Accident Analysis and Prevention 110 (2018) 128–135

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Full length article

Pedestrians' perception and response towards vehicles during road-crossing at nighttime

Venkatesh Balasubramanian*, Rahul Bhardwaj

RBG Lab, Engineering Design Department, IIT Madras, Chennai 600036, India

ARTICLE INFO

Keywords:
Pedestrian perception
Pedestrian response
Accident mitigation
Vehicular illumination
Pedestrian vehicle collision

ABSTRACT

Pedestrian being involved in road traffic accidents (RTA) is about 22% of all road traffic related deaths. In this study, we have estimated the pedestrian's response towards an approaching vehicle and the time taken to correctly recognize it while they crossed the road in dim-light nighttime conditions. This is also extendable to cycles and other low powered vehicles. Thirty volunteers participated in this study. A collection of six videos, which comprised of different vehicle scenarios were shown to each of the participants. It was observed that correct identification and time to recognize the vehicle was fastest when light emitting diode (LED) strip was fixed between headlights of a four–wheeler. Average time to recognize a low beam car and a high beam car with an LED strip was 7.62 ± 2.39 s and 11.23 ± 2.94 s respectively, whereas correct identification rates of the said low beam and high beam cars with LED strips were 93.33% and 86.67% respectively. Earlier when no LED was used, time to recognize low beam car and high beam car without LED strip were 20.55 ± 3.50 s and 25.57 ± 4.14 s respectively whereas correct identification of low beam car without LED strip and high beam car without LED strip were 90.00% and 56.67% respectively. Pedestrians are therefore less confused and can take right decision while crossing the road – particularly in a poor lighting environment – when there is a demarcating illumination between headlights of vehicle.

1. Introduction

According to National Crime Research Bureau (NCRB, 2016) of India, it is estimated that pedestrian death and injury was 28,434 of total urban road traffic accidents (RTA) (464,674) in the year 2015. Out of India's total RTA, 254,878 cases (54.85%) were reported in rural regions and 209,796 cases (45.14%) were reported in urban regions and 7.5% of urban RTA took place at pedestrian crossings. Pedestrian-vehicle collision at nighttime is commonly fatal (Plainis et al., 2006). Place of occurrence also affects the probability of RTA. According to NCRB (2016), it was found that 15.9% of all fatal RTA were reported near residential areas in mega cities in India. Among these, 10.7% accidents were reported at pedestrian crossings. 5.8% of the accidents were reported near schools, colleges, and other educational institutions. These statistics are also of concern to the researchers from a pedestrian-safety point of view. About 1.25 million people die in RTA around the world every year and it is estimated that half of these are pedestrians, cyclists and motor-cyclists (WHO, 2015). It is estimated by WHO (2015) that pedestrian deaths are 22% which is approximately 275,000 deaths a year globally. When other types of road user such as, cyclist and motorcycle riders are added, the numbers reach to about 49% of total deaths. Highest number of road traffic deaths has been reported in the African region and is about 43%.

There are many causal factors for vehicle-pedestrian crashes, and one of the key factors is the poor visibility in nocturnal conditions. It has been observed by the researchers (Owens and Sivak, 1996; Sullivan and Flannagan, 2002) that the increasing trend of vehicle-pedestrian crashes–especially at night–is due to lower illumination rather than other factors such as alcohol use or driver fatigue. According to Sullivan and Flannagan (2002), the probable reason of pedestrian crash would be either pedestrians having not noticed vehicle or vehicles are insufficiently visible to pedestrian. Both the possibilities eventually result in RTA. Sullivan and Flannagan (2002) also concluded that the pedestrians may be 3–6.75 times more susceptible to accidents in the dark than in daylight and it makes very strong point that accidents also depends on the effect of light.

Visual tasks greatly depend on the rods and cones – photoreceptor cells of the eyes. Rod-shaped photoreceptor cells are responsible for providing visual information during low light level conditions, whereas cone-shaped photoreceptor cells are responsible for getting information during brighter conditions. Researchers have demonstrated that visual information processing tasks are poorer in low light conditions than

* Corresponding author.
E-mail address: chanakya@iitm.ac.in (V. Balasubramanian).

https://doi.org/10.1016/j.aap.2017.10.025
Received 23 March 2017; Received in revised form 31 October 2017; Accepted 31 October 2017

brighter light conditions (Gergenfurtner et al., 1999; Plainis et al., 2006) and this might be the reason pedestrians misjudge the vehicle coming at them at night. In low light conditions, visual processing is degraded; this results in misjudgment of the speed of approaching vehicle by the pedestrian (Pai et al., 2009). In the literature, many researchers have also discussed about misjudgment of the speed of the vehicle approaching towards pedestrian as a key factor to RTA (Pai et al., 2009; Peek-Asa and Kraus, 1996; Brenac et al., 2006). Vehicle was perceived to reach later than it actually would, leaving the pedestrian in an endangered state in the low lighting condition and this leads to fatal RTA (Pai et al., 2009; Plainis et al., 2006). Similarly, many studies have focused on the driver's vision limitations in night condition and injuries caused by them. For example, driver's ability to detect a pedestrian and discomfort aroused due to glare effect has been examined by Theeuwes et al. (2002) and Flannagan et al. (2000) and they concluded that increase in glare intensity leads to decrease in distance detection by pedestrian. To enhance the conspicuity of the pedestrian at night, reflective materials have been used on the pedestrian's movable joints such as, wrist, shoulder, knee and ankles (Balk et al., 2008a,b; Blomberg et al., 1986; Luoma and Penttinen, 1998; Luoma et al., 1996; Owens et al., 1994a,b, 2007; Sayer and Mefford, 2004; Wood et al., 2005a,b). In an experiment performed by Owens et al. (1994a,b) possible benefits of different retro-reflective marking materials were assessed for visibility of the pedestrian in nighttime. They had recorded videos of joggers wearing four different marking in four different road environments. Subjects participated in this study were told to press the pedal once they see the joggers. It was reported that the performance was better for all the retro-reflective marking than for dark control. Authors also observed that the performance was enhanced when retro–reflective marking materials were placed on limbs than on the torso. It is very difficult in the nighttime for drivers to see and recognize the pedestrians not wearing conspicuity enhancing clothing (Borzendowski et al., 2015). In developing economies such as India, the use of nighttime clothing is neither affordable nor adhered to by pedestrians in either professional or non-professional environments. Several researchers have analyzed pedestrian crashes and the severity level. They have recognized the possible risk aspects and suitable countermeasures based on different statistical methods (Roudsari et al., 2005; Nasar and Troyer, 2013; Al-Shammari et al., 2009; Tarko and Azam, 2011; Sarkar et al., 2011; Strandroth et al., 2011; Mohamed et al., 2013).

There are several other factors that affect pedestrians while deciding on road crossing such as, effect of the age, vehicle speed coming from the front, time gap and time of day (Liu and Tung, 2014). It has been observed that the walking speed of elders ($>$ 65 years) is significantly slower than young individuals (Guerrier and Jolibois, 1998; Tarawneh, 2001; Oxley et al., 2005). This by itself is not a major finding, however can major implication when see from the perspective of making a decision to cross the road and actually crossing. Oxley et al. (2005) have also found that the elderly pedestrian usually take more time to decide to cross the road. This might be due to the slow brain processing speed in old aged people (Salthouse, 1996). Reducing the decision making time can reduce the overall crossing time and there be an enabler for independently living of elderly.

Although many studies have been performed on pedestrian visibility in the night condition and also on pedestrians' responses towards the speed of the oncoming vehicle, no study has been conducted so far which deals with the pedestrian's dilemma while crossing the road in night condition, especially in the rural areas where ambient light is very minimal.

Many advances are occurring in the field of automotive lighting. The LONG (Longitudinal Oriented Normative time Gap compensation) concept was proposed by Tsutsumi et al. (2008) in which authors implemented LONG configuration in the motorcycle to enhance the conspicuity of motorcycles and thereby making motorcycle look different from car. They further report that the object will be perceived as nearer if distance between horizon line in a visual field and object becomes longer. They also state that the formation of image on the retina will be smaller for small object and it will not develop quickly compared to larger object which will make the pedestrian hard to judge the speed of the motorcycle coming from the front. Based on these facts, lights were embedded on side mirrors and lower part of the front fork so that the image formed on the retina is larger to judge the speed of the vehicle correctly. They concluded that the speed and distance of the motorcycle was the same as that of four-wheeler after implementation of LONG concept.

A tri-light configuration in motorcycle was introduced by Gould et al. (2012) in which authors include two subsidiary lights with motorcycle's headlight and compared the speed of judgment with solo headlight motorcycle in simulated environment. Authors concluded that the individual's capability to judge the speed of the tri–light configured motorcycle was significantly more accurate than car headlights.

Similarly, in four-wheelers also, many advancements in lighting systems have been introduced, such as curve beams, turning beams, active dimming, passing beams and pedestrian spot lighting. These advance systems in two-wheelers and four-wheelers would definitely have a great impact on pedestrian and subsequently, road safety systems. (Götz and Kleinkes, 2008; Spero, 2012; Boyce, 2014). In a growing economy like India, It would be very difficult to incorporate these technologies–especially in the rural areas, where the infrastructural facilities such as streetlights and highway lights are sub-optimal.

High levels of market-penetration of two wheelers have been observed in recent years in the country. According to Investment Information and Credit Rating Agency of India (ICRA) (2016), the Indian two-wheeler segment growth has been reported to be about 3.0% more in the 2016 financial year, as compared to the previous year. It is expected to increase by 4–6% during next financial year (2017). Similarly the number of four- wheelers is also expected to rise in next 10–12 years in India. According to Ghate and Sundar (2013), it is expected that the number of cars is likely to be in the range of 45–60 million by the year 2025, which will be 35 cars per 1000 populations. Huge growth in the number of two wheelers and four wheelers in India is a big concern and this will have serious implications for energy security, air pollution, road safety, and pedestrian safety.

The resemblance of two motorcycles coming in tandem to a car is likely to confuse pedestrian and hence delay their reaction time. The purpose of this study is to evaluate perception of types of on-coming vehicular traffic by pedestrians. In this study, we are evaluating the efficacy of using active light source between head lights to enhance the decision making process of the oncoming traffic. This will help to distinguish between a single four-wheeler and two 2-wheelers driving in tandem amongst pedestrians in night time or low illumination conditions.

2. Methods and materials

2.1. Subject details

Thirty male subjects participated in this study of their own volition. Subjects were screened for physical disability and neuromuscular impairment. Lack of disability and impairments were the qualifying criteria. It was ensured that every subject possessed normal vision.

Their mean age, height and weight were 22(± 5.5) years, 1.70(± 0.08) meters and 62.3(± 6.7) kilograms respectively. All subjects were requested to take 8 h of rest before the commencement of study and were requested to refrain from consuming stimulants such as coffee, tea, tobacco and liquor. All the subjects were informed about the details of study. An informed consent was signed by all the subjects participating in this study–in accordance with the ethical guidelines of IIT Madras.