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Influence of oncoming traffic on drivers' overtaking of cyclists

Giulio Francesco Bianchi Piccinini [a,*], Claudia Moretto [b], Huiping Zhou [c], Makoto Itoh [c]

[a] Department of Applied Mechanics, Chalmers University of Technology, Gothenburg, Sweden
[b] Department of Civil Engineering, University of Bologna, Bologna, Italy
[c] Department of Risk Engineering, University of Tsukuba, Tsukuba, Japan

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ABSTRACT

Active transportation - such as cycling - can provide health benefits to the population. However, cycling safety remains a major threat to favour the use of bicycles and, for this reason, more efforts are needed to reduce the number of crashes involving cyclists. One crash scenario which deserves special attention is driver's overtaking of cyclists since it has an increased likelihood to lead to severe injuries. During the overtaking manoeuvre, the monitoring of subjective risk can influence the decision-making process and lead to different outcomes. In this context, the present driving simulator study aims to investigate how the time to collision between oncoming traffic and subject vehicle affected the overtaking strategy, and the minimum safety margins towards the overtaken cyclist. The results show that a decrease in time to collision against the oncoming vehicle significantly affects the drivers' overtaking strategy (accelerative vs. flying), inducing more drivers to choose an accelerative overtaking manoeuvre. The decrease in time to collision also produces a decrease in minimum safety margins to the cyclists for drivers who opt for a flying overtaking strategy. Finally, the current research shows that the minimum lateral safety margins were smaller and the mean speed higher in flying manoeuvres compared to accelerative manoeuvres. Overall, the combination of lower safety margins and higher mean speeds in flying overtaking manoeuvres seems to pose a risk for cyclists' safety. The findings of the study provide some implications for the design of automated driving.
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1. Introduction

The promotion of cycling brings health benefits for citizens of all age groups and to further favour the use of bicycles, special attention should be dedicated to cycling safety (Götschi, Garrard, & Giles-Corti, 2016). Although most countries have, over the years, reduced cyclist fatality rates per capita and per kilometre, serious injuries data show smaller declines or even increases in rates per kilometre (Buehler & Pucher, 2017). Those serious injuries are mostly the result of single bicycle crashes or crashes in which a cyclist collides with a motorized vehicle (Björnberg, 2016; Schepers, Stipdonk, Methorst, & Olivier, 2017). With respect to the latter category, situations when a motorist may overtake a slower cyclist have an increased likelihood to lead to severe injuries (Stone & Broughton, 2003). In Japan – which is the country of interest for this paper – the Institute for Traffic Accident Research and Data Analysis (ITARDA) reported 9210 vehicle-cyclist crashes on the

* Corresponding author at: Chalmers University of Technology, Department of Applied Mechanics Department, Division of Vehicle Safety, Crash Analysis and Prevention group, Lindholmspiren 3, Lindholmen Science Park, 41756 Gothenburg, Sweden.
E-mail address: giulio.piccinini@chalmers.se (G.F. Bianchi Piccinini).

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roads, during 2016 (ITARDA, 2018). Among the different crash configurations, crashes during overtaking of cyclists represented 20% of the overall dataset and, therefore, deserve the attention of cycling safety researchers.

In addition to objective risk, the overtaking of a slower vehicle against oncoming traffic also involves subjective risk (Farah, Bekhor, & Polus, 2009; Van der Molen & Bötticher, 1988) which is a key aspect influencing drivers' decision making according to the zero-risk theory (Näätänen & Summala, 1974). During driving, individuals try to minimize their risk by choosing sufficient margins to potential hazards to feel safe and comfortable (Summala, 2007). In other words, drivers strive to remain within comfort zones during the driving task as they do during the interactions with other individuals (Hall, 1966). However, together with other factors, the perception of subjective risk (e.g. risk associated to a possible collision with oncoming traffic) might influence the boundaries of the comfort zones and the corresponding safety margins selected by the drivers (Näätänen & Summala, 1974).

Previous studies about driver's overtaking with oncoming traffic showed that errors during the manoeuvre mainly concern misjudgements of the speed of the approaching vehicle and, partly, of the distance to both the oncoming vehicle and the overtaken vehicle (Hills, 1980). Notably, unsafe overtaking manoeuvres can be caused by the fact that some drivers use the distance to the oncoming vehicle as a control variable for the decision to overtake while temporal variables such as the time to collision (TTC) or the time required to overtake (TRO) would be more meaningful (Gray & Regan, 2005). Previous research also showed that errors in overtaking manoeuvres might be due to unexpected hazards during the overtaking (e.g. oncoming traffic coming into view during overtaking), which can lead to some modifications or even to a drastic change of the initial manoeuvring plan (Clarke, Ward, & Jones, 1999). With respect to that, it was found in a real traffic study that the overtaking driver reduces the longitudinal and lateral safety margins to the overtaken vehicle when an oncoming car is suddenly appearing in the opposite lane with a time headway inferior to 4 s (Papakostopoulos, Nathanael, Portouli, & Marmaras, 2015).

To the knowledge of the authors, there is a lack of similar studies focusing on drivers' overtaking of cyclists. As a matter of fact, previous research has investigated safety margins during overtaking of cyclists (Chapman & Noyce, 2012; Dozza, Schindler, Bianchi Piccinini, & Karlsson, 2016; Feng, Bao, Hampshire, & Delp, 2018; Llorca, Angel-Domenech, Agustin-Gomez, & Garcia, 2017; Mehta, Mehran, & Hellinga, 2015; Walker, 2007) but no study has been conducted to investigate the influence of oncoming traffic on the decision-making process and on the selection of safety margins in such manoeuvres. The present study aims to investigate the matter in Japan, through a driving simulator study.

2. Material and methods

2.1. Apparatus

The study was conducted during November-December 2015 in the driving simulator at the University of Tsukuba (Fig. 1). The driving simulator was equipped with steering wheel, accelerator pedal, brake pedal and gearshift, although the participants were not requested to change gear since the vehicle worked on automatic transmission modality. The driving scene was shown on five screens covering about 180 degrees field of view: the angle between the front monitor and the left/right monitors was 45 degrees. The driver eyes' were located about 140 cm from the front screen and the image of the rear field of view was displayed to the driver through the center mirror and the side mirrors. During the experiment, two video cameras were activated to record the driver's face and the forward roadway.

Fig. 1. Image of the driving simulator used for the experiment.

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