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Disentangling the influence of cell phone usage in the dilemma zone: An econometric approach

Naveen Eluru*, Shamsunnahar Yasmin

Department of Civil, Environmental and Construction Engineering University of Central Florida, United States

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ABSTRACT

This paper focuses on developing an analysis framework to study the impact of cell phone treatment (cell phone type and call status) on driver behavior in the presence of a dilemma zone. Specifically, we examine how the treatment influences the driver maneuver decision at the intersection (stop or cross) and the eventual success of the maneuver. For a stop maneuver, success is defined as stopping before the stop line. Similarly, for a cross maneuver, success is defined as clearing the intersection safely before the light turns red. The eventual success or failure of the driver's decision process is dependent on the factors that affected the maneuver decision. Hence it is important to recognize the interconnectedness of the stop or cross decision with its eventual success (or failure). Toward this end, we formulate and estimate a joint framework to analyze the stop/cross decision with its eventual success (or failure) simultaneously. The study is conducted based on driving simulator data provided online for the 2014 Transportation Research Board Data Contest at http://depts.washington.edu/hfsm/upload.php. The model is estimated to analyze drivers' behavior at the onset of yellow by employing exogenous variables from three broad categories: driver characteristics, cell phone attributes and driving attributes. We also generate probability surfaces to identify dilemma zone distribution associated with different cell phone treatment types. The plots clearly illustrate the impact of various cellphone treatments on driver dilemma zone behavior.

1. Introduction

1.1. Background

In the United States (US), crashes involving distracted drivers result in nearly 3300 fatalities and 400,000 injuries annually (NHTSA, 2013, 2014). Of the fatal crashes involving distracted drivers, 12% are attributed to cell phone use at the time of crash. Evidence from earlier studies (Redelmeier and Tibshirani, 1997; McEvoy et al., 2005) suggests that concurrent cell phone use and driving are associated with greater crash risk. Moreover, cell phone use while driving has a negative impact on the driving performance, specifically in determining and identifying traffic events (Horrey and Wickens, 2006; Ishigami and Klein, 2009). Thus, a driver while using a cell phone (talking or texting) might take longer to respond in unexpected situations on the road.

A 2011 Center for Disease Control and Prevention (CDC) study that compared distracted driving across several countries (including the US, Belgium, France, Germany, the Netherlands, Portugal, Spain, and the United Kingdom) found that more drivers in the US are likely to talk or text while driving compared to their counterparts in other countries (CDC, 2013). In the US, more than 90% of the population currently has cell phone subscription (The World Bank, 2014) and approximately 69% of the drivers have reported that they use cell phone while driving (CDC, 2013). Given the growing use of cell phones among younger individuals, it is not a surprise that policy makers are concerned about these trends. Of particular concern to traffic engineers is the effect of cell phone usage on response to traffic control devices. For example, increased reaction times due to cell phone usage might result in longer time to comprehend the message from traffic control devices thus resulting in unsafe situation at traffic signals.

Within the traffic signal design process, driver behavior in the dilemma zone has received significant attention (for example see Rakha et al., 2008a,b; Hurwitz et al., 2011). In traffic signal design mitigating the impact of dilemma zone is a priority and traffic engineers are constantly seeking measures to reduce the problem associated with dilemma zone. In a dilemma zone, drivers are faced

* Corresponding author.
E-mail addresses: naveen.eluru@ucf.edu (N. Eluru), shamsunnahar.yasmin@gmail.com (S. Yasmin).

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with the challenge of making decisions in response to the change of traffic signal from green to yellow. Coupled with the complexity of decision making in the dilemma zone, if the driver is using a cell phone, the driver's decision process might be affected resulting in dangerous conditions for the driver and other road users. Understanding how cell phone usage affects driver response in the presence of a potential dilemma zone is helpful in accommodating traffic signal design approaches and/or educating drivers about potential risks. While several research efforts have explored separately the impact of cell phone usage in the context of road safety (a detailed discussion is presented in the earlier literature section) and dilemma zone driving behavior, there has been little research that explores driver behavior in the dilemma zone using cell phones.

In this context, the objective of the current study is to develop an analysis framework to study the impact of cell phone treatment (cell phone type and call status) on driver behavior in the presence of dilemma zone. Specifically, we are interested in examining how cell phone treatment influences the driver maneuver decision at the intersection (*stop* or *cross*) and the eventual success of the maneuver. The analysis of driver performance while using a cell phone in a dilemma zone requires a substantial data collection effort. It would be impractical to compile such data in the real world. A driving simulator based data collection experiment will provide data on how drivers respond to traffic signal change while using cell phone in a dilemma zone. Employing such driver simulator based data, the current study explores the different types of cell phone use prevalent (hands free, headset or handheld) and distinct calling behavior (no call, incoming and outgoing call) on driver maneuver decision and its eventual success/failure. The study is conducted based on driving simulator data provided online for the 2014 Transportation Research Board Data Contest at http://depts.washington.edu/hfsm/upload.php.

The rest of the paper is organized as follows. Earlier research is presented in Section 2 while positioning the current study in Section 3. Section 4 provides details of the econometric model framework used in the analysis. Section 5 provides the data description. The model estimation results are presented in Section 6. Section 7 concludes the paper.

2. Earlier research

2.1. Background

A dilemma zone at a signalized traffic intersection refers to a stretch of road in proximity to the intersection where the drivers are indecisive in determining whether they should proceed or halt when a signal changes from green to yellow. This hesitation at the onset of yellow may lead to either red-light running violation or an abrupt stop at the intersection (Elmitiny et al., 2010). The indecisiveness might result in safety issues including but not limited to rear-end and right angle collisions (Hurwitz et al., 2012). While discussing the dilemma zone, it is important to recognize the alternative definitions of dilemma zone. In literature, two possible dilemma zone definitions exist – Type I and Type II (see Fig. 1). Type I dilemma zone, identified by Gazis et al. (1960) is described as possibility that a driver on seeing a yellow light is neither able to stop safely or cross the intersection due to intersection design parameters (for no fault of the driver). On the other hand, Type II dilemma zone refers to the possible presence of an indecision zone – stretch of the roadway segment – where drivers are unsure whether to stop or cross. Type I dilemma zone results from poor intersection design issues while Type II dilemma zone results from driver indecisiveness on the right course of action (while in the dilemma zone). In this research effort, we are focussed on Type II dilemma zone identification and improvement.

2.2. Previous research

In this section, we briefly discuss safety literature along two streams: (a) research examining the impact of cell phone usage on motor vehicle collisions and (b) traffic signal design research in the context of dilemma zone.

2.2.1. Cell phone usage research

Given the consequences involved, it is not surprising that several research efforts have examined the impact of cell phone usage on traffic safety. The studies examined data collected on the field or using driver simulators. The earlier literature can be classified along two major themes: (1) studies that found that cell phone usage worsened driver safety (irrespective of the driving task) and (2) studies that concluded that the complexity of cell phone task influenced the impact on road safety, specifically driver safety. In studies from the *first theme*, Redelmeier and Tibshirani (1997) and McEvoy et al. (2005) concluded that use of cell phones quadruples the risk of motor vehicle collision. Other studies such as Strayer et al. (2003) and Rakauskas et al. (2004) studied the effect of cell phone conversation on driver performance using a driving simulator. The authors observed a drop in driving performances during these conversations. Studies not involving driving simulators also have found that conversing while driving worsens driver performance (Atchley and Dressel, 2004; Patten et al, 2004; Horrey et al., 2008; Strayer et al., 2003).

In literature from *second theme*, Klauer et al. (2006), Olson et al. (2009) based on their research on driver simulators concluded that collision risk increases for complex tasks such as texting and dialing while conversing on the cell phone was not associated with an increased crash risk. The authors suggest that complex tasks such as texting and dialing might cause the drivers to take their eyes off the road leading to increased risk (see Fitch et al., 2013; Olson et al., 2009). Most recently, Fitch et al. (2013) compared the cell phone usage risk for hand held, portable hands free and integrated hands free devices. In their analysis, the authors concluded that talking on the cell phone did not elevate collision risk levels; however, tasks that required interaction with the phone (of all types) resulted in elevated collision risk levels.

The major drawbacks of cell phone usage documented in literature include irregular speed and headway distribution (Rakauskas et al., 2004), failure to remember objects seen (Strayer et al., 2003), increased reaction times for unexpected events (Caird et al., 2008), reduced lane change behavior (Cooper et al., 2008), and missing traffic signage (Drews et al., 2004).

2.2.2. Dilemma zone research

The examination of dilemma zone and associated drivers' behavior has started since the initial study by Gazis et al. (1960). Not surprisingly, because of the wide ranging implications for traffic signal design the impact of dilemma zone is a well-researched topic (see Moon and Coleman, 2003; Papaioannou, 2007; Rakha et al., 2008a,b; Hurwitz et al., 2011). The two widely used techniques for examining the dilemma zone are: field data collection (Elmitiny et al., 2010; Gates and Noyce, 2010) and driving simulation (Rakha et al., 2008a,b; Caird et al., 2007; Amer et al., 2010). Several earlier studies (Xiang et al., 2005) also used survey technique for investigating driver behavior at dilemma zone.

Driver characteristics are the major focus of many of the existing studies in examining various aspects of dilemma zone. In terms of driver age, a number of studies argued that young drivers are more likely to drive aggressively compared to adult drivers in response to the yellow-light (Shinar and Compton, 2004; El-Shawarby et al., 2008). Research findings from earlier studies on driver behavior at signalized intersection reveal that female drivers are more likely to stop at the onset of yellow compared to male drivers