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Using naturalistic data to assess e-cyclist behavior

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ABSTRACT

In Europe, the use of electric bicycles is rapidly increasing. This trend raises important safety concerns: Is their use compatible with existing infrastructure and regulations? Do they present novel safety issues? How do they impact other traffic? This study sought to address these concerns, using instrumented electric bicycles to monitor e-cyclists' behavior in a naturalistic fashion. Data was collected from 12 bicyclists, each of whom rode an instrumented bicycle for two weeks. In total, 1500 km worth of data were collected, including 88 critical events (crashes and near-crashes). Analysis of these critical events identified pedestrians, light vehicles and other bicycles as main threats to a safe ride. Other factors also contributed to crash causation, such as being in proximity to a crossing or encountering a vehicle parked in the bicycle lane. A comparison between electric and traditional bicycles was enabled by the availability of data from a previous study a year earlier, which collected naturalistic cycling data from traditional bicycles using the same instrumentation as in this study. Electric bicycles were found to be ridden faster, on average, than traditional bicycles, in addition to interacting differently with other road users. The results presented in this study also suggest that countermeasures to bicycle crashes should be different for electric and traditional bicycles. Finally, increasing electric bicycle conspicuity appears to be the easiest, most obvious way to increase their safety.

1. Introduction

Electric bicycles (also called pedelecs, e-bicycles, or e-bikes) are bicycles with a small electric motor which propels the bicyclist at speeds up to 25 km/h, as long as the bicyclist rotates the pedals. The ride is less effortful than on a traditional bicycle, but the e-bicycle retains the advantages of silent operation and environmentalism (Cherry, Weinert, & Xinmiao, 2009). Electric bicycles have been available on the European market for more than a decade, but only recently has their number become significant: sales in Europe were between 700,000 and 1,200,000 in 2012, twice as many as in 2009 and eight times as many as in 2006[2]. Electric bicycle use is also rapidly growing in China, Australia, and US raising safety issues in those countries (Cherry et al., 2009; Johnson & Rose, 2013; MacArthur, Dill, & Person, 2014). In fact, as electric bicycles become more prevalent, they might change traffic dynamics as the proportion of road users travelling by different modes changes, giving rise to unforeseen traffic situations and road user interactions.

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At first sight, most electric bicycles on the European market look the same as traditional bicycles. In fact, their two largest components, the motor and the battery, are included in the bicycle design (McLoughlin et al., 2012). The motor, commonly mounted on the hub of the front or rear wheel, is approximately 15 cm in diameter. It is powered by a battery which may be combined with the rear rack or installed along the frame under the saddle of the bicycle (McLoughlin et al., 2012). The battery (able to store between 10 and 13.5 Ah) weighs around 3 kg and needs to be recharged every 50–70 km, normally requiring approximately 5–7 h for a complete recharge (Ulrich, 2005).

In Europe, electric bicycles can be used by anyone who can use a traditional bicycle (including minors), can be ridden anywhere a traditional bicycle is allowed (including dedicated bicycle lanes), and do not require a license or insurance. However, electric bicycles are more complex than traditional bicycles and may exhibit very different dynamics. For instance, electric bicycles can maintain a 25 km/h speed even on a steep uphill when the wind is blowing in the opposite direction, as long as the rider keeps pedaling. However, whether electric bicycles behave differently than traditional bicycles in European traffic is currently unknown. Most of today's regulations defining who can ride an electric bicycle, and where and how it can be ridden, are not driven by naturalistic data; electric bicycles are assumed to be just as safe as traditional bicycles.

Very little is known, especially in Europe, about electric bicyclists' safety, the way they behave in traffic, how they interact with other road users, and the types of crashes and near-crashes they experience. Studies in China suggest that rider behavior may differ depending on the type of bicycle ridden; for example e-cyclists are more likely than other bicyclists to run red lights at intersections (Pai & Jou, 2014; Wu, Yao, & Zhang, 2012). Comparisons between e-cyclists and traditional cyclists in China show that electric bicycles enable higher mobility (Cherry & Cervero, 2007) at the expense of more risk-taking behavior (Bai, Liu, Chen, Zhang, & Wang, 2013). Zhang, Cui, Gu, Stallones, and Xiang (2013) report that fatalities and injuries from electric bicycle crashes in China increased steadily between 2004 and 2010 (Zhang et al., 2013). However, to date few studies have addressed electric bicycle safety in Europe (but see (Dozza, Mackenzie, & Werneke, 2013; Gehlert et al., 2012), where infrastructure and traffic regulations for bicycles are different than in China. In Sweden, for example, most bicycle lanes are separated from motorized vehicles and shared with pedestrians, thus potentially creating different conflict scenarios compared to other parts of the world and China in particular.

The study presented in this paper was performed in Sweden and collected extended naturalistic data from electric bicycles. These data captured real-world bicyclist behavior and several safety–critical events (crashes and near-crashes). The analyses presented in this paper show how naturalistic data can be used to understand e-cyclists behavior and safety. The results were compared to results from naturalistic data from traditional bicycles (Dozza & Werneke, 2014) to help determine how to develop countermeasures to electric bicycle crashes.

2. Material and methods

The methods employed in this study were kept as similar as possible to our previous study (Dozza & Werneke, 2014) to facilitate comparisons across the two naturalistic cycling studies.

2.1. Participants

In this study, naturalistic cycling data was collected for 14 bicyclists, each one riding an instrumented electric bicycle for two weeks. All 20 bicyclists from our previous study (Dozza & Werneke, 2014) were contacted and asked to participate in this study, in order to facilitate comparison across the two studies and control for sample bias. Overall, only eight of the original bicyclists chose to participate in the second study, and unfortunately two did not complete it. The additional six bicyclists participating in this study responded to ads or e-mails distributed via the SAFER network. Thus 12 bicyclists (six male, six female), age 22–50 years ($M = 37.6$ years, SD = 10.3 years) completed the study to provide the data analyzed in this paper. Eight out of the 12 bicyclists had no prior experience with electric bicycles, three had ridden one once before (as a test ride) and one bicyclist had an electric bike for private use. All bicyclists signed a standard consent form for naturalistic data collection, detailing the study, the data collected, and the planned analyses. Inclusion criteria favored a balance between female and male bicyclists. Bicyclists committed to not carrying passengers, to prevent data collection from anyone who had not signed a consent form.

2.2. Data collection and procedure

Naturalistic cycling data was collected from three instrumented electric bicycles which rotated among the participants between August and November 2013. All bicycles were equipped with battery-powered front and back lights, reflectors, and a bell, according to Swedish law. The electric part of the bicycle included a motor (250 W), a control unit, a pedal rotation sensor, two brake switches, a throttle (only active up to 6 km/h in accordance with European regulations), and a rechargeable battery on the rear rack. As in our previous study (Dozza, Idegren, Andersson, & Fernandez, 2014), each bicycle was specially modified with GPS, (at least) one forward video camera, two inertial measurement units, two brake force sensors (one for each wheel), and a logger which collected all the data. This time, however, the logger was powered by the same battery as the electric motor. In addition, the electric bicycles required the collection of extra data to monitor their operation. Data was also collected from the pedal sensor (which measured the rotation of the pedals around the hub), two brake