G Model
AAP 3772 No. of Pages 10

ARTICLE IN PRESS

Accident Analysis and Prevention xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Decisions and actions of distracted drivers at the onset of yellow lights

Md. Mazharul Haque*, Amanda D. Ohlhauser, Simon Washington, Linda Ng Boyle[1]

[a] Centre for Accident Research & Road Safety (CARRS-Q), and Civil Engineering and Built Environment, Science and Engineering Faculty, Queensland University of Technology, Australia
[b] Department of Industrial and Systems Engineering, University of Washington, United States
[c] Civil Engineering and Built Environment, Science and Engineering Faculty, and Centre for Accident Research & Road Safety (CARRS-Q), Queensland University of Technology, Australia
[d] Department of Industrial & Systems Engineering, Department of Civil & Environmental Engineering, University of Washington, United States

ARTICLE INFO

Article history:
Received 31 October 2014
Received in revised form 18 March 2015
Accepted 31 March 2015
Available online xxx

Keywords:
Distracted driving
Mobile phone
Motion-based driving simulator
Risk compensation
Yellow light
Driver behavior

ABSTRACT

Driving on an approach to a signalized intersection while distracted is relatively risky, as potential vehicular conflicts and resulting angle collisions tend to be relatively more severe compared to other locations. Given the prevalence and importance of this particular scenario, the objective of this study was to examine the decisions and actions of distracted drivers during the onset of yellow lights. Driving simulator data were obtained from a sample of 69 drivers under baseline and handheld cell phone conditions at the University of Iowa – National Advanced Driving Simulator. Explanatory variables included age, gender, cell phone use, distance to stop-line, and speed. Although there is extensive research on drivers' responses to yellow traffic signals, the examinations have been conducted from a traditional regression-based approach, which do not necessary provide the underlying relations and patterns among the sampled data. In this paper, we exploit the benefits of both classical statistical inference and data mining techniques to identify the *a priori* relationships among main effects, non-linearities, and interaction effects. Results suggest that the probability of yellow light running increases with the increase in driving speed at the onset of yellow. Both young (18–25 years) and middle-aged (30–45 years) drivers reveal reduced propensity for yellow light running whilst distracted across the entire speed range, exhibiting possible risk compensation during this critical driving situation. The propensity for yellow light running for both distracted male and female older (50–60 years) drivers is significantly higher. Driver experience captured by age interacts with distraction, resulting in their combined effect having slower physiological response and being distracted particularly risky.

1. Introduction

1.1. Distracted driving

Driver distraction is a significant and growing road safety issue worldwide. Statistics reveal that about 3328 people were killed and an additional 421,000 people were injured in distracted driving related motor vehicle crashes on U.S. roadways in 2012 (NHTSA, 2014). While cell phone use has become ubiquitous in modern society, road traffic crashes related to cell phone distractions have been on the rise (WHO, 2011). In 2012, cell phone distraction alone was associated with 415 fatalities and another 28,000 injuries on U.S. roads (NHTSA, 2014). Redelmeier and Tibshirani (1997) indicated that distraction due to conversing on a cell phone while driving increased the crash risk by as much as four folds. In 2010, the traffic police of Queensland, Australia fined about 30,780 drivers for talking or texting on mobile phones while driving, indicating the spread of cell phone usage (Ironside, 2011). Making matters worse, distracted driving tends to be more prevalent among younger and less experienced drivers. An Australian study reported that among the 2400 driver distraction related incidents in New South Wales, young drivers had the highest frequency of cell phone use-related injurious crashes (Lam, 2002).

Prior research has documented a variety of performance measures that have been impacted by the distracting effects of a cell phone. Burns et al. (2002) reported that speed control and reaction times of drivers were more influenced by a cell phone use than by having a blood alcohol level at the limit of 8%. A recent study reported that cognitive distraction significantly impairs the

* Corresponding author. Tel.: +61 731384511.
E-mail addresses: m1.haque@qut.edu.au (M. M. Haque), amanda.raven@hotmail.com (A.D. Ohlhauser), simon.washington@qut.edu.au (S. Washington), linda@u.washington.edu (L.N. Boyle).
[1] Tel.: +1 206 616 0245.

http://dx.doi.org/10.1016/j.aap.2015.03.042
0001-4575/

Please cite this article in press as: Haque, M.M., et al., Decisions and actions of distracted drivers at the onset of yellow lights. Accid. Anal. Prev. (2015), http://dx.doi.org/10.1016/j.aap.2015.03.042

reaction time of young drivers in response to a traffic event that originates within the driver's peripheral vision (Haque and Washington, 2014a). Cell phone distraction has also been reported influencing drivers to have higher variation in accelerator pedal position, drive more slowly with greater speed variation, and report a higher workload (*e.g.*, Rakauskas et al., 2004). Törnros and Bolling (2006) reported a risk compensation behavior of distracted drivers where drivers tend to reduce their speed while talking on a phone. Dula et al. (2011) showed that the percent of time spent speeding and the number of centre line crossings were significantly higher among drivers engaged in different types of conversation in comparison to no conversation.

Hancock et al. (2003) investigated the stopping decision of a group of cell phone distracted drivers using test track facilities where participants were instructed to perform a quick stop before reaching the stop line of an intersection upon the onset of a red light. They found that the non-response to a red light increased by 15% for drivers distracted by a cell phone visual-manual task consisting of looking down at a dial pad and confirming a number presented was the same as the number presented earlier. Using a driving simulator, Beede and Kass (2006) found that cell phone distracted drivers took one-third of a second longer before starting from a stop-sign indicating a slower response of distracted drivers. Consiglio et al. (2003) examined the braking performance of distracted drivers upon the activation of a red brake lamp set at a laboratory station and found that both hands-free and hand-held cellular phone conversation significantly increased the reaction time to braking events initiated by the lamp. Haque and Washington (2014b) examined the braking behavior of distracted drivers in response to a pedestrian entering a zebra crossing, and reported that drivers distracted either by handheld or hands-free phone conversation are associated with aggressive braking compared to non-distracted drivers, revealing perhaps an element of risk compensation. Strayer and Johnston (2001) examined the effects of cellular phone conversation on driving performances using a desktop simulator study, where participants performed a pursuit tracking task with a joystick and responded to flashing signals on a computer display. The study reported that drivers distracted by hand-held or hands-free conversation were two times less likely to detect simulated traffic signals and exhibited slower reactions to those signals that were detected.

In summary, using a cell phone while driving appears to influence many common driving behaviors including a deterioration of speed control, reduction in speed, failure to maintain appropriate headway, increase in lane position variation, reduction of peripheral eye scanning, decline in breaking performances, and impairment in the perception of relevant stimuli (*e.g.*, Regan et al., 2009). In particular, the slower reaction and impaired braking performances of distracted drivers might affect their safety at the onset of yellow lights at signalized intersection. However, there is little research on how distracted drivers perform at the onset of yellow lights.

1.2. Driver behavior at the onset of yellow light

Yellow light or phase changing period, the time interval when drivers need to decide on stopping or proceeding through an intersection, has been identified as a critical interval at signalized intersections (*e.g.*, Elmitiny et al., 2010; Papaioannou, 2007). An improper decision at the onset of a yellow or amber light might cause red light running or abrupt stopping at intersections. It was estimated that red light running is associated with about 260,000 crashes on U.S. roads each year, of which about 750 are fatal (Retting et al., 1999). Earlier research on the driver's stop/go decisions at the onset of yellow lights has mainly been focused on developing a model to estimate the propensity of yellow running as a function of driving speed, distance from the stop line, and drivers' demographics like age and gender. Papaioannou (2007) reported that drivers who have an approach speed higher than the posted speed limit are more likely to be caught in a dilemma zone that might force them to make unsafe decisions at the onset of yellow light. Elmitiny et al. (2010) analyzed video-based data of a high-speed signalized intersection and found that red light violations and drivers' stop/go decisions during the yellow light are significantly associated with their distance from the stop line, operating speed, and position in the traffic flow. Using a driving simulator, Caird et al. (2007) investigated younger and older drivers' behavior at the onset of yellow light at signalized intersections and found that all drivers are less likely to run through the yellow light when their time to stop line is higher. Ohlhauser et al. (2011) investigated the effects of distraction at the onset of yellow light across various age cohorts. They reported that compared to middle-aged drivers, novice drivers are more likely to proceed through the intersection when distracted by a handheld phone conversation.

1.3. Research objective

Drivers' stop/go decisions have previously been modeled in relation to driver demographics such as age and gender, and traffic parameters such as speed and distance from the stop line. It is of interest to examine whether distraction will impact a driver's response to the onset of a yellow interval while approaching a signalized intersection. In particular, it is worthy to investigate how a cell phone distraction interacts with age, gender differences and different traffic parameters in relation to the stop/go decisions of drivers at the onset of yellow light. While it might be difficult to expose distracted drivers at yellow light encounters in real world settings repeatedly, a driving simulator could be fully utilized to include such scenarios. The objective of this study is to examine the decisions of distracted drivers at the onset of yellow lights by exposing a group of distracted drivers on a series of signalized intersections using the National Advanced Driving Simulator at the University of Iowa.

2. Experiment details

2.1. Participants

The data analyzed in this study were gathered from two separate studies conducted at the University of Iowa: a wireless urban arterial study and a novice driver study (Mazzae et al., 2005; Ranney et al., 2005). The wireless urban arterial study on three adult groups was conducted in the summer of 2004, and the novice driver study on 16–17 years old male drivers was conducted between May and October of 2006. Details of recruitment, screening, and compensation are available in Marshall et al. (2010).

In total, there were 69 drivers including 49 adults and 20 novice drivers. A valid driver's license was the main criterion for adult drivers and at least 4 weeks but no more than 8 weeks of licensure was the criterion for novice drivers. While the 20 male novice drivers of 16–17 years old formed a separate group, the 49 adult participants were divided into the following three age groups: younger (18–25 years old including 9 male and 9 female), middle-aged (30–45 years old including 9 male and 8 female), and older (50–60 years old including 8 male and 6 female). The average driving experiences for novice, younger, middle, and older drivers were 0.1, 5.5, 19.8, and 36.7 years, respectively.

2.2. Driving simulator

Both studies were conducted in the high fidelity NADS-1 simulator located at the University of Iowa. It is known