Transportation Research Part F 52 (2018) 164–175

Contents lists available at ScienceDirect

Transportation Research Part F

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

Response of major road drivers to aggressive maneuvering of the minor road drivers at unsignalized intersections: A driving simulator study

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ARTICLE INFO

Article history:
Received 26 May 2017
Received in revised form 18 September 2017
Accepted 23 November 2017
Available online 22 December 2017

Keywords:
Driving simulator
Response time
Unsignalized intersection
Driver behavior
Approach speed

ABSTRACT

Drivers' inattention, human error and aggressive behavior are often linked with vehicle crashes. This research studies how major road drivers respond to the aggressive maneuvering of the minor road drivers at unsignalized intersections. The study was also designed to investigate the effect of distracted driving (engaged on handheld phone) on driving performance. In our experiments, 51 drivers were tested for four different events using a driving simulator. The test track comprised of a stretch of 10.4 km having nine unsignalized intersections. A possible conflicting event was designed at each intersection for approaching major road drivers. The major road driver behavior was evaluated with reference to three variables: response time before possible conflict (RTPC), average speed while approaching intersection and at the intersection, and deceleration rate. The analysis results showed that the RTPC values against the right turning vehicles were very low indicating high risk against right turning vehicles (considering left side driving practice). For the same event with handheld phone conversation, the RTPC values were found to be negative indicating that the drivers are more likely to miss the visual reaction time stimuli when engaged in a phone conversation. The 10th and 90th percentile RTPC values were found to vary from 6.3 to 9.4 s and 0.1 to 1.8 s respectively for different events. The driving speed of the drivers was not found to be significantly impacted by the cell phone usage. The approach speed for all drivers at the intersection was found to be lower by 35–40% compared to speeds before responding to the conflicting vehicle. The average decelerating rate for all the drivers was found to be 3.73 m/s^2 and 4.23 m/s^2 when the participants were driving without phone and with phone respectively. The insights from this study can be used to understand pre-crash driver actions which are necessary for the implementation of appropriate countermeasures and to assess the level of safety at unsignalized intersections.

1. Introduction

Intersections are critical elements of any road network from both operational and safety perspectives. Since a common space at intersection is used by drivers from multiple directions, they reduce network capacity, increase delay to drivers, and increase safety risk. The descriptive statistics from National Motor Vehicle Crash Causation Survey (NMVCCS) conducted

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https://doi.org/10.1016/j.trf.2017.11.016
1369-8478/

all over the United States from 2005 to 2007, showed that 36% (787,236) of the estimated 2,188,969 crashes were intersection-related crashes (NHTSA., 2008). In India, the annual accident report for 2015 showed that about 49% of accidents were reported at road intersections (MORTH., 2016). The situation is severe at unsignalized intersections where personal judgements play important roles in maneuvering intersections. At unsignalized intersections in India, the priority rules are often not followed even when the drivers are aware of major and minor approaches. Thus it is important to study the behavior of both minor road vehicles and major road vehicles.

Gap acceptance behavior of minor road vehicles in the presence of conflicting major road vehicle is an important topic of research and has been explored reasonably for Indian traffic (Ashalatha & Chandra, 2011; Patil & Pawar, 2014; Patil & Sangole, 2015). However, the literature on the response of major road vehicles is inadequate even for traffic in developed countries. If minor road vehicles give absolute priority to major road vehicles and if the minor road vehicles make safe judgement i.e. reject smaller gaps while maneuvering through intersection, the main road vehicles do not have to respond and can just drive without reducing speed. Patil and Pawar (2014) and Patil and Sangole (2015) have shown that the critical gap values in Indian are much lesser than that reported in developed countries. In other words, an aggressive minor road vehicle may enter the intersection even when a major road vehicle is approaching the intersection. In such a situation a cautious major road driver may take precautionary measure in the presence of aggressive minor road driver. On the other hand inaction of an average or aggressive major road vehicle driver to the wrong judgement of a minor road vehicle is likely to result into an accident.

At an unsignalized intersection major road drivers face primarily three events which might need a response (events are described with respect to left-hand traffic condition) (1) left side minor road vehicles entering the intersection, (2) right side minor road vehicle entering the intersection, and (3) major road right turning vehicle. It is important to understand how individual drivers make decisions in the presence of other conflicting vehicles. Collecting reasonable sample size of second by second data related to driver's response and vehicle position in the field is not easy. Additionally, it may not be possible to create desired events in the field. An alternative approach is to use the driving simulator in a laboratory to create the desired field condition and obtain data. The use of a driving simulator is precisely recommended as a first step in the assessment of novel road safety interventions (Brown, Williamson, & Lenne, 2009).

In this paper different possible conflicting events have been created and responses of the major road through drivers are recorded. Thus the study makes an attempt to understand and analyze the major road driver's behavior which includes braking (response time), speeding and deceleration behavior. The study also makes an effort to compare the effect of no phone and handheld phone conversation on the driver's performance while approaching an unsignalized intersection.

2. Literature

Drivers approaching unsignalized intersections are at risk due to possible conflict with the vehicles entering from the other directions. Many drivers are cautious while approaching an unsignalized intersection because of the fear of the priority violation from other vehicles. Retting, Weinstein, and Solomon (2003) analyzed motor vehicle crash data at stop-controlled intersections for different US cities during 1996–2000. The data revealed that 70% of all crashes were due to stop sign violations. Chovan, Tijerina, Pierowicz, and Hendricks (1994) examined straight crossings at unsignalized intersections. The detailed analysis for 100 crashes showed that drivers ran the stop sign in approximately 42% of crashes.

If the drivers approaching unsignalized intersections are involved in or distracted by other activities, the situation becomes more complex to understand and analyze. Use of mobile while driving distracts the driver, seriously undermining the safety of other nearby drivers and his/her own safety. With the revolution in the mobile phone industry communication through mobile phones has increased significantly in recent years. Although, use of mobile phone while driving is prohibited by law, many drivers are seen making and receiving calls while driving. Shabeer and Banu (2012) carried out an online survey to determine the number of drivers involved in an accident due to mobile phone use in India. The analysis results revealed that majority of the drivers (82%) agreed using mobile phone while driving, of which 31% of drivers admitted that they have met with an accident as a result of using a cell phone. According to National Safety Council (NSC) of U.S., it is estimated that at least 28% of all traffic crashes or at least 1.6 million crashes each year involve drivers using cell phones. At critical road sections such as unsignalized intersections, the conditions become worse if drivers remain engaged in any physical or cognitive distraction. Researchers are putting consistent efforts to address different issues like distracted driving behavior (Alm & Nilsson, 1995; Treat, Tumbas, McDonald, Shinar, & Hume, 1977; Consiglio, Driscoll, Witte, & Berg, 2003; Dula, Martin, Fox, & Leonard, 2011; Harbluk, Noy, & Eizenman, 2002; Harms & Patten, 2003; Patten, Kircher, Östlund, & Nilsson, 2004), effect of age on driving behavior (Kramer, Cassavaugh, Horrey, Becic, & Mayhugh, 2007; Quillian, Cox, Kovatchev, & Phillips, 1999), effect of gender (Peterson, Brazeal, Oliver, & Bull, 1997), effect of consumption of alcohol (Arnedt, Wilde, Munt, & MacLean, 2001; Christoforou, Karlaftis, & Yannis, 2012; Lenne, Triggs, & Redman, 1999; Meskali, Berthelon, Marie, Denise, & Bocca, 2009; Quillian et al., 1999) and effect of advanced driver warning systems (Burns, Knabe, & Tevell, 2000; Lee & Abdel-Aty, 2008). Many researchers have analyzed effect of cellular phone on the driving attention (Beede & Kass, 2006; Benedetto, Calvi, & D'Amico, 2012; McKnight & McKnight, 1993). Other in-vehicle technologies such as navigation system, entertainment system, integrated phone system, etc. can also distract drivers to a certain extent (Strayer, Drews, & Johnston, 2003; Svenson & Patten, 2003).