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Risky riding: Naturalistic methods comparing safety behavior from conventional bicycle riders and electric bike riders

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ABSTRACT

As electric bicycles (e-bikes) have emerged as a new transportation mode, their role in transportation systems and their impact on users have become important issues for policy makers and engineers. Little safety-related research has been conducted in North America or Europe because of their relatively small numbers. This work describes the results of a naturalistic GPS-based safety study between regular bicycle (i.e., standard bicycle) and e-bike riders in the context of a unique bikesharing system that allows comparisons between instrumented bike technologies. We focus on rider safety behavior under four situations: (1) riding in the correct direction on directional roadway segments, (2) speed on on-road and shared use paths, (3) stopping behavior at stop-controlled intersections, and (4) stopping behavior at signalized intersections. We find that, with few exceptions, riders of e-bike behave very similarly to riders of bicycles. Violation rates were very high for both vehicles. Riders of regular bicycles and e-bikes both ride wrong-way on 45% and 44% of segments, respectively. We find that average on-road speeds of e-bike riders (13.3 kph) were higher than regular bicyclists (10.4 kph) but shared use path (greenway) speeds of e-bike riders (11.0 kph) were lower than regular bicyclists (12.6 kph); both significantly different at >95% confidence. At stop control intersections, both bicycle and e-bike riders violate the stop signs at the similar rate with bicycles violating stop signs at a slightly higher rate at low speed thresholds (~80% violations at 6 kph, 40% violations at 11 kph). Bicycles and e-bikes violate traffic signals at similar rates (70% violation rate). These findings suggest that, among the same population of users, e-bike riders exhibit nearly identical safety behavior as regular bike riders and should be regulated in similar ways. Users of both technologies have very high violation rates of traffic control devices and interventions should occur to improve compliance.

1. Introduction

In recent years, electric bicycles, or e-bikes, have emerged as a new, sustainable form of active transportation. While e-bikes are similar to traditional bicycles (hereafter referred to as *regular bicycles*) in terms of function, they offer differences in terms of performance through the addition of an electric motor, which provides some level of assistance to the user during travel. Different e-bike models provide this assistance through different methods including pedal-based assistance, throttle-controlled assistance, or a combination of the two. The e-bikes considered in this study incorporate a pedal-based assist delivered when the user applies force through the pedals. Compared with regular bicycles, e-bikes could provide some benefits with regard to travel range and effort required by the user, promoting increased travel distance, easier acceleration from stops, and higher average speeds while overcoming challenging terrain and other obstacles. It is unclear how these benefits may affect user behavior, particularly related to safety.

The differences in performance between the two modes raise important questions about the safety of users on the two bicycle types. Following these concerns, much of the regulation on e-bikes, worldwide, is focused on safety concerns (Weinert et al., 2007). In the United States, while e-bikes are a relatively new mode of transportation, there are existing concerns for the safety of bicycle users. In New York, e-bikes are illegal because they are not considered bicycles due to the on-board motor and not motor vehicles as they are not registered and because the increased speed associated with e-bikes is considered riskier (Durkin 2013;

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Macarthur and Kobel, 2014). The State of California requires helmets for users of e-bikes but not for users of regular bicycles; it also requires e-bike users to be 16 years old or older (California Department of Motor Vehicles, 1996). According to the Bureau of Transportation Statistics (2009), 4654 pedestrians and 698 cyclists were killed in traffic crashes in 2007. In the United States, cyclists are 12 times more likely to be killed in an accident than a driver of an automobile (Brustman, 1999). While an increase in modal share for non-motorized transportation generally results in fewer fatalities per user, an increase in the number of vulnerable road users could result in an overall increase in injuries and fatalities for users in that group.

1.1. Bicycle safety

The impacts of bicycling on safety and health have been investigated by many studies, although comprehensive analysis of the combined impact of these parameters is not often considered. Leden et al. (2000) developed a model to estimate safety risk for bicyclists based on speed data and expert evaluations of various components such as initial vehicle speed and risk of collision. The bicyclist intersection safety index developed by Carter et al. (2007) also incorporated expert opinion of several situations through the form of safety ratings. That study also analyzed video footage of various intersections and modeled safety risk based on observed avoidance maneuvers, without which a crash would likely have occurred. A bicycle network analysis tool for comparing perceived safety for bicycles on various facilities was developed by Klobucar and Fricker (2007). One common thread amongst these models is the inclusion of user or expert perception about the safety of the facilities in question.

Other studies have investigated bicycle-related crashes at intersections. Wang and Nihan (2004) modeled collision risk between bicycles and automobiles at signalized intersections, and Schepers et al. (2011) modeled bicycle-automobile collisions at unsignalized intersections. These models highlight the role of intersection geometry and, at signalized intersections, the role of phasing on collision risk. Weinert et al. (2007) studied e-bike use in Shijiazhuang, China, and found that, among other conclusions, e-bikes promote a perception of increased safety compared to regular bicycles at intersections.

The behavior of the cyclists themselves, for instance route choice, speed, and other behaviors, also has a large influence on safety. By relating route information of bicyclists to facility attributes in a geographic information system (GIS), Aultman-Hall and Hall (1998) studied the exposure of cyclists on roadways, on off-road paths, and on sidewalks, finding that the relative rates for falls or injuries was least on roadways, followed by off-road paths, and lastly by sidewalks. A study of bicycle users in Brazil found that, while most cyclists, over 95%, agree they should respect traffic rules, a significant number of them violate basic traffic safety laws such as running red lights or riding the wrong direction on the street (Bacchieri et al., 2010). That study found that violating traffic rules as well as riding seven days per week, as opposed to riding fewer days each week, increases the risk of an accident. An Australian study shows that most crashes involving adult cyclists occur in the roadway, primarily at intersections; however, for adolescents, most crashes involve a cyclist entering the roadway from a sidewalk and colliding with an automobile (Boufous et al., 2011). A recent study in the Netherlands found that e-bike and bicycle crash outcomes are about the same (Schepers et al., 2014). In Switzerland, e-bike crashes tend to follow the same mechanisms as bicycle crashes (Papoutsi et al., 2014).

Educational efforts to curb dangerous or risky cycling behavior are not always successful. In one study, over 1000 individuals in Brazil were invited to meetings, which included educational material covering bicycling safety in traffic, distribution of a safety kit, and bicycle maintenance as necessary. Many cyclists did not attend, and there was no observed effect from the meetings on either the number of accidents or near-accidents (Bacchieri et al., 2010). Furthermore, a study of adolescents, age 13–18, in the Netherlands shows that not only do they often violate traffic rules while cycling, many of them are aware that they are conducting risky cycling behavior (Feenstra et al., 2010).

The issue of safety is particularly important because of the vulnerability of users of active transportation. In China, for instance, although the total number of deaths resulting from traffic crashes and the number of regular bicycle related deaths have decreased, the number of casualties resulting from crashes involving e-bikes has risen. Also, as the number of injury cases involving regular bicycles has decreased, the number of injury cases for e-bikes has risen (Feng et al., 2010). A likely explanation for this increase in e-bike injuries is the rapid increase in e-bike use. Several studies have focused on video analysis of Chinese intersections and found that e-bike behavior is as bad or slightly worse than bicyclist behavior (Wu et al., 2012; Bai et al., 2013; Du et al., 2013; Zhang and Wu, 2013).

1.2. Introducing new technologies through e-bike sharing

Along with the introduction of e-bikes as a new transportation mode, another recent innovation is bicycle sharing. Bikeshare systems have emerged around the world (DeMaio, 2009; Kanthor, 2010; Tang et al., 2011) with many systems installed in the United States in recent years as well (Shaheen et al., 2012; Toole Design Group, 2012). As an evolution of bikesharing, the integration of e-bikes with bikesharing introduces e-bikes to a new audience of users who otherwise may not be familiar with the technology or have access to it. This was implemented at the University of Tennessee, Knoxville, through an on-campus e-bike sharing system pilot project, which offers users access to both regular bicycles and e-bikes (Langford et al., 2013).

The motivation for this study stems from this introduction of new technology. Introducing e-bikes and e-bike sharing technology could influence user behaviors, which raises concerns over the impact to user safety. For instance, behaviors on shared use facilities, greenways, or bicycle paths as well as user behaviors in mixed traffic conditions can have impacts to user safety (Wachtel and Lewiston, 1994; Moritz, 1998; Rasanen and Summala, 1998; Forester 2001; Pucher and Dijkstra, 2003). This study seeks to investigate the differences in behavior between users of regular bikes and e-bikes and uses the on-campus e-bike sharing system as a platform for this investigation. We focus on four key behaviors that could reduce safety, comparing e-bike rider behavior with bicycle rider behavior: (1) wrong-way riding on one-way streets and two-way streets, (2) speed on shared-use paths, (3) stopping behavior at stop-controlled intersections, and (4) stopping behavior at signalized intersections. The primary objective is to objectively quantify user behavior to inform policy on an e-bike's role in the transportation system. On one hand, we expect that e-bikes could influence more dangerous riding behavior because of increased speed. On the other hand, e-bikes could influence safer driving behavior because of improved acceleration and hill-climbing capability, prompting the rider to adhere to auto-oriented traffic control devices (e.g., stop signs on hills).

2. Methods

2.1. Electric- and conventional-bikeshare pilot test

The University of Tennessee developed a pilot bikeshare system that operated from Summer 2011 to Summer 2013. The system