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Introducing naturalistic cycling data: What factors influence bicyclists' safety in the real world?

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ABSTRACT

Presently, the collection and analysis of naturalistic data is the most credited method for understanding road user behavior and improving traffic safety. Such methodology was developed for motorized vehicles, such as cars and trucks, and is still largely applied to those vehicles. However, a reasonable question is whether bicycle safety can also benefit from the naturalistic methodology, once collection and analyses are properly ported from motorized vehicles to bicycles. This paper answers this question by showing that instrumented bicycles can also collect analogous naturalistic data. In addition, this paper shows how naturalistic cycling data from 16 bicyclists can be used to estimate risk while cycling. The results show that cycling near an intersection increased the risk of experiencing a critical event by four times, and by twelve times when the intersection presented some form of visual occlusion (e.g., buildings and hedges). Poor maintenance of the road increased the risk tenfold. Furthermore, the risk of experiencing a critical event was twice as large when at least one pedestrian or another bicyclist crossed the bicyclist's trajectory. Finally, this study suggests the two most common scenarios for bicycle accidents, which result from different situations and thus require different countermeasures. The findings presented in this paper show that bicycle safety can benefit from the naturalistic methodology, which provides data able to guide development and evaluation of (intelligent) countermeasures to increase cycling safety.

1. Introduction

Bicycling is an environmentally friendly, economical, and healthy mode of transportation increasingly popular in Europe and US (Pucher, Buehler, & Seinen, 2011). As the number of bicyclists grows, promising to decrease pollution and prolong life (de Hartog, Boogaard, Nijland, & Hoek, 2010), new concerns arise about cycling safety (Wegman, Zhang, & Dijkstra, 2012). Accident statistics show that cycling safety did not improve as much as driving safety in the last few decades (DaCoTa-Project, 2011a, 2011b), reflecting the fact that countermeasures to traffic accidents have focused mainly on motorized vehicles. As the number of bicyclists increases in Europe and the US, bicyclist safety becomes an ever more important concern, expanding the current debate about its effect on traffic safety (Elvik, 2009): in 2009, 2334 bicyclists died in Europe (CARE, 2011) and 630 in the US (Karsh, Hedlund, Tison, & Leaf, 2012).

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Some bicycle accident scenarios also involve motorized vehicles (Isaksson-Hellman, 2012; Räsänen & Summala, 1998; Wachtel & Lewiston, 1994; Walker & Brosnan, 2007); however, in most countries in Europe, 70% of bicycle accidents involve a single bicycle. The prevalence of bicycle-specific scenarios is probably due to the fact that bicycle stability can be suddenly degraded in unexpected situations, or when the bicyclist is distracted (Dozza & Fernandez, 2014). For motorized vehicles such as cars and trucks, the probability of experiencing an accident without hitting another road user is much lower (DaCoTa-Project, 2011a), as stability is not as critical. However, most of the bicyclist fatalities were the result of collisions with motorized vehicles (DaCoTa-Project, 2011b). Thus, traffic safety analysis should understand bicycle dynamics (i.e. motion and equilibrium) and bicyclist behavior, including interaction with other road users from the bicyclist's point of view. In fact, trying to assess bicycle safety from a driver's point of view, by collecting data from a car or a truck, for example, would only address specific situations (where a bicycle interacts with a motorized vehicle) and a specific, limited point of view (the driver's). To date, the most accredited tool to address traffic safety is naturalistic data. Nevertheless, so far, naturalistic data has been mainly collected from motorized vehicles (Hickman & Hanowski, 2011) and, when collected from bicycles, data was limited to GPS and/or videos in geographically restricted areas (Gustafsson & Archer, 2012; Johnson, Charlton, Oxley, & Newstead, 2010). Several new scientific contributions, as well as large financial investments from governmental agencies (Campbell, 2013), show that naturalistic data is able to answer questions that other data, such as data from accident databases, cannot answer. In fact, naturalistic data is currently driving the development and evaluation of intelligent in-vehicle systems (Malta et al., 2012); by recording all events leading to an accident, naturalistic data can provide a better understanding of the driver's behavior, and thus valuable and unique insight into accident causation (Dingus, Klauer, et al., 2006), including issues such as distraction (Lee, Simons-Morton, Klauer, Ouimet, & Dingus, 2011). Inspired by previous research on naturalistic driving (Bao, LeBlanc, Sayer, & Flannagan, 2012; Dingus, Neale, Klauer, Petersen, & Carroll, 2006), we propose a novel methodology for the collection and analysis of naturalistic cycling data. Using this methodology, we collected data from 16 bicyclists in Gothenburg in order to verify the hypothesis that multiple interactions with other road users and elevated bicycle dynamics increase accident risk. Odds ratio analysis (Agresti, 1999) was used to determine whether critical events differed from normal cycling, while correlation analyses were used to assess the extent to which cycling longer or faster affected the probability of critical events. The analyses presented in this paper were informed by previous research on naturalistic driving data such as the Commercial Vehicle Operation Study (Hanowski, Perez, & Dingus, 2005), the 100-Car Naturalistic Driving Study (Dingus, Klauer, et al., 2006; Hanowski et al., 2005), and the Integrated Vehicle-Based Safety Systems (Sayer et al., 2011). However, the video analysis was adapted to better capture bicyclist behavior, such as interaction with other road users, and cycling accident scenarios.

2. Materials and methods

2.1. Participants

Bicyclists participated in this study by riding instrumented bicycles for two weeks. Initially, 20 bicyclists were recruited by posting ads and sending e-mails to SAFER mailing lists. Due to sickness, other commitments, and technical problems, four bicyclists could not complete the study. A total of 16 bicyclists (8 male, 8 female) participated, aged 26–66 years (M = 39.1 years, SD = 11.4 years).

A standard consent form for naturalistic data collection, detailing the study, the data collected, and the planned analyses, was signed by all bicyclists. Inclusion criteria assured a perfect balance between female and male bicyclists, and further stipulated that the bicyclist not carry any passenger on the bicycle (since carrying children on the back of a bicycle is legal and relatively common in Sweden). This latter criterion was necessary to guarantee no personal data (i.e. GPS) was collected from any person who had not consented to the study.

During the two weeks, the 16 bicyclists used the instrumented bicycle as a substitute for their own bicycle during their daily activity, such as commuting to work. Bicyclists were expected to cycle frequently (an average of 40 min per day on weekdays) and were compensated for their participation with two cinema tickets.

2.2. Data collection and procedure

In this study, data was collected from five instrumented bicycles (Dozza, Werneke, & Fernandez, 2012) which were rotated among the 20 bicyclists between August and November 2012. All bicycles were equipped with battery-powered front and back lights, reflectors, and a bell according to Swedish law. Each bicycle used a logger (Dozza, Idegren, Andersson, & Fernandez, 2013) to collect data from at least one forward video camera, two inertial measurement units, GPS, and two brake force sensors (one for each wheel). Data was collected continuously with a 100-Hz frequency on all signals, except video (30 frames per second) and GPS (10 Hz). Data collection was automatic, starting about two minutes after the bicyclist began riding and stopping after the bicycle had not moved for two minutes. The bicyclists were also instructed to signal every critical event, which was defined in this study as anything that made the bicyclist uncomfortable about her/his own safety while cycling. A push button on the handlebar enabled the bicyclists to timestamp critical events encountered during the ride.