

2.3. Analysis

There were no missing data as only cases with complete responses on the above scales were included in the sample. Data were analysed with IBM® SPSS® and AMOS™ v.25. The structure of the CAX was examined using confirmatory factor analysis (CFA) with goodness of fit determined through a number of metrics including: comparative fit index (CFI) value greater than 0.90 (Hu and Bentler, 1999); the root mean square of approximation (RMSEA) less than 0.06 (Browne et al., 1993); and non-significant p-close (Hu and Bentler, 1999).

The consistent Akaike's information criterion (CAIC: Bozdogan, 1987) was used to compare models, with lower values indicating better fit. Bollen-Stine bootstrapping procedures on 2000 samples, as recommended by Bollen & Stine, were used due to violations of

multivariate normality (Bollen and Stine, 1992). Traditionally non-significant p values indicate good fit. However, Byrne (2013) cautions that significant p values are common with large samples and so goodness of fit was determined by the above metrics over the p value.

The resulting CAX factors were assessed for normal distribution and found to be within normal range, with the exception of personal physical aggressive expression which was positively skewed. Subsequent analyses were conducted using tests which are robust against slight deviations from normality.

Linear regressions were conducted for each CAX subscale as well as on the total CAX. Age, gender, average distance travelled per week, cyclist typology and average riding anger scores were all entered and kept in the regression model allowing for an understanding of their contribution, while adjusting for the other variables. As the personal physical factor, and by default the total CAX were skewed, bootstrap procedures on 1000 samples, the recommended amount by Field (2018) were conducted for these factors. This produces bootstrapped p values and 95% confidence intervals for each beta.

3. Results

3.1. Cyclist aggression expression scale

Table 1 shows the models fitted for the CAX. The 13-item, three factor model from Møller and Haustein (2017) showed a promising fit although the RMSEA values were marginally higher than the 0.06 suggested cut-off. A second model was tested which included the item "I ride a lot faster" loaded onto the personal physical factor (Model 2). As Møller and Haustein (2017) found items "I ride right up to the other road user" and "I do to the other road user what they did to me" were better fitting in the personal physical factor rather than the use of vehicle factor, the testing of this made theoretical sense. However, the model fit statistics showed this inclusion of the additional factor did not improve model fit. Examination of the standardised residuals suggested the removal of item 12: "I tell myself it's not worth getting involved in" and this showed improved fit to the data. One final modification was performed, where error terms for item 8: "I do to the other road users what they did to me" and item 9 were co-varied. This final model showed acceptable fit to the data.

Factor loadings were all significant and ranged between 0.30 and 0.85, with 85% of items having a loading greater 0.40. The final model is displayed in Table 2, which also presents the item means across the three-factor solution.

Across the 13 items, the most frequent responses to anger were adaptive constructive responses such as accepting there are frustrating situations and telling oneself it is not worth getting mad at. On average, these were reported for about "half of the time" to "most of the time" by riders, averaging 3.51 (± 1.05) and 3.24 (± 1.06) respectively out of a possible 5. When anger was expressed aggressively, it was most commonly expressed verbally. Making negative comments about the road

Table 2
Cycling Aggression Expression Inventory factor and items means (SD).

Factor and items		M (SD)
Adaptive Constructive ways of dealing with anger		**3.12 (0.83)**
13	I accept there are frustrating situations	3.51 (1.05)
11	I tell myself it's not worth getting mad at	3.24 (1.06)
14	I tell myself to ignore it	3.10 (1.08)
10	I think of positive solutions to deal with the situation	2.62 (1.05)
	Composite Reliability / Cronbach Alpha	0.80 / 0.79
Verbally aggressive expressions of anger		**2.02 (0.72)**
1	I make negative comments about the road user aloud	2.27 (0.88)
2	I swear at the other road user aloud	1.92 (0.82)
3	I yell at the other road user	1.87 (0.80)
	Composite Reliability / Cronbach Alpha	0.83 / 0.82
Personal physical aggressive expressions of anger		**1.28 (0.29)**
9	I ride a lot faster	1.83 (0.83)
7	I ride right up to the other road user	1.36 (0.57)
4	I get off the bicycle and tell the other driver off	1.24 (0.47)
8	I do to the other road users what they did to me	1.14 (0.43)
6	I try to scare the other road user	1.08 (0.34)
5	I get off the bicycle to have a physical fight	1.03 (0.20)
	Composite Reliability / Cronbach Alpha	0.65 / 0.82
Total CAX (excludes adaptive constructive items)		**1.53 (0.36)**

NB: average scores out of a 1 (never) to 5 (always) scale.

user aloud was the most frequent type of verbal expression (M = 2.02 ± 0.72). As would be expected, extreme forms of aggression, such as trying to scare the other road user or engaging in a physical fight were very infrequent (averaging 1.08 ± 0.34 and 1.03 ± 0.20).

3.2. Inter-correlations among CAX and other variables

The relationships between CAX scores with age, self-reported cycling anger propensity (total average CAS score) and average distance travelled per week are reported in Table 3. The average self-reported cycling anger score was 3.31 (0.61). Inter-correlations between CAX factors were all significant and ranged between 0.18 and 0.40 showing that the factors were related but distinct constructs. Adaptive constructive expressions of aggression were negatively related to the other aggressive means of expressing anger as well as the overall aggressive anger expression. Anger tendencies were positively related to aggressive expression of anger indicating that riders with higher trait anger tend to report more frequent aggressive expressions of anger. Significant relationships were found between age and adaptive constructive expression, indicating that as riders age they tend to incorporate more frequent adaptive ways of expressing anger. In contrast, a negative significant relationship between age and physical aggression suggests that younger riders tend to engage in these behaviours more frequently. Age was unrelated to verbal aggression and consequently total aggressive expression.

Table 4 shows self-reported aggressive tendencies across gender and crash and infringements in the past two years. Tests for mean

differences showed that males reported significantly more frequent personal physical aggression while verbal aggression did not differ across gender. Riders who had crashed in the previous two years had higher average frequencies of personal physical aggression and total aggressive expression. No significant differences were identified amongst participants who reported an infringement, albeit very few cyclists reported receiving an infringement.

3.3. Factors associated with aggressive expressions of anger

Table 5 shows the regression analyses examining factors associated with how riders express their anger. Average anger propensities were negatively associated with adaptive constructive means of dealing with anger and positively associated with both aggressive expressions of anger. This indicates that riders who generally experience more anger while riding report more frequent aggressive expression and less frequent constructive responses to anger.

Age was also a significant predictor of both positive and negative ways of expressing anger, with younger riders reporting more frequent personal physical aggression and less frequent adaptive constructive aggression. As is to be expected, distance travelled was also significantly associated with frequency of aggression, with cyclists who rode greater distances reporting more frequent verbal and physical aggression, but interestingly, distance travelled was not a significant predictor of adaptive constructive ways of dealing with anger. Therefore, it is not simply that increased distances provide riders with more opportunity to deal with anger and aggression.

Rider typology was not significantly associated with adaptive constructive aggression nor verbal aggression; suggesting that these responses were independent of rider comfort or interest levels. Typology was a significant predictor of the frequency of personal physical aggression. In particular, as is shown in Table 5, riders who were classified as "Strong and fearless" (13% of the sample) had significantly more frequent personal aggression when compared to "Interested but concerned" (53% of the sample) riders. An additional regression not displayed in the table used "Enthused and confident" (34% of the sample) riders as the reference group and showed that riders classified as Strong and fearless, but not those Interested and concerned riders, were significantly different from enthused and confident riders B = 0.11 (95% CI: 0.02; 0.22) β = 0.13, p = 0.029).

4. Discussion

The aim of this study was to understand self-reported aggressive behaviours in cyclists and to determine factors associated with this aggression. We were specifically interested in anger-based aggression and therefore used the CAX (Møller and Haustein, 2017) to measure aggression frequencies. The CAX provides information on aggression directed toward other road users. Our results showed that overall, the most and least common types of aggression reported by cyclists are similar to what has been previously reported by drivers (Deffenbacher

Table 3
Relationships between self-reported aggressive anger expression, age, and anger tendency.

	Adaptive constructive expression	Verbal aggressive expression	Personal physical aggression	Total aggressive expression	Age	Average cycling anger
Adaptive constructive expression	–					
Verbal aggressive expression	−.40[***]	–				
Personal physical aggression	−.18[***]	.32[***]	–			
Total aggressive expression	−.36[***]	.84[***]	.75[***]	–		
Age	.13[***]	−.006	−.12[**]	−.07	–	
Average cycling anger	−.13[***]	.25[***]	.15[**]	.22[***]	−.17[***]	–
Distance travelled per week	.02	.18[***]	.16[***]	.21[***]	.17[***]	−.04

[***] p ≤ .001.

[**] p ≤ .01.

Table 4

Self-reported cycling aggression across gender, crashes and infringements in the previous two years.

		Adaptive constructive responses to anger	Verbal aggressive expression	Personal physical aggression	Total aggressive expression
Gender	Male (n = 431)	3.16 (.80)	2.04 (.70)	1.31 (.32)	1.55 (.38)
	Female (n = 191)	3.02 (.88)	1.99 (.75)	1.20 (.20)	1.46 (.32)
	[*]t (620) =	**1.99, p = .047**	.77, p = .44	[†]**t (545.18) = 5.25, p < .001**	**2.88, p = .004**
Crashes	Yes (n = 303)	3.12 (.82)	2.07 (.75)	1.31 (.28)	1.56 (.37)
	No (n = 320)	3.12 (.84)	1.98 (.68)	1.25 (.30)	1.50 (.35)
	t (621) =	.01, p =.99	1.57, p = .12	**2.25, p = .03**	**2.24, p = .03**
Infringements	Yes (n = 15)	3.17 (.94)	2.29 (.98)	1.34 (.28)	1.66 (.38)
	No (n = 608)	3.12 (.83)	2.02 (.71)	1.28 (.29)	1.52 (.36)
	t (621) =	.23, p = .82	1.46, p = .15	.87, p = .39	1.43, p = .15

[*] NB: One participant did not identify with male or female gender hence the different degrees of freedom.

[†] Equal variances not assumed hence the different degrees of freedom.

Table 5

Factors that contribute to different types of anger expression.

Adaptive constructive responses to anger	R^2 0.06; F (6,615) = 6.29, p < 0.001		
	B (95% CI)	β	p
Cyclist typology	–		
- Interested but concerned (reference)			
- Enthused and confident	−0.09 (-.23; -.06)	−0.05	0.24
- Strong and fearless	0.07 (-.13; .27)	0.03	0.52
Age	**0.009 (.003; .014)**	**0.12**	**0.003**
Gender (males reference)	−0.10 (-.24; .04)	−0.06	0.16
Average kilometres ridden per week	−0.02 (-.07; .04)	−0.02	0.55
Average cycling anger propensity	**−0.23 (-.33; -.12)**	**−0.17**	**< 0.001**

Verbal aggressive expression	R^2 0.10; F (6,615) = 11.39, p < 0.001		
	B (95% CI)	β	p
Cyclist typology	–		
- Interested but concerned (reference)			
- Enthused and confident	−0.05 (-0.17; 0.08)	−0.03	0.46
- Strong and fearless	0.06 (-0.11; 0.22)	0.03	0.52
Age	−0.002 (-0.01; 0.003)	−0.03	0.45
Gender (males reference)	−0.03 (-0.15; 0.09)	−0.02	0.62
Average kilometres ridden per week	**0.09 (0.05; 0.14)**	**0.16**	**< 0.001**
Average cycling anger propensity	**0.31 (0.22; 0.40)**	**0.27**	**< 0.001**

Personal physical aggressive expression	R^2 0.10; F (6,615) = 11.59, p < 0.001		
	B (95% CI)[*]	β	p[*]
Cyclist typology	–		
- Interested but concerned (reference)			
- Enthused and confident	−0.004 (-0.05;0.04)	−0.07	0.85
- **Strong and fearless**	**0.11 (0.02;0.21)**	**0.13**	**0.019**
Age	**−0.004 (-0.005;-0.002)**	**−0.15**	**0.001**
Gender (males reference)	**−0.11 (-0.15;-0.07)**	**−0.17**	**0.001**
Average kilometres ridden per week	**0.03 (0.01;0.05)**	**0.13**	**0.001**
Average cycling anger propensity	**0.06 (0.02;0.11)**	**0.13**	**0.001**

Total aggressive expression	R^2 0.12; F (6,615) = 14.57, p < 0.001		
	B (95% CI)[*]	β	p[*]
Cyclist typology	–		
(Interested but concerned reference)			
- Enthused and confident	−0.02 (-0.07; 0.04)	−0.02	0.58
- Strong and fearless	0.09 (-0.01; 0.21)	0.09	0.10
Age	**−0.003 (-0.005; 0.-001)**	**−0.10**	**0.014**
Gender (males reference)	**−0.08 (-0.14; -0.03)**	**−0.10**	**0.004**
Average kilometres ridden per week	**0.05 (0.03; 0.07)**	**0.18**	**0.001**
Average cycling anger propensity	**0.15 (0.10; 0.20)**	**0.25**	**0.001**

[*] Bootstrapped on 1000 samples.

et al., 2002; Stephens and Sullman, 2014). Specifically, riders reported that they tend to deal with anger in constructive ways, with more extreme personal physical expressions of anger being rare. These are discussed below in more detail. The predictors of aggression differed across the type of aggression being displayed, however generally, and unsurprisingly, higher anger tendencies were related to more frequent aggression, as was more frequent mileage. When these were controlled for, age, gender and cyclist typology predicted some, but not all, types of aggression.

The study reported in this paper was the first to confirm the

structure of the CAX in a sample of riders from Australia. In line with Møller and Haustein (2017), our findings supported three general ways that riders deal with anger: adaptive constructive responses to anger; personal physical aggressive responses and verbal aggression. However, modifications were made to the configuration to fit the data. In particular, the item "I ride faster" was included as a personal physical item and the item "I tell myself it's not worth getting involved" was removed from the adaptive constructive factor. This improved model fit. Conceptually the removed item was very similar to one retained in the model "I tell myself it's not worth getting mad". The resulting CAX factors shared significant and modest relationships, with correlation coefficients ranging from 0.18 to 0.40, demonstrating they were related but independent constructs. Our findings therefore broadly support the CAX as a three-factor measure of anger-based aggression in cyclists.

Despite the minor differences in items included in two of the three factors, the frequency of self-reported aggression was similar to both that reported by cyclists (Møller and Haustein, 2017) and also by drivers (Deffenbacher et al., 2002; Stephens and Sullman, 2014). As expected, the frequency of aggression ranged on a continuum with the most aggressive acts (personal physical aggression) being reported the least frequently. On average, personal physical aggression was reported infrequently (e.g., 'almost never') by cyclists. In contrast, adaptive constructive ways of dealing with anger and verbal expressions of anger were the most common. Riders reported that between half to most of the time they "accepted there are frustrating situations" and "told themselves it's not worth getting mad at". When riders did express their anger aggressively, this was more commonly through verbal means, such as "making negative comments about the road user aloud" or "swearing aloud at the road user". Due to the nature of the question, it is unclear whether these only occurred toward specific road users or were a general way of dealing with anger across a variety of circumstances.

Given the vulnerability of cyclists when interacting with motor-vehicles, compared to when interacting with other cyclists or pedestrians, it is likely that a more nuanced assessment of recipient type would highlight differences in aggressive responses. For example, verbal aggression directed toward a car driver may be less confrontational than verbal aggression directed at a pedestrian, simply due to the fact that the driver has a physical barrier surrounding them and may not hear the aggression. Therefore, certain types of aggression may be more prevalent toward certain types of road users. For example, personal physical aggression with drivers represents a higher degree of physical risk, than the same type of interactions with pedestrians (O'hern et al., 2019). This might explain why adaptive measures were the most common type of response for cyclists using the CAX. Our sample were all active cyclists who regularly ride on road. However we do not know who "other road users" were when reporting aggression. This is important to know as aggressive interactions with other cyclists, who are not strong and confident, may deter future cycling participation. Further understanding of the road environments and road user interactions that result in aggressive manifestations is warranted.

Associations were also found between aggression and crashes. Total mean aggressive expression frequencies were significantly higher for riders who also reported having been involved in a crash in the previous two years while riding when compared to those who had not crashed during that time. This also aligns with research into aggressive driving (Dahlen and Ragan, 2004; Stephens and Sullman, 2015). However, when considered across subscales for verbal aggression and personal physical aggression, it was only the latter that differed according to crash involvement. Therefore, the more extreme versions of aggression showed associations with the worst outcomes: crashes.

Research in the driving domain has shown reciprocal relationships between near crash and anger (Underwood et al., 1999). Underwood et al., found that drivers who were angry reported more near crashes. However, a relationship was also observed for near crash and subsequent driver anger. Therefore, the relationships between cyclist

behaviour and crash involvement may also be reciprocal. It is unclear in our sample whether more aggressive riders tend to have an overall riskier riding style that places them at greater risk, or whether these riders are aggressive due to crash or near crash history. This is an avenue that warrants further exploration, given the vulnerability of this group of road users.

Personal physical aggressive expression also showed the most discrimination between types of riders. Regression analyses on each type of aggressive expression showed that there were no specific rider characteristics associated with verbal aggression, beyond anger tendency and average weekly distance travelled. Therefore, regardless of age, gender and classification according to interest and comfort level, anger-prone, higher mileage cyclists were more likely to be verbally aggressive when angry. However, when anger and distance were controlled for, age, gender and cyclist typology were significant predictors of personal physical aggression. It should be cautioned however, that the variance explained by these factors was low at 10 percent. While this is similar to Møller and Haustein (2017), who did not include trait anger in their model, it indicates other unexplained factors also contribute to these aggressive behaviours. Follow up research is warranted to understand what these may be.

Although reported as infrequent, it is worth exploring personal physical aggression because of its association with crashes and potential harm to both the cyclist and other road users. Six items are included in this factor and these are, in order of self-reported frequency: "I ride a lot faster"; "I ride right up to the other road user"; "I get off the bicycle and tell the other driver off"; "I do to the other road users what they did to me"; "I try to scare the other road user"; "I get off the bicycle to have a physical fight". The latter two were reported as extremely rare, scoring 1.03 and 1.08 on a one (never) to five (always) scale. It should also be noted that items. "I try to scare the other road user"; "I do to them what they did to me" are ambiguous regarding how aggression is manifested. Notwithstanding this, the pattern of frequencies aligns with broader driving aggression literature that suggests there are a small group of road users who exhibit extreme behaviours (see Stephens and Fitzharris, 2017). Our results suggest this may be related in part to comfort level and interest in cycling and may indicate that more confident riders are those who express their anger aggressively more frequently. These findings provide possible avenues for interventions aimed at the more confident cyclist to improve rider safety as well as the riding experience for other types of cyclists who may be prone to receiving aggression from these cyclists.

It is worth reiterating that the translation of a driving specific scale has resulted in ambiguity over the recipients of the aggression. For example, the Driving Anger Expression Inventory specifically refers to interactions drivers have with other drivers (Deffenbacher et al., 2002; Stephens and Sullman, 2014). In contrast, the CAX items are about behaviours directed towards "other road users". Cyclists interact with a variety of road users which may include drivers, but can also include other cyclists and pedestrians. It is highly likely that cyclists would regulate their expressions of anger according to who the recipient of the aggression may be. Indeed, recent research has shown that anger-provocation for cyclists differ according to who the road user is, with cyclists reporting more anger over interactions with vehicles compared to pedestrians or other cyclists (Oehl et al., 2016; O'hern et al., 2019). This is likely due to the threat posed by the different road users, and the types of situations leading to anger. Consequently, the CAX would be improved by specification of who the recipient might be, with the current items replicated across three types of recipients: drivers, pedestrians and cyclists.

Some limitations of the current study should be noted. The study suffers from a sample bias that adult participants were those who regularly cycled on-road, referred to as "active" cyclists. This has excluded those who do not cycle frequently and those that only cycle off road, which limits the generalisability of the findings to the broader range of cyclists. However, given that our sample are those that are cycling often

in proximity of vehicles and self-reporting aggressive behaviours, the findings provide clear safety implications regarding the importance of understanding rider aggression and the factors associated with it.

5. Conclusion

Overall, we found that the CAX structure for measuring self-reported types of anger-based aggression was suitable for a sample of active cyclists in Australia. We do, however, recommend that the item wording be revised and items replicated for specific recipients of anger in order to provide a clearer picture of how and when cyclists become aggressive.

Our results show that generally, cyclists tend to deal with anger in constructive ways, however cyclists who are prone to anger and ride more often have more frequent verbal aggression. Younger, male and avid cyclists, classified as "Strong and fearless", are more likely to engage in personal physical aggression. This may include acts such as riding faster, getting off the bicycle to tell a driver off, and trying to scare other road users. Personal physical aggression is also related to crash involvement, suggesting this is a group of cyclists who are more likely to be riding on-road and engage in behaviours putting themselves, and potentially others, at higher risk for harm. More research is clearly warranted to understand this group of riders further, in order to develop effective strategies to lessen cyclist aggression and mitigate the potential risks associated with these behaviours.

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