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Self-reported mindfulness, cyclist anger and aggression

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ABSTRACT

Anger is a common behaviour exhibited by road users when one's goals are perceived to have been blocked by another. Recent research has demonstrated that, generally, cyclists tend to deal with anger in constructive ways. However, when anger does manifest, it can result in behaviours that increase their crash risk. Amongst motor vehicle drivers, mindfulness levels have been associated with less anger and appear to mediate anger and associated aggression. The current study sought to understand whether mindfulness has similar associations with anger and aggression in a sample of cyclists. A total of 583 cyclists (males = 68 %) completed an online questionnaire that sought information on their levels of mindfulness, current mindfulness practices and tendencies for anger and aggression while cycling. The relationships between these were then examined using structural equation modelling. The results showed that cyclists with higher mindfulness levels tended to report less anger across a range of situations (e.g., interactions with pedestrians, cyclists, motor vehicle drivers and police). Both direct and indirect (through anger) relationships were found between mindfulness and aggression, again showing that more mindful cyclists tended to engage in less frequent aggression. These findings align with recent research investigating this relationship amongst motor vehicle drivers and suggest that mindfulness may be a promising strategy to reduce or avoid anger and aggression in cyclists.

1. Introduction

Mindfulness is the act of paying full attention to what is happening in each moment and is both an everyday experience and something that can be enhanced through training (Kabat-Zinn, 2005). This attention can be directed internally to thoughts and emotions and externally to the environment and the task at hand (Brown and Ryan, 2003). Mindfulness can also be conceptualised as the self-regulation of attention, which involves a deliberate, focused awareness of one's moment-to-moment internal and external experiences (Germer et al., 2016; Shapiro et al., 2006; Siegel et al., 2009). This comprises the ability for sustained attention, intentionally switching attention between objects or mental sets (e.g., problem solving approach) (Posner, 1980) and not being distracted (Heeren et al., 2009). Mindfulness additionally involves equanimity and non-reactivity, whereby whatever is happening is simply noticed, without evaluations, judgments or emotional reactions (Baer et al., 2008).

There has been an explosion of research into the benefits of mindfulness, which has recently extended into the area of road safety (see Koppel et al., 2019). The application of mindfulness in road safety is warranted, given that higher levels of mindfulness are associated with more desirable driver behaviours. In a recent systematic review of the literature, Koppel et al., found 17 published studies across 2011 – 2017 that had examined mindfulness in road safety. The key findings highlighted that there are positive relationships between mindfulness and driver performance and lower crash risk. In particular, increased mindfulness has been shown to be associated with lower rates of intentional and unintentional aberrant driving behaviours and fewer self-reported crashes (Koppel et al., 2018), as well as lower frequencies of engagement in potentially distracting activities while driving e.g. mobile phone use (Young et al., 2018).

Increased mindfulness has also been associated with lower tendencies for both driver anger and aggressive expressions of anger (Stephens et al., 2018). One explanation for this finding may be that more mindful drivers are better able to regulate their emotions and direct their attention to driving-related tasks, instead of reacting to frustrating driving circumstances. Emotional regulation is a term used to describe several abilities including the capacity to be self-aware of one's emotional state without being compelled to act on those emotions. Given that a driver's crash risk is significantly increased during periods of

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aggressive driving (Dingus et al., 2016), these findings offer promising evidence for mindfulness strategies in the reduction of emotion-based dangerous driving behaviours.

Despite the emerging evidence of a link between higher levels of mindfulness and less aggressive behaviour, this has yet to be examined for vulnerable road user groups, such as cyclists. However, recent research on cycling behaviour has successfully extrapolated driving specific anger and aggression measures to cycling populations (Møller and Haustein, 2017; Oehl et al., 2019). The findings from these studies show that propensities for anger and aggression in cyclists are like that of drivers, thereby suggesting similar associations with mindfulness may also be present with cyclists.

Oehl et al. (2016) developed a Cyclist Anger Scale (CAS) to measure the propensity to become angered across various cycling situations. They found four broad types of anger provoking interactions reported by cyclists: (1) interactions with pedestrians, (2) with car drivers, (3) with police and (4) with other cyclists. Except for the police factor, which involved receiving fines, other factors contained situations where the cyclist's progress was impeded or there were conflicts with each type of road user (Huemer et al., 2018; Oehl et al., 2019). Responses to the CAS have shown that the most angering types of situations that cyclists report involve conflicts with car drivers, while the least angering situations involved interactions with police (Oehl et al., 2016). This finding may be explained by the vulnerability of cyclists when interacting with motor vehicles, noted in the crash statistics (O'Hern and Oxley, 2018). Previous research in the area of driving anger has shown similar patterns, e.g. anger is more prevalent in situations where someone can be directly blamed for impediment or perceived danger (Deffenbacher et al., 2016). This research has also shown strong relationships between tendencies to become angered, anger experienced while driving and subsequent aggressive expressions of anger (see Deffenbacher et al., 2016). Thus, angry drivers display this anger aggressively; similar relationships have been found between anger and aggression for cyclists (Stephens et al., 2019).

Møller and Haustein (2017) examined how cyclists express their anger and whether they do this aggressively. Using an adapted version of the short Driving Anger Expression Inventory (DAX: Deffenbacher et al., 2002; Stephens and Sullman, 2014), they found that cyclists either deal with anger in adaptive constructive ways (i.e., able not to engage), express their anger verbally (i.e., yelling or swearing) or physically (i.e., get off the bicycle to have a physical fight). Stephens et al. (2019) used the same scale on a sample of cyclists from Australia and found similar frequencies of aggressive behaviours. While most cyclists dealt with anger in adaptive ways, there were certain types of cyclists, for example those who ride on the road regularly and do so confidently, who were more likely to report physical aggression when angry. A relationship between physical aggression and self-reported crashes was also noted indicating that, as with drivers, aggression may contribute to some cyclist crashes.

As cyclists, particularly those who ride on-road, lack the same physical protection afforded to drivers by their motor vehicle, it is important to understand whether the potential benefits of mindfulness for driver anger also extends to cyclists. As discussed by Deffenbacher et al. (2016), mindfulness is one of a number of interventions, including cognitive, relaxation, and behavioural, that have been shown to be effective in reducing anger and aggression in drivers. Indeed, in one study, mindfulness was found to be significantly more effective than a cognitive intervention in reducing driver anger and aggressive driver anger expression (Kazemeini et al., 2013). The similarities between drivers and cyclists in their self-reported anger and aggression (Møller and Haustein, 2017; Oehl et al., 2016) offer promising evidence to suggest that mindfulness may be beneficial to cycling anger and subsequent aggression. This is particularly true because these have all been measured on a self-report retrospective basis and may reflect traits that are expressed similarly across different traffic contexts. The aim of the study reported here was to examine the relationships between self-reported mindfulness levels and cyclists' anger and aggression. Based on similar research in the driving domain (Stephens et al., 2018) it was hypothesised that cyclists with higher levels of mindfulness would report less propensity for cycling anger, and that the relationship between mindfulness and aggression would be mediated by cyclist anger.

2. Method

2.1. Participants

A total of 829 participants started the survey, however only 583 completed all items. This is a completion rate of 70 %. Of the 583 respondents, 68 % identified as male, 32 % as female. Participants ranged in age from 18 to 75 years (M = 42.5 ± 11.9). Participation was sought from active cyclists (who indicated that they cycled on the road at least once per week) and resided in Australia. The larger percentage of males and average age are consistent with statistics on the Australian cycling population (Munro, 2011).

2.2. Procedure

Data were collected via an online survey advertised on social media (Facebook, LinkedIn and Twitter) and through flyers posted around the campus of a large University. Data were collected between June 2018 and March 2019. Participants were provided with an explanatory statement outlining the types of questions asked and that they could complete the survey in their own time and allowed to skip questions if they preferred not to answer them. Hence the lower completion rates. The survey contained several questionnaires and no specific research question was provided to the participants. Ethical approval for the study was obtained from the University Human Research Ethics Committee. The online survey took approximately 15 min to complete and upon completion, participants were provided the opportunity to enter the draw to win an iPad Air2.

2.3. Materials

The survey comprised questions on demographic and socio-economic characteristics, cycling frequency and patterns, and cycling crash and infringement history. The survey also contained a range of existing validated survey instruments: the Mindfulness Attention and Awareness Scale (MAAS; Brown and Ryan, 2003) and the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006), the Cycling Anger Scale (CAS; Oehl et al., 2016), Cycling Anger Expression Inventory (CAX; Møller and Haustein, 2017), the Cyclist Behaviour Questionnaire (CBQ; Useche et al., 2018), and the International Personality Item Pool (IPIP) Big-Five Factor Markers (Goldberg, 1999).

2.3.1. Cycling Anger Scale (CAS)

The CAS (Oehl et al., 2016) assessed anger propensity across a variety of cycling-specific situations. The following research used the 12-item version of the scale. Each item describes a hypothetical interaction with the cycling environment (e.g., "a cyclist forces you off your path"). For each item, participants are asked to rate how much anger they would experience as a result of the situation, basing this on their own experiences and knowledge of their emotional reactivity. Responses are on a five-point Likert scale (1 = not at all; 5 = very much). Items are summed and averaged with higher scores indicating higher propensities for anger. The items are considered to form four broad factors describing interactions with: police (i.e. "you are fined for cycling without lights"); other cyclists (i.e. "a cyclist overtakes you on a narrow lane"); pedestrians (i.e. "a pedestrian blocks the bicycle lane") and drivers (i.e. "a car fails to give you right of way"). Cronbach alphas for internal consistency for these factors ranged from 0.61 (car driver interactions) to .88 (police interactions) (Oehl et al., 2016).

2.3.2. Cycling Anger Expression Inventory (CAX)

The CAX (Møller and Haustein, 2017) is a scale designed to measure aggressive expressions of anger while cycling. The CAX was developed from a scale for the driving population in order to compare anger expression across cyclists and drivers; the Driving Anger Expression Inventory (DAX; Deffenbacher et al., 2002) and its short form, the DAX-short (Stephens and Sullman, 2014). The CAX contains 14 items that each describe a response to an anger provoking situation (e.g., "I ride faster"). Participants are asked to rate the frequency of each type of response on a five-point Likert scale (1 = never; 5 = always). The 14 items are summed and averaged to form three broad types of responses: adaptive constructive responses; personal physical responses and verbally aggressive responses. Higher scores on the adaptive constructive factor represent more adaptive ways of dealing with anger, while higher scores on the other factors represent more frequent aggressive expressions of anger. These have demonstrated good internal consistency with Cronbach alphas ranging from 0.86 to .93 (Møller and Haustein, 2017). Recently, Stephens et al. (2019) confirmed the factor structure of the CAX after one item was removed and therefore recommend a 13-item scale as more appropriate for Australian cyclists. This version also displayed good reliability: Cronbach alphas ranging from 0.79 to .82. A total CAX score is derived from the summed aggressive items (not including adaptive constructive items).

2.3.3. The Mindful Attention and Awareness Scale (MAAS)

The MAAS (Brown and Ryan, 2003) is a scale designed to measure trait mindfulness; specifically, general self-awareness and the ability to keep attention focused within the present moment. The MAAS contains 15 negativity-worded items, all of which describe an example of not paying attention to what is happening at the time (e.g., "I find myself doing things without paying attention"). For each item, participants rate how often this statement is true of their level of attention. Participants respond to items on a six-point Likert scale (1 = almost always; 6 = almost never). The MAAS is unidimensional with lower scores indicating higher levels of mindfulness. Cronbach's alpha for the total MAAS was 0.87, demonstrating good reliability (Brown and Ryan, 2003).

Mindfulness scales can measure a person's state at one moment in time, or a trait, that is, their tendency to be more or less mindful in day-to-day life. Mindfulness, anger or other aspects of a person's character and behaviour can be measured as traits, but if they practice being more mindful, or regulating their emotions, then that trait will change over time. That it changes does not mean that it was not a trait at one time in a person's life, but just that traits can change with practice.

Information on mindfulness meditation practices was also sought. This included whether participants had a current practice and if so, whether they had meditated in the past week. These questions were "Have you previously participated in any mindfulness courses?"; "If you have previously participated in any mindfulness courses, what was the nature (e.g., online course, face-to-face course, etc.) and duration (e.g., number of sessions, number of weeks) of the course?"; "How many times did you do formal meditation practice in the past week?"; "If you have previously participated in any mindfulness courses, do you practice mindfulness meditation on a regular basis?" It was assumed that more frequent (and recent) practice would be associated with greater trait mindfulness, and therefore less anger and aggression.

2.4. Data handling and analysis

Data were analysed using IBM© SPSS v.24 and AMOS v.24 and Alpha was set to 0.05. There were no missing data as only complete datasets were included in the analysis. Bonferroni corrections were applied when multiple comparisons were conducted. Relationship strength was determined as weak (< 0.20), moderate (.20–.40) and strong (> .40) as recommended by Cohen (1988).

Structural Equation Modelling was used to analyse relationships between mindfulness levels, anger propensities and self-reported aggression. Indicator variables for the unidimensional MAAS were made by parcelling items (Little et al., 2002). This helps to reduce the number of observed variables and was more suitable to the current sample size. Therefore, for the MAAS, three parcels of five items were constructed. For the CAS factors, items were used as indicators. For the CAX, adaptive constructive items were reverse coded to follow the same response pattern as the aggressive displays of anger items. That is, higher scores indicate more aggression / less constructive responses. This was only performed at the SEM stage and other descriptives for the adaptive constructive factor included the original, traditional scoring where higher scores indicated more constructive ways for responding to anger. CAX indicators were factor means.

The SEM was conducted using maximum likelihood estimations. As multivariate normality was violated, Bollen-Stine bootstrap analysis on 2000 samples was also used (Bollen et al., 1992). Goodness-of-fit was assessed with Chi-Square (χ^2) indices, with non-significant values indicating good fit. However, significant p values are common with larger samples. Byrne (2001) recommends using other goodness of fit statistics to overcome this problem. Therefore, other goodness of fit values were considered. These included, the Comparative Fit Index (CFI); values > .90 are considered good fit (Hu and Bentler, 1999). The Root Mean Square Error of Approximation (RMSEA); values < 0.06 are considered to be good fit, while values between 0.06 and 0.08 are considered fair fit (Browne and Cudeck, 1993). The 90 percent confidence intervals around the RMSEA was also included. The Consistent version of Akaike's (1987) Information Criteria (CAIC; Bozdogan, 1987) was also examined. The CIAC provides information on comparisons between two models, with smaller values representing better fit of the hypothesised model (Hu and Bentler, 1999).

3. Results

3.1. Sample demographics

Table 1 shows the riding frequency across the participant sample. The majority of the sample (72.6 %) rode more than 50 km per week on average and rode two or more times per week (90.1 %).

Most of the sample had not previously completed a mindfulness course (73.6 %). Of the 26.4 % who had (n = 154), only 35.5 % (n = 55) continued to practice mindfulness on a regular basis. All participants with an ongoing meditation practice reported having meditated in the past week.

3.2. Anger, aggression and mindfulness levels across gender and mindfulness practices

Table 2 shows the scale scores for anger, aggression and trait mindfulness across gender (male/female) and current mindfulness practices (yes/no). Overall, cyclists reported moderate anger tendencies

Table 1
Riding frequency (N = 583).

Average kilometres per week riding	Sample representation %
Less than 10km	4.1
11 – 20km	6.0
21 – 50 km	17.3
51 – 100km	28.5
101 – 200km	30.2
201 or more	13.9
Frequency of riding a bicycle	
Less than once a week	0.5
Once a week	9.4
2 – 3 times per week	27.3
4 – 6 times per week	42.7
Daily	20.1

Table 2
Means and standard deviations for cycling trait anger, aggression and trait mindfulness across gender and current mindfulness practices.

				Gender		Mindfulness	
		Total sample (N = 583)		Males (n = 394)	Females (n = 187)	Practicing (n = 55)	Not practicing (n = 528)
Total mean (possible range)	α	Response Range	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Total CAS(1–5)	.82	1 – 4.83	3.32 (.60)	3.30 (.57)	3.37 (.63)	3.32 (.74)	3.33 (.59)
CAS: Police interactions	.74	1 – 5	2.78 (.92)	2.42 (.92)	2.30 (.94)	2.41 (1.06)	2.38 (.91)
CAS: cyclist interactions	.79	1 – 5	3.10 (.88)	**3.03** (.86)	**3.28** (.92)	3.16 (.95)	3.10 (.88)
CAS: pedestrian interactions	.89	1 - 5	3.16 (1.08)	**3.08** (1.04)	**3.31** (1.14)	3.24 (1.18)	3.15 (1.07)
CAS: car interactions	.84	1 - 5	4.29 (.74)	4.28 (.72)	4.28 (.75)	4.15 (.80)	4.30 (.72)
Total CAX (1–5)	.74	1 – 5	1.65 (.43)	1.67 (.44)	1.60 (.42)	1.64 (.48)	1.65 (.43)
Total CAX adaptive (1–5)	.83	1- 5	3.20 (.83)	3.24 (.80)	3.11 (.86)	3.32 (.78)	3.18 (.83)
Total MAAS (1–6)	.89	1.53 – 5.93	4.06 (.72)	4.09 (.74)	4.00 (.70)	4.09 (.83)	4.06 (.72)

Notes: CAS = Cycling Anger scale; CAX = Cycling anger expression inventory (includes only aggressive responses); CAX Adaptive = Adaptive responses, higher means indicate more constructive style responses; MAAS = Mindful attention and awareness scale; **Significant differences in bold.**

across different cycling situations scoring an average of 3.32 (± 0.60) from a possible 5 for anger levels. Aggressive expressions of anger were, on average, relatively low with the average CAX score being 1.65 (± .43) out of a total 5, representing only low levels of aggressive response. Likewise, adaptive constructive ways of dealing with anger were more frequent, with average scores being 3.20 (± 0.83) out of five. Mindfulness levels in the sample were moderately high, scoring 4.06 (± .72) out of a possible 6. Cronbach alphas showed good internal consistency reliability for each scale ranging from 0.74 to .89.

When compared across gender, females reported significantly higher levels of anger over interactions with other cyclists (M = 3.28 ± .92) compared to males (M = 3.03 ± .86); $t_{(579)}$ = 3.35, p = .001. This p value was robust to adjustments for multiple comparisons (.05/8). Females also had higher anger scores for pedestrian interactions (M = 3.31 ± 1.14) than males (M = 3.08 ± 1.04; t (579) = 2.29, p = .019. Mean mindfulness scores did not differ between cyclists who were currently practicing mindfulness and those that were not (p > .05). When it came to expressing anger, the average aggression score for males was higher (M = 1.67; ± .44) than females (M = 1.60 ± .42), however this was not significant (t (579) = 1.89, p = .061) and had a small effect size (Cohen's d = .16). It is possible, with a larger sample, this difference may be significant.

3.3. Intercorrelations among anger and mindfulness, aggression and age

Table 3 shows the individual relationships among age, cycling anger (CAS), aggression (CAX) and mindfulness (MAAS) scores. As would be expected, negative relationships were found between mindfulness levels with anger and aggressive behaviours. While these were weak, they indicate that cyclists who tend to have higher levels of mindfulness tend to report less anger and aggression while cycling. In support of this, a weak positive relationship was found between mindfulness levels and adaptive constructive ways of responding to anger, while riders with lower mindfulness tended to report more anger propensities across a range of riding circumstances. Thus, the relationships that emerged showed that increased levels of mindfulness in daily situations was related to lower levels of anger while cycling, regardless of the situation provoking the anger. Additionally, both low anger and higher mindfulness were related to less aggression and more constructive ways of coping with anger while cycling.

Spearman's correlations were conducted on scores for mindfulness, cycling aggression and trait anger with frequency of weekly riding and average weekly kilometres (see lower panel Table 3). Cyclists with higher mileage tended to have higher aggression scores. Interestingly, a positive relationship between mindfulness levels and average weekly kilometres was also observed showing a relationship between engaging in cycling and increased mindfulness.

Table 3
Intercorrelations among trait cycling anger, aggression and mindfulness levels with age (upper panel) and with weekly riding frequency and average kilometres (lower panel).

	Age	Total CAS	CAS: Police	CAS Cyclist	CAS Pedestrian	CAS Car	Total CAX	CAX adaptive	CAX Verbal	CAX Personal Physical	MAAS
Age	–	−.11**	−.04	−.06	−.03	−.23***	−.08	.13***	−.01	−.11**	.25***
Total CAS		–	.58***	.76***	.64***	.78***	.22***	−.19***	.24***	.12**	−.17***
CAS: Police interactions			–	.19***	.10*	.24***	.01	−.04	−.01	.03	−.04
CAS: cyclist interactions				–	.41***	.49***	.06	−.13**	.15***	−.06	−.09*
CAS: pedestrian interactions					–	.38***	.20***	−.16***	.24***	.09*	−.19***
CAS: car interactions						–	.14***	−.20***	.24***	−.03	−.10***
Total CAX							–	−.29***	.86***	.75***	−.14***
CAX Adaptive								–	−.36***	−.17**	.11**
CAX Verbal									–	.37***	−.07
CAX Personal Physical										–	−.17s***
Frequency of riding	−.08	.16**	.13**	.01	.07	.12**	.09*	−.05	.05	.08	.07
Average weekly kilometres	.39***	−.05	−.08*	−.08	.03	.03	.18***	.05	.17***	.14***	.14***

CAS = Cycling Anger scale; CAX = Cycling anger expression inventory (includes only aggressive responses); *** p ≤ .001;** p ≤ .01; * p ≤ .01. The distributions were within normal range demonstrating good absolute values for skewness (< 2) and kurtosis (< 7).

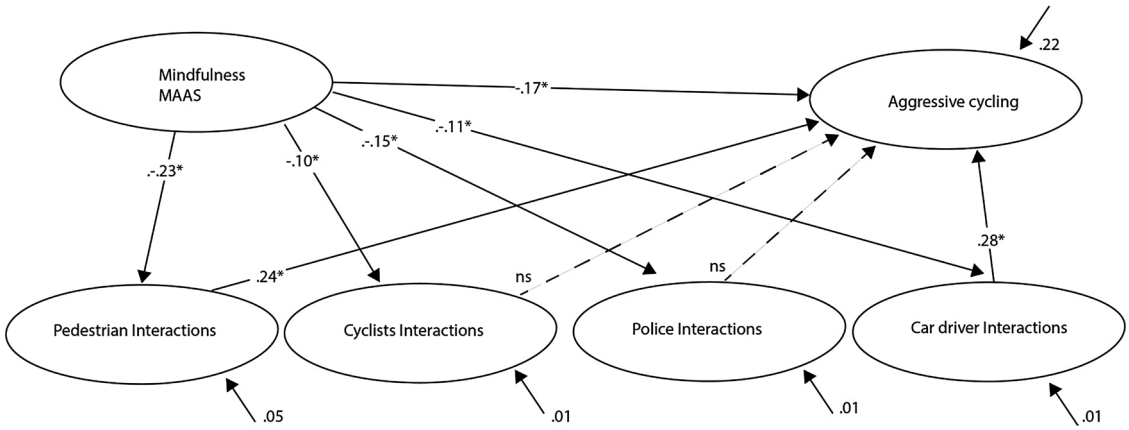

Fig. 1. Relationships between mindfulness, cycling anger and aggressive cycling. NB: disturbance terms shown next to arrows on the endogenous variables. These were allowed to covary for the CAS factors.

3.4. Relationships among trait anger and mindfulness and aggression

A SEM was conducted to simultaneously examine the relationships between trait mindfulness, cycling anger and cycling aggression. An initial model with mindfulness and aggression was conducted, showing good fit to the data $\chi^2_{(4)} = 6.66$, $p = .15$; Bollen-Stine $p = .18$; CFI = .99; RMSEA = .03 (90 %CI: .00–.08). MAAS scores were associated with aggression, with a significant standardized regression of -.25, $p < .001$, explaining 6% of the variance in aggression scores.

A number of models were subsequently tried before the final model (displayed in Fig. 1). Initially the model for mindfulness, anger and aggression was conducted and showed acceptable fit: $\chi^2_{(104)} = 344.74$, $p < .001$; Bollen-Stine $p < .001$; CFI = .94; RMSEA = .06 (90 %CI: .06–.07), CAIC = 705.78. Significant p values are common with larger samples, and therefore the collective goodness of fit values was used to determine fit.

Further models were conducted which tested the inclusion of mileage $\chi^2_{(120)} = 410.11$, $p < .001$; Bollen-Stine $p < .001$; CFI = .93; RMSEA = .06 (90 %CI: .06–.07), CAIC = 785.88, and age and gender: $\chi^2_{(135)} = 476.81$, $p < .001$; Bollen-Stine $p < .001$; CFI = .93; RMSEA = .07 (90 %CI: .06–.07), CAIC = 881.87 but they failed to improve model fit. In addition, neither sex nor age were significantly related to aggression scores in the model, and none of the three variables improved the variance explained in aggression in the aggressive cycling scores. Therefore, the initial model was retained as the final model.

The regression loading of mindfulness to aggressive cycling was reduced to -.17, $p < .001$ when anger variables were introduced in to the model. Overall, the combination of mindfulness and anger explained 22 % of the variance in the aggression scores. Mindfulness level was a significant predictor of all anger interactions, however these were weak and explained only a small amount of the variance across each factor. Only pedestrian and car driver interactions were significantly associated with aggressive cycling frequencies.

4. Discussion

The aim of the study was to explore whether mindfulness levels predict less cycling anger and whether any relationship between mindfulness levels and aggression while cycling, is mediated by anger. Based on similar research conducted with motor vehicle drivers, it was expected that cyclists with higher levels of mindfulness would report less anger tendencies and less aggression. The results supported this hypothesis, however the relationships that emerged with the cycling sample were weaker compared to what has previously been found with drivers. For example, weak negative relationships were found between mindfulness with anger and aggression, indicating that cyclists who have higher levels of mindfulness also tend to have lower anger and less aggression while cycling. When these relationships were examined simultaneously, anger did not fully mediate the relationship between mindfulness and aggression but did account for a significant amount of the relationship. This will be discussed further below.

The pattern of self-reported anger and aggression identified in the current study is consistent with the broader cycling literature. Anger propensities were highest in situations where cyclists were interacting with car drivers (Huemer et al., 2018; Oehl et al., 2019) and the most frequent responses to anger were adaptive constructive (Møller and Haustein, 2017). In our study, female cyclists reported higher anger from pedestrian and cyclist interactions compared to male cyclists. This aligns with the same gender differences reported by Oehl et al. (2019). Møller and Haustein (2017) also found that male cyclists reported more aggressive expressions of anger. In our study, slightly higher means for aggression were reported by males, however these were poorly evidenced. Therefore, an interesting gender difference emerged for cyclist anger and aggression; female cyclists tended to report higher anger propensities while male cyclists tended to report more frequent aggression. This trend is similar to what has been observed in driving research (Deffenbacher et al., 2016) and is likely to be explained by the trait nature of anger, which appears to transfer across different modes of travel (Møller and Haustein, 2017). This pattern also fits with research showing small but significant gender differences in emotional expression, with males more likely to express the anger they feel and often as aggression and females more likely to internalise the anger they feel (Chaplin, 2015). Given the vulnerability of cyclists, it may also be that higher level of anger females experience while cycling is related to the level of fear through their interactions with other road users. This is worthy of further investigation.

The SEM showed that higher levels of mindfulness were related to lower tendencies for anger across each type of anger-provoking situation. Cyclists with higher levels of mindfulness reported less propensity to become angered over interactions with cyclists, pedestrians, car drivers and police. However, the strongest relationships between mindfulness and anger were found for anger related to pedestrians and car drivers. Interactions with pedestrians and motorists represent situations that include key elements that lead to anger. These are immediate danger, progress blocking and a potential target of blame (Berkowitz, 1990). For example, anger is more common when there is someone who can be blamed for what has happened. This anger is exacerbated when the behaviour of that person is seen as being unnecessary or avoidable. Therefore, more mindful cyclists may resist readily blaming others for what has happened and avoid emotional reactivity to these situations (Brown and Ryan, 2003).

Anger was found to be a partial mediator of the relationship between mindfulness and aggression in cyclists; cyclists with higher levels of mindfulness reported less anger over cycling situations and less

aggression. Interestingly, not all anger-provoking situations were associated with aggression. Interactions with cyclists and police were not significantly associated with aggressive responses, which might be due to anger compounding, rather than addressing the problem. In contrast, pedestrian and car driver provocations were associated with aggression. This highlights the importance of the nature of the situation and the recipient in an aggressive response. It appears that when angry, cyclists may be more likely to display this aggressively to pedestrians or motorists, but not other cyclists. This may reflect in-group/out-group dynamics (e.g. Struch and Schwartz, 1989) between pedestrians and cyclists, whereby cyclists may actively work to maintain social harmony with their own 'in-group' i.e. other cyclists. The interactions with pedestrians in the CAS also related to pedestrians blocking or walking on bicycle lanes, which again is likely to represent an outgroup or lack of shared safety perspective. It is most likely that cyclists perceive a sense of threat from drivers and therefore be more likely to both react aggressively toward this group. Previous studies have also shown that anger rumination is a partial mediator of mindfulness and general aggression (Peters et al., 2015), with both direct and indirect relationships between mindfulness and aggression. While Peters et al., used a multifaceted measure of mindfulness (e.g., the Five Factor Mindfulness Questionnaire), the MAAS was used in the present study. The MAAS focusses on propensities for mindful attention and awareness to different situations (Brown and Ryan, 2003). Therefore, our results show that both a direct relationship in that cyclists who have greater tendencies to attend to what is happening in the current circumstance also report less aggression, as well as an indirect relationship where mindfulness is related to the level levels of anger experienced while riding and subsequent aggression.

Interestingly, higher average weekly mileage was associated with greater mindfulness. One way of interpreting this is that cycling may itself be an activity that encourages present-moment attention – that is, keeping one's eyes on the road, rather than daydreaming. This may be truer of cycling compared to driving, given the inherent dangers associated with the former and possibilities for distraction inherent in the latter (e.g. mobile phone use). It may be, therefore, that cyclists with greater experience are more mindful overall. Older cyclists in the present sample were indeed more mindful and less prone to aggression. However, they also tended to be angrier. This may suggest that greater cycling exposure on the road might lead to greater perceived threat from drivers and resentment toward pedestrians, with a concomitant increase in anger, with a simultaneous increase in mindfulness and concomitant *decrease* in aggression.

Although the direction and strength of the relationships for cyclists in the current study were similar to what was observed for drivers (Stephens et al., 2018), some differences also emerged. In the current study, weaker relationships were found between anger and aggression for cyclists compared to what has been found for drivers. Further, less of the variance in aggression was explained by the combination of mindfulness and anger. Only between 1%–5% of the variance in cyclist anger was explained by mindfulness; compared to 16 % for the drivers. In addition, the combination of MAAS scores and anger explained 22 % of the variance in aggressive cycling, compared to 44 % found in drivers by Stephens et al. (2018). These findings suggest that there are other factors which need to be considered when examining cyclists' motivation and behaviours. Our results show that the recipient of aggression is one factor. Other factors may be related individual differences among cyclists (i.e. personality factors) as well as the infrastructure regularly used, which relates to the types of interactions likely to be had, or riding confidence (Damant-Sirois et al., 2014).

In the current study, some, but not all, of the relationship between mindfulness and aggression was through anger. This is again in contrast to drivers, where the relationship between mindfulness and aggression was fully mediated by anger. This difference is unlikely to be explained by differing mindfulness levels as cyclists in our study had significantly higher average MAAS scores (4.06 ± .72) compared to the drivers in previous study by Stephens et al. (2018): 3.68 (.79), $p < .001$. Instead, the relationships may be explained by the nature of the cycling environment frequented by our sample. Cyclists in our study reported that they regularly rode on-road and it might be their increased vulnerability interacting with vehicles (O'Hern and Oxley, 2018) that is contributing to aggression, or lack thereof. Indeed, the most anger provoking situations reported by the cyclists were conflicts with drivers. However, while our results suggest relationships between anger from motorists and aggression, our data do not allow understanding of whether this aggression is directed toward the source of the provocation. This is a limitation of the scale used to measure aggression, the CAX.

This limitation of the CAX might offer another explanation for the relatively low contribution of anger and mindfulness to aggression. The CAX was based on a scale to measure driver responses to anger directed at other drivers (Møller and Haustein, 2017). The items for cyclists were translated into aggression directed at "other road users", which assumes that all expressions of aggression are equal across road users. This is unlikely to be the case, given the vulnerability of cyclists mentioned above. A more nuanced scale that specifies who the aggression is targeted toward might capture more expressions of aggression across different types of interactions.

4.1. Limitations

The data reported above were collected via self-report and as such may be open to criticism regarding socially desirable responding. To counteract this, all potential participants were assured that participation was voluntary and their responses were anonymous. Inclusion criteria for the study also required participants to be "active cyclists" meaning that on average they ride on the road at least once a week. Therefore, our findings cannot be generalised beyond this group of cyclists. It should also be noted that two participants reported less frequent average riding. Further research could be undertaken to explore mindfulness, emotion and behaviours using other populations of cyclists.

5. Practical implications and conclusions

Our results show that cyclists who tend to have higher levels of mindful attention and awareness in their current situation, also tend to report less aggression. This is largely due to the lower levels of anger experienced while cycling for these cyclists. While aggression in cyclists is relatively uncommon compared to drivers (Møller and Haustein, 2017), it is associated with behaviours that increase a cyclist's crash risk. Therefore, mindfulness may offer a promising strategy for cyclist safety, particularly for those cyclists who are frequently encountering anger-provoking situations and are prone to emotional reactivity. Mindfulness training has been shown to have a range of potential road safety benefits, including reducing driver anger and aggression (Kazemeini et al., 2013), and our results suggest that similar benefits could be expected for cyclists. Mindfulness training that focusses on improving cyclists' ability to act without judgement and to be more aware of their actions and associated consequences is likely to be particularly effective.

Author statement

All authors contributed to the design of the project and manuscript preparation and reviewing

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.aap.2020.105625.

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