Drivers' behavioural responses to red-light-cameras

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INTRODUCTION

Numerous signalized intersections worldwide have been equipped with enforcement cameras in order to tackle red light running and often also to enforce speed limits. Both red light running and speeding are considered to be substantive problems, frequently leading to crashes. Crashes caused by red light running are typically associated with side impacts, which often lead to severe injuries (Garber et al., 2007). In general, red light cameras (RLC) tend to increase the number of rear-end crashes and to decrease the occurrence of side crashes. The latest meta-analysis (Høye, 2013) results in a beste estimate of a non-significant decrease with 13% in the number of injury crashes. Høye (2013) also found a 19% increase in rear-end injury crashes and a 33% decrease in right-angle injury crashes. A recent study (De Pauw et al., 2014) evaluated the effectiveness of red light cameras at 253 signalized intersections in Flanders, Belgium. The results indicate a significant increase (+44%) in rear-end collisions whereas side collisions non-significantly decrease with 6%. However, in the latter study the observed overall effect of red light cameras is an almost significant decrease of 14% for the more severe injury crashes.

The present study, is a follow-up study of De Pauw et al. (2014) designed to investigate the behavioural responses of road users approaching red light camera sites. The principal objective of this study is to provide a better insight in possible explaining factors for the revealed effects on crashes, in particular the observed increase in the number of rear-end crashes.

METHOD

Two methods are used to take a closer look at the actual behaviour of drivers who are approaching an intersection equipped with RLC: 1) before and after observations at 2 RLC intersections, 2) a driving simulator study.

Real-world observations

A before and after study was implemented at two urban signalized intersections where red light cameras were going to be installed. A video-based data collection system was used at one intersection leg to record the road user behaviour before and after the installation of the red light camera. Both intersections were observed during two weeks each time in both the before and after period. The observations for the after period started 6 weeks after the installation of the red light camera to reduce the novelty effect. So far we analysed the video footage of 1 location, 24 hours of footage before installation of the camera, 24h afterwards. This intersection was a 50 km/h four-arm intersection with 2x1 lanes and a separated lane for left-turning traffic. The observed variables consisted of vehicle speeds, red/green/yellow light crossing, dilemma zone behaviour and rear-end conflicts.

Driving simulator study

A real world intersection was selected and replicated in the driving simulator at Hasselt University's Transportation Research Institute. The primary objective of this study is to evaluate the driving and looking behaviour of drivers at signalized intersections equipped with RLCs in an urban area. For this purpose, 63 participants approached a 50 km/h four-arm intersection with 2x1 lanes three times while they were confronted with the following conditions: control condition (no RLC), RLC condition and

RLC + warning sign (RLCWS) condition. The conditions appeared in a randomized order (within subjects design). Participants have always been confronted with a leading vehicle (at 65m) and a following vehicle (at 25m) when approaching the intersection. The signal light turned from green to yellow when participants were 2.5 sec. removed from the stop line (i.e. time headway of 2.5 sec.). This way, each participant had an equal time interval to react to the yellow onset. Subjects were asked to drive as they normally would do with their own car and apply the traffic laws as they would do (or would not do) in reality.

Insert figure 1 here

RESULTS

Real-world observations

Preliminary results of the four-arm intersection indicate that RLCs have a significant impact on road user behaviour. Based on a simple before/after comparison, the results for the speed measurements show a decrease (-3 km/h) in the 85th percentile and a reduction (-3.92%) in the number of speed offenders. These results are not corrected for possible general trends and are based on 1 full week of data for each period. Furthermore, it is important to note that the results also include the vehicle speeds of the drivers that stopped for the red or yellow light.

Secondly, the number of red and yellow light violations decreases after the introduction of the red light camera (X^2 (1, N =9049) = 2.872, p = 0.090). Truck drivers drive significantly less through the yellow phase after the installation of the red light camera (X^2 (1, N =419) = 4.065, p = 0.044).

Insert figure 2 here

Thirdly, the stopping or driving behaviour in the dilemma zone is observed. The dilemma zone is a theoretical area of an intersection approach where a driver must take a decision (stop or go) when confronted with the yellow traffic light (McGee et al., 2012). In this study, the dilemma zone is empirically derived from the observed data. Especially when drivers approach a signalized intersection with high speeds, the dilemma zone problem results in some drivers stopping abruptly while others decide to stop (or even to accelerate). This variation in driving behaviour may lead to collisions (mainly rear-end) on the intersection approach (Institute of Transportation Engineers (ITE), 2009; Yan et al., 2009). In this study, the dilemma zone is defined as the area in which more than 10% but less than 90% of the drivers decide to stop at the onset of the yellow phase (Zegeer, 1977). The RLC changed the location of the dilemma zone at the intersection. The size of the zone remained unchanged (± 2.5 sec.) but the zone is situated closer to the stop line indicating that drivers even tend to stop when they are situated very close to the stop line.

Insert figure 3 here

Finally, the presence of rear-end conflicts was analysed based on the Swedish conflict observation technique. However, the analysis so far did not result in any serious conflicts neither in the before-period nor in the after-period. This indicates that the currently used dataset is still insufficient to enable the observation of effects on traffic conflicts.

Driving simulator study

The decision behaviour of the driver (stop or go) at the onset of the yellow phase is studied for the 3 conditions. In the control condition 7 (i.e. 11%) participants stopped for the yellow sign. For the RLC and RLCWS conditions the number of participants who did not drive through was 8 (i.e. 13%) and 19 (i.e. 30%), respectively. This means that slightly more participants stopped when a RLC was implemented. The condition with the warning sign (RLCWS) even lead to a further increase in stopping manoeuvres. Furthermore, the mean deceleration values of -2.83 m/s², -4.28 m/s² and -3.45 m/s² were found for the control, RLC and RLCWS condition respectively. The decelerations appear to be much stronger in case for the RLC condition and are more or less mitigated by the introduction of a

warning sign where they approximate the more normal comfortable braking deceleration value of -3m/s² (Koppa, 2003).

Furthermore, the risk of rear-end collisions was estimated by a Monte Carlo simulation based on simulator speed/acceleration data and real-world observations of time headways observed in the before-and-after study. The stopping distances were calculated for both the following and the leading vehicle. A rear-end collision occurred when the sum of the stopping distance of the following vehicle plus the distance headway was larger than the stopping distance of the leading vehicle. 100.000 iterations were executed for each condition. As the resulting odds of a rear-end collision in the RLC (6.42) and the RLWWS condition (4.01) compared with the control condition were clearly above 1, the revealed probability of a rear-end collision in those conditions is higher than in the control condition.

Insert figure 4 here

Finally, the looking behaviour of the drivers was measured with an eye tracking system. Several regions of interest (ROI) are selected: leading vehicle, traffic light, rear view mirror, speedometer (on screen, below the rear view mirror), RLC, and RLCWS. Fixation durations < 0.05sec. are not taken into account. The results did not reveal any statistically significant differences in looking behaviour between the 3 conditions. Drivers who observed the RLC tended to stop more often while drivers who fixated on the warning sign tended to look less at the RLC. Subsequently, the study also revealed some interesting findings regarding the looking behaviour:

- A higher percentage of the participants who stopped observed the RLC (62% vs. 28%) and the RLCWS (68% vs. 51%) compared to the participants who did not stop. Participants who stopped had a longer mean fixation duration for the RLCWS compared to drivers who did not stop (0.38sec. vs. 0.23sec.).
- In general, a higher percentage of the participants who stopped fixated on their rear view mirror and speedometer than the participants who did not stop.
- Only 70% of the drivers who did not stop fixated on the traffic light. However, this does not mean that the other 30% of the drivers did not notice the traffic light (cfr. peripheral vision; (Dewar & Olson, 2007)).

DISCUSSION AND CONCLUSIONS

This study investigated the behavioural responses of road users approaching red light camera sites to gain a better understanding of possible explaining factors for the revealed effects on crashes, in particular the observed increase in the number of rear-end crashes. The actual behaviour of drivers approaching an RLC intersection was observed by means of an on-site before and after study and a driving simulator study.

The preliminary results of both studies indicate that red light cameras do influence road user behaviour. The results of the on-site observation study reveal decreases in the number of red and yellow light violations, V_{85} reductions, fewer speeding offences and a shift in the dilemma zone after the installation of the red light camera. The findings of the driving simulator study also reveal possible adverse effects of the presence of red light cameras on road user behaviour such as stronger decelerations and an increase in the number of rear-end collisions. However, in case the presence of red light cameras is announced with warning signs, these adverse effects are somewhat reduced. However, this effect is still highly unsure.

When the findings of both studies are combined, they reveal behavioural responses that might explain the increase in rear-end crashes. However, no observable effects on the level of conflicts could yet be found.

Although the preliminary results reveal behavioural effects after the implementation of the red light camera, it is not known yet whether these observed behavioural effects are as such not desirable or even responsible for the increase in the number of rear-end collisions. Consequently, the challenge lies

in further discovering which types of behavioural responses exactly occur at RLC sites and how these responses are related to rear-end crashes and conflicts. For example, Corbett (2000) defined a typology of drivers' responses to speed cameras in which she distinguished between manipulators, defiers, conformers and deterred drivers. If the driving population mainly comprises deterred drivers and manipulators, it is possible that their avoiding behaviour (decelerating before camera sites and accelerating afterwards) might be responsible for the stronger decelerations at camera sites. Further developing such insights is likely to be helpful in identifying possible countermeasures to cope with possible adverse effects.

REFERENCES

1. Aarts, L., & Van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis & Prevention*, *38*(2), 215–224.
2. Corbett, C. (2000). A typology of drivers' responses to speed cameras: Implications for speed limit enforcement and road safety. *Psychology, Crime & Law, 6(4),* 305-330.
3. De Pauw, E., Daniels, S., Brijs, T., Hermans, E., & Wets, G. (2014). To brake or to accelerate? Safety effects of combined speed and red light cameras. *Journal of Safety Research*, *50*, 59–65.
4. Dewar, R., & Olson, P. (2007). Human factors in traffic safety. Tucson: Lawyers & Judges Publishing Company, Inc.
5. Garber, N. J., Miller, J. S., Abel, R. E., Eslambolchi, S., & Korukonda, S. K. (2007). The impact of red light cameras (photo-red enforcement) on crashes in Virginia (No. FHWA/VTRC 07-R2). Virginia: Virginia Transportation Research Council.
6. Høye, A. (2013). Still red light for red light cameras? An update. *Accident Analysis & Prevention*, *55*, 77–89.
7. Institute of Transportation Engineers (ITE). (2009). Traffic Engineering Handbook (6th ed.).
8. Koppa, R. J. (2003). "Human Factors" Chapter 3 of: Gartner, N.H., Messer, C.J. and Rathi, A.K. (Eds) Traffic Flow Theory. Washington, D.C.: Transportation Research Board Monograph, National Research Council.
9. McGee, H., Moriarty, K., Eccles, K., Liu, M., Gates, T., & Retting, R. (2012). Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections (No. 731). Washington, D.C.: Transportation Research Board.
   Washington, D.C.: ITE.
10. Yan, X., Radwan, E., Guo, D., & Richards, S. (2009). Impact of "Signal Ahead" pavement marking on driver behaviour at signalized intersections. Transportation Research Part F: Traffic Psychology and Behaviour, 12(1), 50–67.
11. Zegeer, C.V. *Effectiveness of green-extension systems at high-speed intersections.* Research report 472. Bureau of Highways, Kentucky Department of Transportation, Lexington, 1977.

Figure 1: Real world vs. simulator image at intersection.

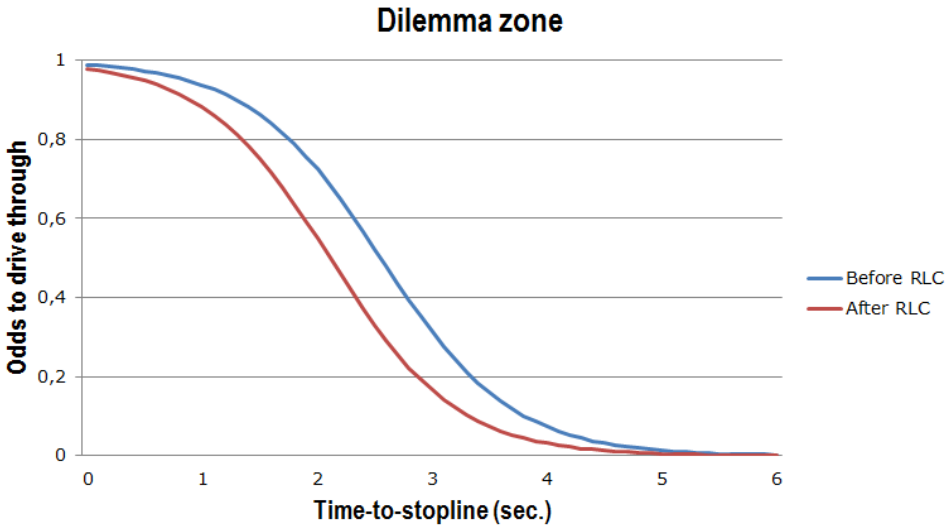


Figure 2: Dilemma zone

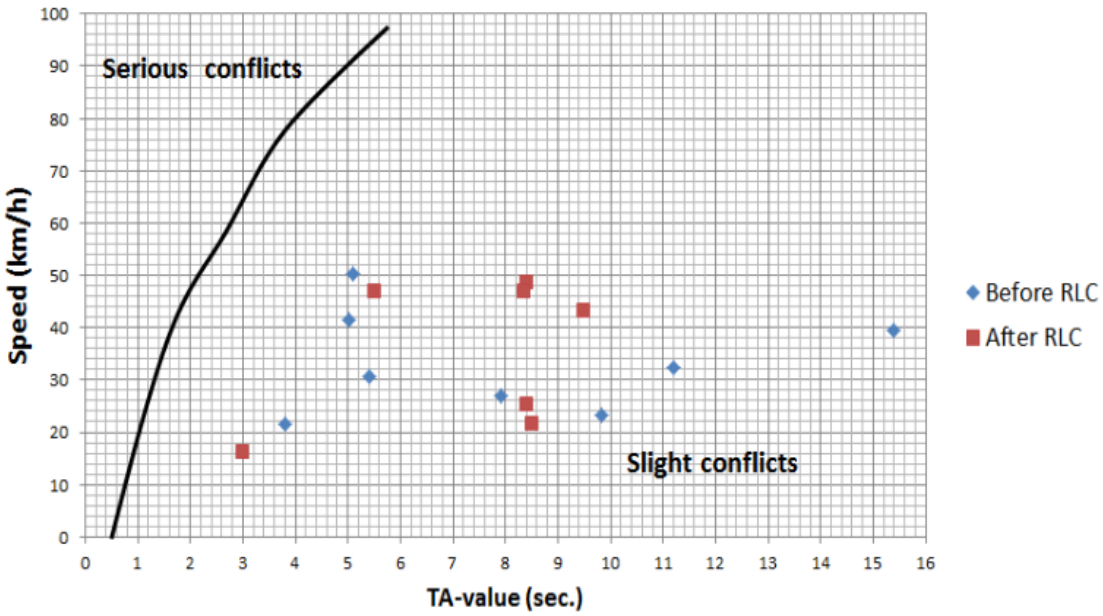
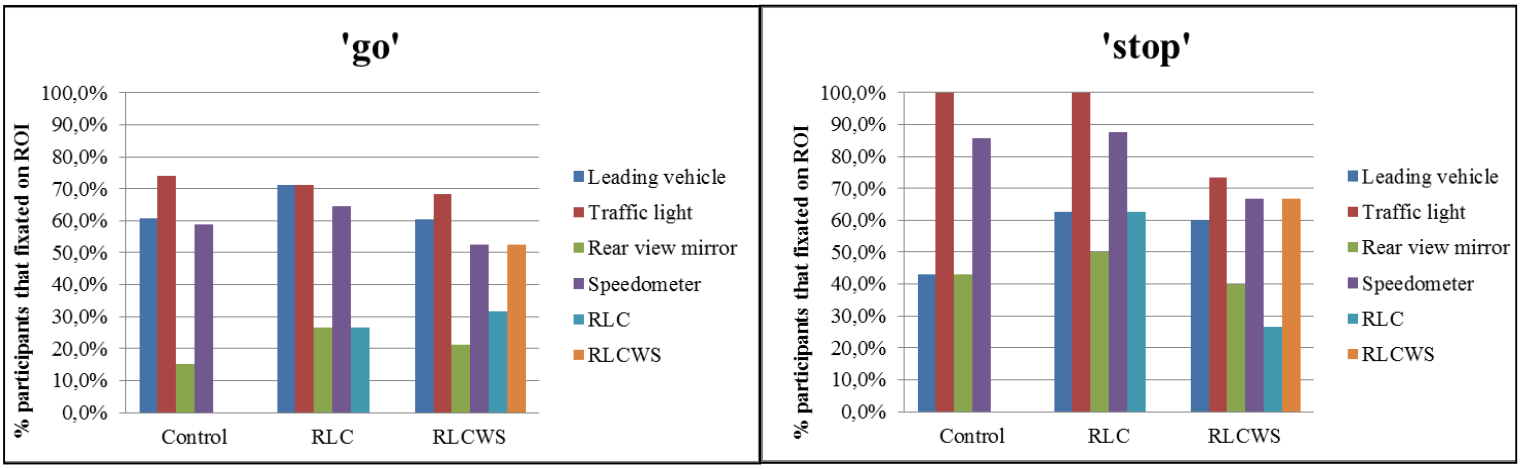


Figure 3: Potential rear-end conflicts



(a) **(b)**

Figure 4: Number of participants that fixated on ROI (a) ‘go’ and (b) ‘stop’