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Safety–critical events in everyday cycling – Interviews with bicyclists and video annotation of safety–critical events in a naturalistic cycling study

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A B S T R A C T

Research in cycling safety seeks to better understand bicycle-related crashes and injuries. The present naturalistic cycling study contributes to this research by collecting data about bicyclists' behavior and impressions of safety–critical situations, information unavailable in traditional data sources (e.g., accident databases, observational studies). Naturalistic data were collected from 16 bicyclists (8 female; $M = 39.1$ years, $SD = 11.4$ years) who rode instrumented bicycles for two weeks. Bicyclists were instructed to report all episodes in which they felt uncomfortable while riding (subjective risk perception), even if they didn't fall. After data collection, the bicyclists were interviewed in detail regarding their self-reported safety–critical events. Environmental conditions were also recorded via video (e.g., road surface, weather). In total, 63 safety–critical events (56 non-crashes, 7 crashes) were reported by the bicyclists, mainly due to interactions with other road users – but also due to poorly maintained infrastructure. In low-visibility conditions, vehicle-bicycle and bicycle-bicycle events were the most uncomfortable for the bicyclists. Self-reported pedestrian–bicycle events primarily consisted of pedestrians starting to cross the bicycle path without looking. With one exception, all crashes found in the study belonged to poorly maintained road and infrastructure. In particular, construction work or obstacles in the bicycle path were reported as uncomfortable and annoying by the bicyclists. This study shows how naturalistic data and bicyclists' interviews together can provide a more informative picture of safety–critical situations experienced by the bicyclist than traditional data sources can.

1. Introduction

Bicycling is increasing in popularity as a means of transport, particularly in urban areas (see, e.g., Mobilität in Deutschland 2008 in Follmer et al., 2010; National Household Travel Survey 2009 in OECD/International Transport Forum, 2013; Santos,

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McGuckin, Nakamoto, Gray, & Liss, 2011). Although cycling can have positive consequences on an individual level, such as improved health, and on a societal level, such as reduced emission completions, it also entails risks. In fact, a large number of injuries and deaths from cycling are reported every year worldwide (e.g., Candappa, 2012; National Highway Traffic Safety Administration, 2014; World Health Organisation, 2013).

In order to decrease the risks associated with bicycling, it is essential to understand the causes of near-crashes and crashes, including the behaviors of bicyclists and other road users involved. To gain this insight, earlier studies have primarily analyzed secondary data such as accident databases, like the Swedish Traffic Accident Data Acquisition STRADA (see, e.g., Thulin & Niska, 2009), the German In-Depth Accident Study GIDAS (see, e.g., Otte, Jänsch, & Haasper, 2012), the Western Australian Road Injury Database (see, e.g., Gavin, Meuleners, Cercarelli, & Hendrie, 2005; Rosman, 2001), and the US National Highway Traffic Safety Administration Fatality Analysis Reporting System FARS (see, e.g., National Highway Traffic Safety Administration, 2011). Accident databases, which include police and hospital reports, categorize crashes according to location, time of day, and roadway condition, as well as describing contributing factors (e.g., alcohol, bicycle failures, curb, speed, telephone use, weather, and cycling direction). For example, in STRADA Thulin and Niska (2009) described and analyzed influential factors leading to various bicycle crashes and injury situations. Hospital reports also provide important primary data about bicycle-crash injuries in terms of type, severity, long-term psychological effects, and diagnosis. They may also include information about the crash itself, and sometimes refer to accident databases (e.g., Juhra et al., 2012; Kingma, Duursma, & ten Duis, 1997).

In addition, other experimental approaches have investigated bicyclists' behavior and their hazard perception in safety–critical situations, including simulator studies (e.g., Plumert, Kearney, & Cremer, 2007; see also the projects Safety Research Using Simulation – SAFER-SIM, University of Iowa) and studies with instrumented vehicles and bicycles (see, e.g., Chuang, Hsu, Lai, Doong, & Jeng, 2013; De Waard, Lewis-Evans, Jelijs, Tucha, & Brookhuis, 2014; Dozza & Fernandez, 2012; Kettwich & Fors, 2011). For example, Kettwich and Fors (2011) used an instrumented vehicle to explore the dynamics of a risky situation; they examined drivers' gaze and driving behavior at bicycle crossings after right turns at night. Observational road studies have also been used to investigate drivers'/bicyclists' attention allocation and the effectiveness of different countermeasures, such as speed bumps and stop signs, for reducing crash risk (see, e.g., Summala, Pasanen, Räsänen, & Sievänen, 1996; Summala & Räsänen, 2000).

The research approaches described above all contribute to our understanding of bicycle crashes, but they also have limitations. Analyses based on information in accident databases have two main disadvantages. First, official accident databases under-report less serious bicycle crashes, in which little or no damage or injury was sustained. If the police aren't called and the involved road users don't go to the hospital, there is no record in the primary data sources. As a result the official accident databases will not have any information either (e.g., Elvik & Mysen, 1999; Langley, Dow, Stephenson, & Kypri, 2003; Wegman, Zhang, & Dijkstra, 2012). Thus, a complete picture is lacking about safety–critical situations involving bicyclists. Second, they are mainly post hoc, descriptive analyses, containing little information about the behavior(s) of road users involved.

Alternatively, to investigate road users' behavior in detail and learn more about cause-and-effect relations of factors contributing to safety–critical situations, driving and cycling simulators are mainly used. Due to high controllability, reproducibility, and standardization of conditions, situations can be easily studied. However, simulator studies also have limitations. First, experimental studies addressing cycling safety have been run mainly in driving simulators with a focus on driver behavior (e.g., Caird et al., 2008). Hence, a bicyclist's perspective is lacking. Simulator studies using bicycle simulators are relatively rare (although this has been changing in the last few years). So far, only a few studies have used bicycle simulators (Plumert et al., 2007). Second, although the simulator set-up allows for controlled studies and comparisons, lack of ecological validity is another limitation. The results cannot easily be transferred to the real world, because the environment is artificial. Alternatively, instrumented vehicles and bicycles can be used in more realistic conditions with a higher degree of external validity. However, with this method mainly test tracks with unrealistic environment or pre-defined routes in real road-traffic are used. Additionally, an experiment characteristic is still given due to an experimenter in the car.

A complementary alternative to the limitations mentioned above is naturalistic studies and the collection of naturalistic data. Naturalistic studies have already been established in the driving domain (see, e.g., Dingus et al., 2006; Eby, 2011; Regan, Williamson, Grzebieta, & Tao, 2012; Twisk, Van Nes, & Haupt, 2012) and more recently also in the cycling domain (see, e.g., Dozza, Piccinini, & Werneke, 2015; Dozza & Werneke, 2014; Gehlert et al., 2012; Gustafsson & Archer, 2013; Johnson, Charlton, & Oxley, 2010; Johnson, Charlton, Oxley, & Newstead, 2010). The rationale for naturalistic studies overall is that they avoid the non-ecological effects of artificial surroundings and experimental set-ups. Second, naturalistic cycling data enable a detailed analysis of bicyclists' behavior, including their interactions with other road users, in normal cycling as well as safety–critical situations. Another advantage of naturalistic studies lies in the fact that even crash situations resulting in minor injuries (or even when no crash occurred, as in near-crashes) can be analyzed, avoiding the under-reporting observed in accident databases. Bicycle data which cannot be found in other data sources provide a much more complete picture of bicycle safety in real road traffic. Fourth, in safety–critical situations, they facilitate the collection and analysis of pre-crash information, and thereby allow us to identify factors contributing to crashes and near-crashes under real-road traffic conditions. Therefore, bicycle data (e.g., GPS, speed, braking, kinematics) and video data from before, during and after the crash can be analyzed. This wealth of information enables us to better understand the dynamics and causes of the crash itself, but is unavailable from accident databases. Furthermore, video data provide a detailed picture of (safety–critical) situations and mobility behavior. For example, in order to identify and describe mobility and accessibility/safety problems while cycling,