Transportation Research Part F 51 (2017) 103–144

Contents lists available at ScienceDirect

Transportation Research Part F

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

Identifying effects of driving and secondary task demands, passenger presence, and driver characteristics on driving errors and traffic violations – Using naturalistic driving data segments preceding both safety critical events and matched baselines ☆

Lisa Precht [a,*], Andreas Keinath [a], Josef F. Krems [b]

[a] BMW Group, 80788 München, Germany
[b] Technische Universität Chemnitz, 09107 Chemnitz, Germany

ARTICLE INFO

Article history:
Received 11 July 2017
Received in revised form 3 September 2017
Accepted 25 September 2017

Keywords:
Driver behavior
Driver distraction
Naturalistic driving
Crash causation

ABSTRACT

Researchers have identified various factors that likely affect aberrant driving behaviors and therefore crash risk. However, it remains unclear which of these factors poses the greatest risk for committing either errors or violations under naturalistic driving conditions. This study investigated important variables contributing to driving errors and traffic violations based on naturalistic driving data from the second Strategic Highway Research Program (SHRP 2). The analyzed driving segments preceded both safety critical events and matched baselines. Results showed that *intersection influence*, high-risk *visually distracting secondary tasks*, and the *severities of the safety critical events* were the main factors associated with driving errors. The primary factors linked to violations were *intersection influence*, *persistent individual differences* in driver behavior, and the *severities of the safety critical events.* Furthermore, the number of aberrant driving behaviors in trip segments preceding crashes was higher than in the matched segments unrelated to safety critical events. However, the most common aberrant driving behavior types in the respective segment groups appeared to resemble each other. This suggests that crashes became more likely due to drivers committing more violations and errors overall as opposed to drivers making one certain type of error or violation.

1. Introduction

According to the World Health Organization, road traffic crashes lead to the loss of over 1.2 million lives and cause non-fatal injuries to as many as 50 million people around the world each year (World Health Organization, 2017). Road user behavior is a central factor in crash risk (Rowe, Roman, McKenna, Barker, & Poulter, 2015). A survey on crash causation (Singh, 2015) indicated that driving errors and violations were key in about 74% of the crashes. Therefore, these "aberrant driving behaviors" are a crucial threat to road safety (Zhang, Chan, & Zhang, 2015). Environmental, situational, and individual factors may play a role in driving errors and traffic violations. The current study's focus was on how these factors contribute

☆ The findings and conclusions of this paper are those of the authors and do not necessarily represent the views of the VTTI, SHRP 2, the Transportation Research Board, the National Academies, or the BMW Group, who funded the current work.

* Corresponding author.
E-mail address: Lisa.Precht@bmw.de (L. Precht).

https://doi.org/10.1016/j.trf.2017.09.003
1369-8478/

to aberrant driving behaviors in naturalistic driving segments. In addition, this study examined possible differences in the number and types of aberrant driving behaviors between driving segments preceding safety critical events of varying intensity and matched driving segments unrelated to safety critical events.

1.1. Aberrant driving behaviors

A connection between aberrant driving behaviors and accidents has been well supported (e.g., Singh, 2015). Nevertheless, relatively little research exists that has systematically examined the nature of and particularly the factors contributing to errors and violations in naturalistic driving.

Errors and violations are distinct given their different psychological origins (Reason, Manstead, Stradling, Baxter, & Campbell, 1990). Errors are defined as unwitting deviations of action from intention or the failure of planned actions to achieve their intended consequence (Reason, 1990; Reason et al., 1990; e.g., unintentional lane deviation; signal violation, apparently did not see signal). In contrast, violations are "deliberate deviations from those practices believed necessary to maintain the safe operation of a potentially hazardous system" (Reason et al., 1990, p. 1316; e.g., stop sign violation, intentionally ran stop sign at speed; signal violation, intentionally disregarded signal).

The following sections provide an overview of the potential risk factors examined in the current study for aberrant driving behaviors related to driving task demands, secondary task demands, passenger presence, and driver characteristics (see Precht, Keinath, and Krems, 2017b, for a more detailed review).

1.2. Potential risk factors for aberrant driving behaviors

1.2.1. Driving task demands

Evidence exists that the driving context can affect crash risk either directly or through moderating driver distraction effects. Environmental and situational factors, such as *traffic density, driving through intersections, lighting* and *weather conditions* were found to be associated with crash risk as well as the risk of driving errors (e.g., Johansson, Wanvik, & Elvik, 2009; Qiu & Nixon, 2008; Tian, Li, Chen, Chen, & Witt, 2013; Young, Salmon, & Lenne, 2013).

However, Young and Regan (2013) point out that drivers can engage in behavioral adaptation in the form of compensatory or self-regulatory behaviors, either to prepare themselves for distraction or to compensate for its effects. A recent naturalistic driving study (Precht et al., 2017b) observed that drivers indeed consider the driving context in several ways. For example, drivers committed fewer violations during demanding traffic conditions or when driving through interchanges.

Therefore, it still remains unclear how the driving context affects aberrant driving behaviors under real-world conditions and to what extent drivers adapt their behavior to minimize crash risk, for example with respect to committing violations.

1.2.2. Secondary task demands

Inattention and driver distraction due to secondary task engagement are among the leading causes of motor vehicle accidents (e.g., Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Klauer et al., 2014). It is assumed that a large number of these accidents are the result of driving errors caused by the driver being distracted (e.g., Staubach, 2009). Driving distractions can stem from competing visual, manual, or cognitive resources (Strayer & Turrill, 2014). All of these distraction types have been associated with detrimental effects on driving performance. However, whereas there is broad agreement on the negative impact of visual and visual-manual distraction (e.g., Carsten & Merat, 2015), researchers still debate the effects of cognitive load from secondary task engagement on driving errors and crash risk.

Some findings suggest that cognitive distraction impairs driving performance due to a diversion of attention (e.g., Horrey & Wickens, 2006; Strayer et al., 2013). However, a recent naturalistic driving study found that cognitively distracting secondary tasks, such as *passenger conversation* and *talking on the phone,* did not impact driving errors (Precht et al., 2017b). These results were found despite factoring in the visually distracting subtask *talking while looking at the passenger*. Moreover, cognitive distraction can mitigate driving error risk caused by fatigue (Jellentrup, Metz, & Rothe, 2011). Therefore, it is not surprising that cognitively distracting tasks have been associated with a decreased crash and near-crash risk in several naturalistic driving studies (Hickman, Hanowski, & Bocanegra, 2010; Klauer et al., 2006; Olson, Hanowski, Hickman, & Bocanegra, 2009; Simmons, Hicks, & Caird, 2016; Victor et al., 2015).

In contrast, activities requiring the driver to glance away from the road are known to carry the highest crash risk (e.g., Dingus et al., 2016; Simmons et al., 2016). Congruent with this finding, numerous investigations have suggested a connection between visual/visual-manual distraction and driving errors (e.g., Olson et al., 2009).

Even though driver distraction and error causation have been thoroughly investigated, the impact of cognitive distraction compared to visual and visual-manual distraction on driving performance in real-world traffic remains controversial. In addition, many observable distractions related to secondary tasks are not purely cognitive, but are combinations of cognitive and manual distraction (e.g., talking on the phone) or of cognitive and visual distraction (e.g., passenger interactions). Due to the high crash risk associated with visual distraction, further examination is particularly needed for cognitively distracting tasks coupled with visually distracting subtasks such as passenger interaction.