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Riding through red lights: The rate, characteristics and risk factors of non-compliant urban commuter cyclists

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ABSTRACT

This study determined the rate and associated factors of red light infringement among urban commuter cyclists. A cross-sectional observational study was conducted using a covert video camera to record cyclists at 10 sites across metropolitan Melbourne, Australia from October 2008 to April 2009. In total, 4225 cyclists faced a red light and 6.9% were non-compliant. The main predictive factor for infringement was direction of travel, cyclists turning left (traffic travels on the left-side in Australia) had 28.3 times the relative odds of infringement compared to cyclists who continued straight through the intersection. Presence of other road users had a deterrent effect with the odds of infringement lower when a vehicle travelling in the same direction was present (OR = 0.39, 95% CI 0.28–0.53) or when other cyclists were present (OR = 0.26, 95% CI 0.19–0.36). Findings suggest that some cyclists do not perceive turning left against a red signal to be unsafe and the opportunity to ride through the red light during low cross traffic times influences the likelihood of infringement.

1. Introduction

Crossing an intersection against a red light is one of the most overt illegal road user behaviours. Intuitively, red light infringement may contribute to cyclist-driver collisions as these crashes predominately occur at intersections (Watson and Cameron, 2006). However, while numerous studies have investigated driver and motorcyclist red light infringement (Retting et al., 1999; Porter and England, 2000; Green, 2003; Herbert Martinez and Porter, 2006) and pedestrians who jaywalk (Jason and Liotta, 1982; Kim et al., 2008), little research has examined the rate, characteristics or risk factors of cyclist red light non-compliance in Australia or internationally.

Riding through red lights is frequently cited as the cyclist behaviour that most annoys drivers and is perceived as typical behaviour (O'Brien et al., 2002; Kidder, 2005; Fincham, 2006). Observed rates of red light infringement in Melbourne have been reported at 7–9 per cent (Daff and Barton, 2005; Johnson et al., 2008). Daff and Barton observed cyclists' behaviour at sites before and after bicycle storage boxes were installed, however these authors provided no further information on how many cyclists were observed. Johnson et al. observed cyclists' behaviour at only two sites. Further research is needed to confirm that the findings from these studies are representative of red light compliance among urban commuters. In a cross-sectional survey of commuter cyclists in Brazil, the self-reported rate of red light non-compliance was 38.4% ($n = 1151$), however, the authors provide no detail of the non-compliant cyclists' characteristics and behaviour (Bacchieri et al., 2010).

Higher rates of non-compliance have been reported among bunch riders, formal or informal groups of cyclists who ride together in formation (O'Connor and Brown, 2007). A review of existing video footage was conducted, following a pedestrian fatality after a bunch of riders rode through a red light at a pedestrian crossing, found that non-compliance decreased from 46% of all red lights faced prior to the collision (2005) to zero following the collision (2007) (Johnson et al., 2009). Despite the reported improved behaviour, no further observations have been analysed to determine if the behaviour change is representative of all bunch riders or if compliance has been maintained. Further, it is unlikely these findings can be generalised to other types of cyclists.

Cyclist crash involvement as a result of red light non-compliance has been found to be low in the United Kingdom (1.8%, $n = 508$ Police reported collisions) (Lawson, 1991) and in Queensland, Australia (6%, $n = 199$ collisions) (Green, 2003), (6.5%, $n = 1214$ collisions) (Schramm et al., 2008). However, there are more subtle repercussions of cyclist non-compliance beyond their safety when crossing intersections and include the negative impact on driver attitudes towards cyclists (Basford et al., 2002). Further, driver attitudinal research has found that cyclist gender and clothing influence

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Fig. 1. Video camera box in position on a sign post.

drivers' perception of cyclist competency (Walker, 2007) and likelihood of road rule compliance (Basford et al., 2002).

The aim of this study was to establish the rate, characteristics and risk factors of commuter cyclists who rode through a red light at intersections in metropolitan Melbourne. The findings of this study will provide new information on non-compliant cyclists.

2. Methods

2.1. Research design

A cross-sectional observational study was conducted using a video camera (Sony DCR-SR62) placed inside a small grey box and attached to a roadside sign post that displayed parking time details (see Fig. 1). The covert camera position eliminated potential behavioural bias, as road users were unaware they were being observed. Ethics approval was obtained from the Monash University Human Research Ethics Committee.

2.2. Site observations

Observations of cyclists were made at 10 sites along the most frequently used on-road commuter routes in metropolitan Melbourne. All sites were within 5 km of the CBD, had two lanes of forward travel, four lanes of cross traffic, a pedestrian crossing and a tram line parallel to the right vehicular lane. Morning observation sites were in-bound and afternoon observation sites were out-bound. Site gradient was flat with the exception of the continuous site (type 3) which had one downhill (morning) and one uphill (afternoon) site.

Cyclist behaviour at three cycling facility types was observed (see Fig. 2). The first type, referred to as standard, is the most common configuration in Melbourne. Standard facilities had a bicycle storage box (also know as an advanced stop line or bike box) at the front of the left turning lane; the lane did not have a turn filter light and the midblock bike lane discontinued on approach to the intersection. Six sites with this facility were observed, three in the morning and three in the afternoon. The second type had a bicycle storage box in front of the centre lane; the left parallel lane was a dedicated turning lane for vehicles with a filter light and the midblock bike lane discontinued on approach to the intersection. Two sites with this facility were observed, one in the morning and one in the afternoon. The third type is an uncommon cycling facility in Melbourne and was a continuous green painted bike lane that continued parallel with the vehicular lane from midblock to the intersection. Two sites were observed with this facility, one in the morning and one in the afternoon.

Each observation was for 3 h, from either 7–10 AM or 4–7 PM over 6 non-consecutive days, resulting in 18 h of footage per site. As observations were conducted during peak travel times it was assumed that cyclists were commuters. It was not necessary to observe multiple approaches as peak flow of cyclists travelled in one direction. All observations were conducted during warmer months (October–April) and during daylight savings period. Observations were restricted by the weather. Days when the forecast temperature exceeded 35 °C or days with rain during the morning observation period were excluded to minimise potential biases, such as fewer cyclists and a higher proportion of male cyclists.

Manual analysis of the data is resource intensive and was limited by project funding. Given that there were a number of other research questions to be addressed using other aspects of the same data, a subset was selected for the purpose of this study. In total, three observations (9 h) per site were analysed, this length of footage was chosen to provide sufficient power to address the hypotheses set.

2.3. Participants

All road users who entered the site were video recorded. Included in the analysis were cyclists who travelled through the intersection on the road and included cyclists who approached the intersection via the footpath or pedestrian crossing. Cyclists who turned off the road and onto the footpath or pedestrian crossing and did not continue through the intersection were excluded from further analysis.

It is important to note that the observations are unlikely to be of unique cyclists. The sites were repeatedly observed over 6 days and it is likely that some cyclists were filmed on more than one observation session and possibly faced a red light on more than one occasion. The correlation between observations of the same cyclist could not be accounted for since it was not possible to reliably identify cyclists from the video footage in order to link multiple observations in the data. Consequently the statistical values quoted in the analysis results may be conservative.

2.4. Data analysis

The outcome measure was cyclist red light compliance (yes/no). In Australia, it is illegal to cross any intersection against a red signal and left turn on red is not permitted in the state of Victoria where the observations were conducted. Non-compliance was defined as crossing the intersection against a red light, as described in previous studies of driver behaviour (Lawson, 1991; Porter and England, 2000; Green, 2003). Cyclists who entered the intersection on a green or amber light were coded compliant, even if the light turned from amber to red during the crossing. Cyclists who entered the

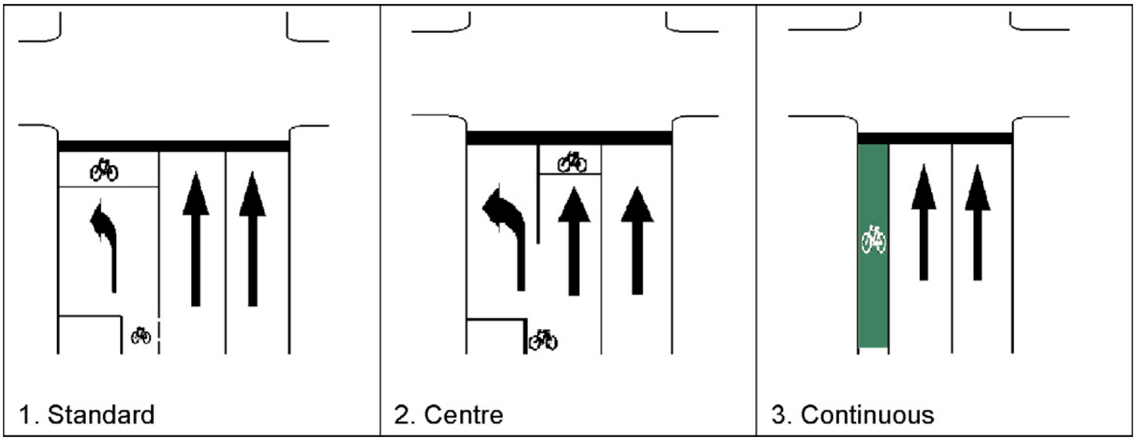

Fig. 2. Three cycling infrastructure types observed.

intersection but stopped and waited for the light to change to green or who made a 'rolling stop' but did not come to a complete stop were coded compliant. Cyclists who stopped but then 'jumped' the red light (Johnson et al., 2008) crossing before the light they were facing turned green, typically in the few seconds the cross light had changed to red, were coded non-compliant.

Given the binary outcome measure, a single binary logistic regression analysis model was used. The model included all available predictor variables and selected interactions simultaneously to determine the relationship between each predictor variable or interaction and the outcome measure along with the statistical significance of the measured associations. Since all factors were included in the model simultaneously each is automatically adjusted for confounding effects of the other predictor variables included in the model. All variables were treated as categorical variables in the model. The statistical analysis package SPSS 18.0 was used to calculate the descriptive statistics and construct the logistic regression models.

Three groups of predictor variables were recorded: location, cyclist characteristics, and other road users. The location variables and categories were time (AM or PM), gradient (flat, downhill or uphill) and cycling facility type (standard, centre, continuous).The cyclist variables and categories were: gender (male/female), bicycle type (road bike: drop handlebars; flat bar/mountain bike; other: included recumbent bikes, folding bikes and ladies bikes) and clothing (full cycling: jersey and cyclist pants; half cycling: either jersey or cyclist pants and; non-cycling: all other clothing which included sportswear, casual clothing and work attire), helmet use (yes/no), direction of travel (left/straight). None of the cyclists made a conventional right turn at the intersection from the right lane; rather they performed a right turn using a hook turn – that is, they first rode straight across the intersection and waited in front of the cross traffic lane for the cross flow traffic signal to turn green. The travel direction for these cyclists was coded as straight. The other road user variables and categories were: number of other cyclists (count), number of cross vehicles (count from left and right) and presence/absence of a vehicle at the intersection (yes/no). Cross traffic was defined as all vehicles that crossed the intersection from either direction from the time the cyclist came into view until the cyclist cleared the intersection. The traffic volume (count) was categorised (0, 1–10, 11–20, 21+). Vehicles in the same lane were vehicles at the intersection travelling in the same direction as the cyclists, at the standard and centre sites these vehicles were in the same lane as the cyclists and at the continuous facility sites the vehicle was in the adjacent lane.

Two logistic regression models were constructed. The first was conducted for all cyclists including all predictor main effects. A second analysis was conducted for male cyclists only and included a number of selected interactions. Since the majority of infringements were observed for male cyclists analysis of interactive effects between factors was only possible through restricting the analysis to male cyclists. To test for potential problems of co-linearity between predictor variables non-parametric correlations between all of the variables included in the model were examined. This analysis showed no evidence of co-linearity between any of the predictor factors. Subsequent cross-correlations between parameter estimates from the logistic regression models were examined confirming no problems of co-linearity between the factors.

Classification tables were used to assess the predictive power of the binary logistic regression models. A cut off of predicted probability of infringing of 0.07, the overall infringement rate in the study sample, was used as this yielded the highest sensitivity and specificity for the model.

To address potential coding bias, 10 h (11.5%) of footage was recoded by an independent research assistant and analysed using the Kappa statistic. The inter-rater reliability was Kappa = 0.688 ($p < 0.001$), 95% CI (0.472–0.904). This measurement of agreement is statistically significant and can be interpreted as substantial (Landis and Koch, 1977).

3. Results

A total of 4225 cyclists faced a red traffic light and 292 cyclists (6.9%) were non-compliant. The proportion of non-compliant cyclists varied across sites from 3.9% to 13.0%. No collisions were observed.

3.1. Descriptive statistics

The descriptive statistics for all cyclists were cross-tabulated with red light compliance (Yes/No) and are presented in Table 1.

Cyclists turning left had the highest proportion of infringement and this was higher among male cyclists (62.3%) than females (38.0%).

The types of bikes ridden and clothing worn were similar for male and female cyclists. The most observed bike type was mountain/flat bar (males: 68.5%, females: 82.1%) with more males riding road bikes (30.2%) than females (9.9%) and more females on 'other' bikes (8.1%) than males (1.3%). The majority of all cyclists wore non-cycling clothing (females: 84.5%, males: 65.0%). Males were more likely to wear full cycling clothing (24.1%) than females (6.7%) with a similar proportion wearing half cycling clothing (males: 11.0%, females: 8.8%).

Table 1
Observed variables for all cyclists by compliance ($n = 4225$).

	Compliance				
	Yes		No		Total
Time					
AM	1798	(94.1%)	112	(5.9%)	1910
PM	2135	(92.2%)	180	(7.8%)	2315
Gradient					
Flat	2900	(92.9%)	220	(7.1%)	3120
Downhill	367	(92.4%)	30	(7.6%)	397
Uphill	666	(94.1%)	42	(5.9%)	708
Facility					
Standard	2299	(93.1%)	170	(6.9%)	2469
Centre	601	(92.3%)	50	(7.7%)	651
Continuous	1033	(93.4%)	72	(6.5%)	1105
Gender					
Male	2871	(92.3%)	239	(7.7%)	3110
Female	1062	(95.2%)	53	(4.8%)	1115
Bike type					
Road	979	(93.3%)	70	(6.7%)	1049
Mountain/flat bar	2833	(93.0%)	213	(7.0%)	3046
Other	121	(93.1%)	9	(6.9%)	130
Clothing					
Full cycling	778	(94.5%)	45	(5.5%)	823
Half cycling	404	(91.8%)	36	(8.2%)	440
Non-cycling	2751	(92.9%)	211	(7.1%)	2962
Helmet					
No	7	(87.5%)	1	(12.5%)	8
Yes	3926	(93.1%)	291	(6.9%)	4217
Direction					
Straight	3872	(94.9%)	210	(5.1%)	4082
Left	61	(42.7%)	82	(57.3%)	143
Other cyclists present					
No	557	(80.0%)	139	(20.0%)	696
Yes	3376	(95.7%)	153	(4.3%)	3529
Cross traffic					
0	122	(50.6%)	119	(49.4%)	241
1–10	1174	(90.5%)	113	(9.5%)	1287
11–20	847	(95.9%)	36	(4.1%)	883
21+	1790	(98.7%)	24	(1.3%)	1814
Vehicle in lane					
No	1537	(89.4%)	183	(10.6%)	1720
Yes	2396	(95.6%)	109	(4.4%)	2505

3.2. Binary logistic regression – all cyclists

All factors were included in a binary logistic regression model, with non-compliance as the outcome variable (see Table 2). The overall predictive percentage of the model was 87.6%, sensitivity was 88.5% and specificity was 74.7%.

As demonstrated by the analyses reported above, direction of travel was associated with the highest likelihood of non-compliance. Cyclists turning left were 28.4 times more likely to infringe than cyclists riding straight. Gender was statistically significant: females had odds of infringement of 0.60 compared with males. Cycling facility was also statistically significant as cyclists at the centre facility had a 2.6 higher odds of infringement than cyclists at the standard facility site.

The presence of other road users had a deterrent effect; infringement was most likely when the cross traffic volume was low and decreased when cross traffic volume increased. When compared to cyclists at the intersection alone, odds of infringement were 0.39 compared when a driver was present and 0.26 when other cyclists were present.

Bike type and clothing were not significantly associated with infringement in the model at any level, despite high proportions in the descriptive statistics. Bicycle helmet use was high and while there is some suggestion that helmet use may be related to infringement odds, there were insufficient data to determine significance.

Table 2
Relative odds of infringement related factors in the model.

	Adj, Rel. odds of non-compliance	95% C.I. for odds	Statistical Sig.
Time			
PM vs AM	0.885	0.609–1.285	0.520
Gradient			0.902
Downhill vs flat	1.047	0.504–2.178	0.902
Facility			0.000
Centre vs standard	2.640	1.626–4.286	0.000
Continuous vs standard	1.305	0.780–2.181	0.310
Gender			
Female vs male	0.596	0.410–0.869	0.007
Bike type			0.385
Mountain/flat bar vs road	1.126	0.737–1.721	0.583
Other vs road	1.938	0.758–4.955	0.167
Clothing			0.226
Half cycling vs full cycling	1.657	0.906–3.029	0.101
Non-cycling vs full cycling	1.444	0.883–2.363	0.143
Helmet			
Not worn vs worn	0.205	0.021–2.029	0.176
Direction			
Left vs straight	28.399	17.770–45.386	0.000
Other cyclists present	0.260	0.189–0.359	0.000
Vehicle present	0.387	0.280–0.535	0.000
Cross traffic			0.000
1–10 vs 0	0.085	0.057–0.125	0.000
11–20 vs 0	0.035	0.021–0.059	0.000
21+ vs 0	0.014	0.008–0.024	0.000

3.3. Analysis of interactive effects

Additional logistic regression models were constructed to analyse interactions between all combinations of gender, bike type and clothing. None of the interactions tested were statistically significant. A systematic analysis of the interactions between male and female cyclists was also attempted however the model was non-convergent due to too many empty cells. The problem with empty cells was caused by the generally low infringement rate for females and their relatively homogeneous choice of bike type. Given this limitation, the analysis was limited to male cyclists.

A second regression model was constructed using only male cyclists data to determine if male-specific interactions were evident. The bike type ‘other’ was also excluded due to insufficient observations. Findings were similar to those of the whole group, the only notable difference was that odds of infringement when turning left increased to 31.4 times more likely compared with travelling straight through the intersection. Interactions for bike type and clothing were not statistically significant ($p = 0.78$). Estimated odds for all other variables were not significantly different from the full sample.

4. Discussion

This study examined cyclist red light infringement, the rate and related factors and identified a number of behavioural and environmental predictors. Findings highlight that cyclists’ propensity to ride through intersections against a red light as a multivariate issue.

Travel direction, specifically turning left, was the greatest predictor of infringement. Cyclists may perceive turning left to be a relatively safe manoeuvre since they are exposed to fewer points of conflict from cross traffic and cross traffic did have a deterrent effect and the perception of safety and opportunity to infringe decreased as the cross traffic volume increased (Wang and Nihan, 2004). However, despite the perceived safety associated with turning left against a red light, this manoeuvre may lead to an increased risk of cyclist-pedestrian collisions as was experienced in the United States of America when the right turn on red was introduced (Preusser et al., 1982). Further analysis is needed to determine the role of direction of cross vehicular traffic.

No collisions were observed. While this may suggest that non-compliance is a safe behaviour, collisions are relatively rare events. More importantly, the potential repercussions of this behaviour go beyond the individual cyclist. Cyclist red light non-compliance is the most frequently cited behaviour at annoys drivers (O’Brien et al., 2002; Kidder, 2005; Fincham, 2006) and there is potential that this annoyance may influence the attitudes and behaviours of some drivers when they interact with cyclists, beyond the individual non-compliant rider observed. In addition, unpredictability is a key concern of drivers when interacting with cyclists on the road (Basford et al., 2002) and cyclist red light non-compliance is likely to increase driver perceptions of unpredictability and reduce driver confidence when interacting with cyclists.

The presence of other road users, cyclists and drivers, travelling in the same direction had a deterrent effect on infringement. Other road users may be a proxy measure for high traffic periods or it may have a direct deterrent effect or other cyclists may speak to cyclists and admonish a non-compliant cyclist. Further investigation of cyclist attitudes is needed to understand the influence of others on red light non-compliance.

Despite drivers’ perception that they can anticipate cyclists’ behaviour based on appearance and bicycle type (Basford et al., 2002; Walker, 2007), this analysis found these characteristics had no predictive value on cyclists’ likelihood of red light non-compliance.

Further, variations in non-compliance were also observed across the cycling facility types with cyclists more likely to be non-compliant at the centre sites than the standard or continuous sites. While there may be numerous reasons for this finding, for example differences in light phasing (left turn filter lights were available at the centre sites and not at other sites), or arrival time in the red light phase, these were not able to be determined from the observational data. More in-depth analysis is required to fully understand these contributing factors.

Finally, cyclists’ non-compliance was deliberately not compared to driver behaviour as the opportunity to infringe is different. Any driver who may intend to infringe is restricted by the lead vehicle in the lane, therefore no following drivers have an opportunity to infringe. This is not the case for cyclists. Every cyclist is able to ride between waiting vehicles or cyclists and can choose to be non-compliant at almost every intersection. While it is likely that the predilection to infringe at red lights varies when people are cycling compared to driving, the opportunity to infringe is more comparable to pedestrians than drivers. Further analysis is planned to compare the rates of non-compliance between cyclists and pedestrians.

5. Strengths and limitations

This study determined the rate, characteristics and risk factors of commuter cyclists’ red light infringement and provided an objective measure of actual cyclist behaviour and was not subject to behaviour modification or self-reporting bias. The multivariate analysis identified the impact of individual components on risk.

There were a number of study limitations. The infringement rate is not likely to be representative of all intersection types as observed sites had comparable traffic flow and complexity and are unlike less complex sites with no cross traffic (e.g. pedestrian crossings) or highly complex intersections with greater cross traffic volume. In addition, findings were for metropolitan commuter cyclists and may be comparable to cyclists in other urban areas however they may not represent non-urban riders or weekend behaviour.

Further, cyclist gender was determined by physical appearance and there is potential for some error in this subjective classification. It is also possible that factors that cannot be determined by observation, including age and socioeconomic factors, may contribute to the likelihood of non-compliance. Finally, cyclists are heterogeneous and findings may not relate to other types of riders.

6. Conclusion

The rate of red light non-compliance (7%) is lower than that found in previous studies have found and is not as widespread as reported in studies of drivers’ perception. This study provides a baseline rate of red light non-compliance and establishes the types of behaviour that might be targeted for behavioural change countermeasures, such as turning left. Further research directions may include investigating the rate of red light infringement at various intersection types or among different cyclist types such as training riders, bicycle couriers, recreational riders or children. In addition, investigations into cyclist red light non-compliance may address: driver attitudes and perceptions and influences on driver behaviour; the mechanism of the deterrent role of other cyclists and vehicles and; cyclists’ perceptions about the apparent safety of turning left and the potential implications on cyclist safety.

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