ARTICLE IN PRESS

Safety Science xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Special Issue Article: Cycling Safety

Motor vehicles overtaking cyclists on two-lane rural roads: Analysis on speed and lateral clearance

Carlos Llorca *, Antonio Angel-Domenech, Fernando Agustin-Gomez, Alfredo Garcia

Highway Engineering Research Group (HERG), Universitat Politècnica de València (UPV), Camino de Vera s/n, 46022 Valencia, Spain

ARTICLE INFO

Article history:
Received 10 March 2015
Received in revised form 29 October 2015
Accepted 9 November 2015
Available online xxxx

Keywords:
Bicycle
Overtaking
Sport cycling
Two-lane rural road
Lateral clearance
Instrumented bicycle
Risk perception

ABSTRACT

Two-lane rural roads in Spain accommodate significant bicycle traffic volumes, mainly associated to sport and leisure activities. Motor vehicles' higher speed, weight and volume, compared to cyclists, represent a serious safety concern when overtaking a bicycle. Spanish traffic rules determine a minimum 1.5 m lateral distance.

This research characterised 2928 overtaking manoeuvres in the overtaking lateral clearance between motor vehicle and bicycle, as well as in the motor vehicle speed, in contrast with previous research. Two instrumented bicycles were equipped with laser rangefinders, a GPS tracker and three video cameras. They rode along seven rural road segments at a speed between 15 and 25 km/h, centred on the paved shoulder, or as close as possible to the outer edge. Besides, this methodology allowed the characterisation of the overtaken vehicle type, its left lane occupation as well as its interaction with opposing traffic flow. For each session, rider's general risk perception was also registered.

The analysis suggested that lateral clearance is not the only factor that influenced rider's risk perception, although current standards are only related to it. On the contrary, a combined factor of lateral clearance, vehicle type and vehicle speed had a more significant correlation with the perceived risk. This agreed with literature models of transient aerodynamic forces between overtaking and overtaken vehicles. Results showed that effect of heavy vehicles on bicyclists was also strong. In addition to this, the combined factor of clearance and speed was higher on tangent sections where overtaking was permitted.

1. Introduction

Two-lane rural roads in Spain accommodate significant bicycle traffic volumes, mainly associated to sport and leisure activities. According to Spanish traffic regulations (Ministerio del Interior, 2003), cyclists must ride as close as possible to the outer edge of the road, on the shoulder if it exists. This research focuses on two-lane rural roads, which do not have any specific lane marking for bicycles. Motor vehicles that overtake cyclists must keep a minimum lateral distance of 1.5 m.

According to Spanish Traffic Directorate (2013), there were 5835 accidents with personal injuries or deaths involving bicycles in Spain in 2013. Only 26% of accidents occurred in rural roads, being the rest on urban areas. However, 46% of severe injuries (297 of 646 severe injuries) corresponded to rural roads. Moreover, the proportion of deaths in rural roads with respect of the total was up to 65% (45 of 69 deaths). Despite the higher use of bicycles on urban environments, cycling on rural roads represents a serious safety concern, affecting around 45 deaths a year in 2013. Compared to urban areas, the severity of crashes involving bicycles on rural roads is much higher.

Previous research reported this higher severity. Boufous et al. (2012) found that, although only a 5% of bicycle crashes in Victoria region (Australia), their severity was higher (46% of crashes involved severe injuries, compared to 33% on urban crashes). Those authors explained that the cause of this result was the higher speed of motor vehicles. Tin Tin et al. (2013) reported lower risk on rural roads compared to urban streets, although they did not analyse the severity.

Despite the higher relative severity of bicycle crashes on rural roads, there have been very few studies, compared to urban cycling safety. Results of urban safety analyses (Hamann and Peek-Asa, 2013; Klassen et al., 2014; Osberg et al., 1998) cannot be extrapolated to overtaking manoeuvres of motor vehicles and bicycles on rural roads, because of the higher speeds of motor vehicles and the type of manoeuvres that take place on them.

* Corresponding author.
E-mail addresses: carlloga@cam.upv.es (C. Llorca), anngedom@cam.upv.es (A. Angel-Domenech), feraggo@cam.upv.es (F. Agustin-Gomez), agarciag@tra.upv.es (A. Garcia).

http://dx.doi.org/10.1016/j.ssci.2015.11.005
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For this reason, some researchers focused specifically on the observation of overtaking manoeuvres on rural road segments. Savolainen et al. (2012) installed video cameras on high masts to observe the interaction between motor vehicles and bicycles on a rural road tangent section in United States. They analysed how frequent motor vehicles crossed the centreline, as a function of the position of the cyclist on the road shoulders, the presence of opposing traffic or the existence of centreline rumble strips. However, they did not measure accurately the lateral separation between the bicycle and the motor vehicle at the overtaking time. Later, Kay et al. (2014) found that the average vehicular speeds were slightly reduced by the presence of a “Share the Road” sign treatment.

Alternatively, a research project in UK (Walker, 2007; Walker et al., 2014) developed an instrumented bicycle to observe motor vehicles overtaking it. This bicycle was equipped with an ultrasonic distance measurement sensor and a video camera. These authors investigated the influence of using a helmet as well as the effect of cyclist gender, cyclist clothing and bicycle position on the mean overtaking proximity (lateral distance between the motor vehicle and the bicycle). A sample of 2355 manoeuvres were characterised. The absence of a helmet was related with slightly higher overtaking proximities, although a higher effect was associated with the bicycle distance from road edge. The larger the distance from the outer edge of pavement of the road, the smaller the mean overtaking proximity (from 1.40 m if the bicycle was only 0.25 m from the outer edge to 1.2 m if it rode 1.25 m from it). The influence of clothing visibility was small, and therefore authors could not provide any recommendation to prevent very close overtaking manoeuvres. Lastly, female-looking cyclists were associated with a higher lateral clearance.

Chapman and Noyce (2012) used also an instrumented bicycle to observe overtaking manoeuvres on two-lane rural roads. This bicycle was equipped with two cameras and an ultrasonic sensor to measure the distance to the overtaking vehicles. Observing 1151 manoeuvres the authors investigated the effect of motor vehicle type and existence of shoulder in centreline violations. Those violations were more frequent on highways without paved shoulders, which might be related with the necessity of keeping the same lateral distance, but on a narrower road. The violations of the 3 ft (1 m) lateral distance between motor vehicle and bicycle (named lateral clearance) were very rare. The study did not analyse the frequency distribution of the lateral clearance.

Love et al. (2012) studied the compliance of the three-foot (1 m) lateral separation regulation in Baltimore, Maryland. They also used an instrumented bicycle equipped with video-cameras, and measured only the lateral distance from video images. They evaluated the proportion of motor vehicles that kept that distance, although all the experiment took place on urban streets.

The above-cited studies only considered the overtaking proximity or distance between motor vehicle and bicycle. However, a previous study of this paper authors (García et al., 2015) used a highly instrumented bicycle to measure the speed of motor vehicles and the lateral distance during overtaking. The study was carried out in 7 road segments with different lane and shoulder widths. The main findings were that the lateral distance (and obviously the compliance of the 1.5 m criterion) decreased on narrow roads.

Although most of previous research did not measure or analysed the speed of motor vehicles in relation with the lateral distance, Ata and Langlois (2011) identified the collision risk as the combination of two factors: common space occupancy and aerodynamic effect of trucks or buses overtaking a cyclist. The effect of aerodynamic forces depended on both the lateral distance and the speed of the motor vehicle. These results showed that different combinations of speed and clearance generated the same aerodynamic forces. According to Ata and Langlois (2011), the aerodynamic force increased with speed and decreased with lateral distance. It is zero for distances over approximately 3 m. Noger et al. (2005) presented a similar result, calculating the lateral force according to Eq. (1):

$$F_y = \frac{1}{2}\rho S V^2 C_y \quad (1)$$

where

- F_y: lateral force.
- ρ: air density.
- V: speed of the overtaking vehicle.
- S: frontal area of the overtaking vehicle.
- C_y: dimensionless coefficient, which decrease with lateral distance.

Other studies (Corin et al., 2008; Noger et al., 2005; Uystepruyst and Krajnović, 2013) investigated aerodynamic forces between overtaking and overtaken vehicles. Their results also stated that aerodynamic forces are proportional to the square of the overtaking vehicle speed and decrease with lateral clearance. They only focused on overtaking between motor vehicles, and therefore, the results cannot be easily applied to bicycles. Only Kato et al. (1981) investigated the overtaking involving bicycles using experimental and numerical tests. However, this study only analysed the evolution of aerodynamic forces during a controlled manoeuvre, without testing the influence of speed or distance between the interacting bodies.

Lastly, cyclists risk perception of motor vehicles overtaking them on rural roads has not been researched. On the contrary, some studies focused on this variable on urban environments, measuring it using 5 or 10-point scales. Winters et al. (2012) found that perceived risk affected route choice, after interviewing a sample of cyclists on different routes. Parkin et al. (2007) compared perceived risk with bicycle infrastructure and its acceptability. They interview cyclists that observed video clips recorded from a moving bicycle. However, the variables that affect urban cycling could be very different from those related with sport and leisure cycling on two lane rural roads. On urban roads, the presence of signalised intersections, parked cars or separated tracks is crucial, but these factors are not present (or are less frequent) on two-lane rural roads.

Previous research on motor vehicle overtaking bicycles on rural roads has been centred on the study of lateral clearance (Chapman and Noyce, 2012; García et al., 2015; Walker, 2007; Walker et al., 2014), being speed of motor vehicles not measured or analysed. However, there are evidences of the relationship among these variables. On the one hand, speed is a significant factor of aerodynamic forces between overtaken an overtaking vehicles (Ata and Langlois, 2011; Noger et al., 2005), on the other hand, it might be associated with the higher severity of rural bicycle crashes (Boufous et al., 2012; Spanish Traffic Directorate, 2013). The contribution of this paper, in comparison with previous research, was the simultaneous characterisation of lateral clearance, motor vehicle speed and rider’s subjective risk perception of overtaking process.

2. Objectives and hypotheses

The aim of this paper was the analysis of compliance and adequacy of the 1.5 m lateral distance criterion with respect of objective and subjective risk measures. The study had the following objectives:

- Compare the effect of lateral clearance and overtaking vehicle speed (and their combination, in terms of aerodynamic forces) with a rider’s subjective and relative risk perception on the different road segments.