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Characteristics of turn signal use at intersections in baseline naturalistic driving

John M. Sullivan[a,*], Shan Bao[a], Roy Goudy[b], Heather Konet[b]

[a] University of Michigan Transportation Research Institute, 2901 Baxter Rd., Ann Arbor, MI 48109-2150, USA
[b] Nissan Technical Center North America, 39001 Sunrise Drive, Farmington Hills, MI 48331-3287, USA

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ABSTRACT

The purpose of this study was to determine whether a driver's use of turn signals is sufficiently reliable to forecast a vehicle's future path around an intersection, when detailed information about the intersection is unavailable. Naturalistic observations of turn signal use among 108 drivers on surface streets were extracted from the baseline portion of a field operational test of a safety system. Left and right turns that resulted in heading changes of between 70 and 110° and turn radii between 18 and 90 m were selected from the dataset. The odds that a driver would signal a turn were modeled as a function of road type, turn direction, presence of a forward vehicle, whether the vehicle stopped before the turn, and driver age and gender. Overall, 25 percent of left turns and 29 percent of right turns were not signaled. Road type, turn direction, and presence of a forward vehicle were found to influence the odds that a turn is signaled, while gender and age of the driver did not. The results suggest that situational factors like road type and turn direction are more powerful predictors of whether a turn will be signaled than either age or gender. Signaling on major and minor surface roads was about 5 times more likely than on local roads and 1.5 times more likely when a forward vehicle was present, suggesting a possible effect of traffic volume. It was concluded that turn signal activation alone may be insufficiently reliable to forecast a driver's path.

1. Introduction

In this study, naturalistic data were examined to help determine what systematic characteristics can be observed in a driver's turning maneuvers that might be used to inform the development of a connected-vehicle-based intersection collision avoidance (ICA) application. Such an application would warn the driver not to proceed along a projected course if there is a high likelihood that a collision with another vehicle might occur. For such a system to do this well, it must be able to anticipate what the driver intends to do as the intersection is approached as well as determine what the other vehicles in the immediate vicinity are also likely to do. Prior attempts to address this type of road conflict have experimented with both vehicle-based radar to assess conflict (e.g., Pierowicz et al., 2000) as well as site-based radar approaches (Misener et al., 2010; Nowakowski, 2006; Penney, 1999). With the new capabilities enabled by connected vehicle technologies (also known as dedicated short range communications – DSRC), equipped vehicles within an approximately 300-m radius of each other will be able to transmit to and receive detailed information from other nearby vehicles. This form of wireless communication has been called vehicle-to-vehicle (V2V) communication to distinguish it from other kinds of connected-vehicle communications involving interactions between the vehicle and the local infrastructure (called V2I). Advantages of a V2V communications capability were noted more than 10 years ago by Miller and Huang, 2002 who proposed a peer-to-peer data sharing algorithm to be used to address intersection collision crashes with possible extensions to address both frontal and rear-end collisions. In their framework, the peer vehicles primarily shared position data derived from global positioning systems (GPS). Route contention was determined by calculating trajectories from the GPS data, and warnings were issued if the time-to-collision (TTC) fell to a value near to the time a driver was projected to require in order to avoid the collision. This time was called the time-to-avoidance (TTA). If the driver took any mitigating action (e.g., braking) before TTC became too low, the warning was withheld.

Unlike an exclusively GPS-based system, V2V transmissions contain additional information that describes driver actions in nearby vehicles. Besides latitude, longitude, heading, and speed

* Corresponding author. Tel.: +1 734 764 8560; fax: +1 734 764 1221.
E-mail addresses: jsully@umich.edu (J.M. Sullivan), shanbao@umich.edu (S. Bao), goudyr1@nrd.nissan-usa.com (R. Goudy), ?KonetH@nrd.nissan-usa.com (H. Konet).

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(available from on-board GPS), the basic safety message may also contain information about steering angle, braking, and turn signal use (see Society of Automotive Engineers, 2010 for message details). Thus, a collision avoidance system may be able to better predict a driver's intention to stop, turn, or proceed through an intersection based on some of this additional information. A warning system's reliance on this information will likely depend on how well it predicts what a driver will do in the immediate future. For example, recent work on turn signal use reports systematic variation in drivers' use of turn signals. In two observational studies, Faw (2013) observed the turning maneuvers of drivers of passenger vehicles tabulating whether there was no signal, a late signal, or a good signal. In the first study, 3149 vehicles were observed executing both left and right turns at 47 different intersections; in the second study, selected based on low rates of turn signal use, 2455 right turns were observed at two intersections. Signaling was performed less often when turning right versus turning left, and less often when a dedicated turn lane was present. Turns at intersections were reported to be signaled about 76 percent of the time. This suggests that a turn is likely to be executed when a driver is signaling, but a turn may also be made 24 percent of the time when the driver is not signaling. Presence of traffic was also found to influence use of turn signals: in one study (Lebbon et al., 2007), 63 percent of drivers signaled turns in the presence of oncoming traffic compared to 44 percent when no traffic was present. On the other hand, Faw (2013) reports that turn signal use is lowest in heavy traffic (79 percent signaling), compared to light (89 percent) and moderate traffic (92 percent), suggesting less signaling in the presence of other traffic. The discrepancy might be a consequence of the small number of intersections sampled – Lebbon et al. (2007) sampled drivers at two intersections; Faw (2013) sampled drivers at 22 different intersections. Intersection characteristics and road configuration have also been noted to influence driver use of turn signals. For example, Faw (2013) reports 87 percent signaling when a dedicated turn lane is present, compared to 90 percent when no lane is present.

The purpose of the present analysis is to examine naturalistic vehicle turning maneuvers for systematic regularities that could help indicate a driver's intention to turn as the driver approaches an intersection. This study examines turn signal use and its association with driver demographics (age and gender), and other factors derived from the naturalistic driving dataset including road type, turn direction, and the presence of lead vehicles on the roadway. Some of these factors could also be considered reasonable surrogates for traffic density – for example, it might be expected that arterial roads have a higher traffic density than local roads; likewise, the presence of a lead vehicle may be indicative higher traffic density than no lead vehicle. We also note that the naturalistic data differs in significant ways from the observational studies: driver age and gender are known; the drivers involved are all driving the same make and model vehicle (a 2006/2007 Honda Accord); and the set of 3830 turns in the sample were drawn from approximately 2732 unique locations.

2. Methods

2.1. Naturalistic data sample

Turning data were developed from the driving data obtained in the Integrated Vehicle Based Safety System naturalistic driving study (Sayer et al., 2011). In this study, 108 licensed drivers were recruited to drive passenger vehicles equipped with a combination of safety systems. The sample of drivers was equally divided between male and female drivers and stratified into three age groups: 20–30 years (younger), 40–50 (middle-aged), and 60–70 (older), resulting in 18 drivers in each cell. Drivers were given test vehicles to drive unsupervised for a 12-day baseline period in which safety systems were inactive, followed by a 28-day period in which the safety systems were activated. The sample used for these analyses were derived from the baseline period of driving, when the safety systems were inactive. Thus, the baseline represents driving a vehicle equipped with no special warning systems that might artificially raise a driver's awareness of the need to signal turns.

2.2. Turn selection criteria

2.2.1. Road type

Because the targeted countermeasure scenario is intersection collision avoidance, selection of turn maneuvers was restricted to surface streets. This eliminated ramps, limited access roadways, and unknown road types which are largely parking lot maneuvers. Three road types were included in the analysis: major surface, minor surface, and local roads. Road types were derived from a commercial mapping database's (NavTeq/HERE) five function classes and whether the roadway is identified as a limited access roadway or ramp. Major surface streets included roads supporting moderate-speed travel within cities and travel between cities (function class 2 and 3); minor surface streets included moderate-speed travel between neighborhoods (function class 4); and local roads were defined as supporting lower-speed travel between neighborhoods (function class 5).

2.2.2. Turn characteristics

Turn maneuvers were selected that involved a heading change of between 70 and 110°. Turns were initially detected by examining vehicle yaw rates that exceeded $8^\circ\,s^{-1}$. The beginning and end of the turn was determined by backtracking and forward-tracking in the yaw-rate time series until the absolute yaw rate dropped to about $0.5^\circ\,s^{-1}$. This produced an approximate start and end of a turn (see the example turn shown in Fig. 1). Change in heading was determined by calculating the difference in heading at the start of the turn and the end of the turn. A negative difference was used to indicate a left turn; a positive difference indicated a right turn.

After direct video inspection, several turns in the initial sample were found to occur in parking-lots or parking structures and were unrelated to intersection traversal; this occurred because the proximity of the parking area to a nearby road resulted in the

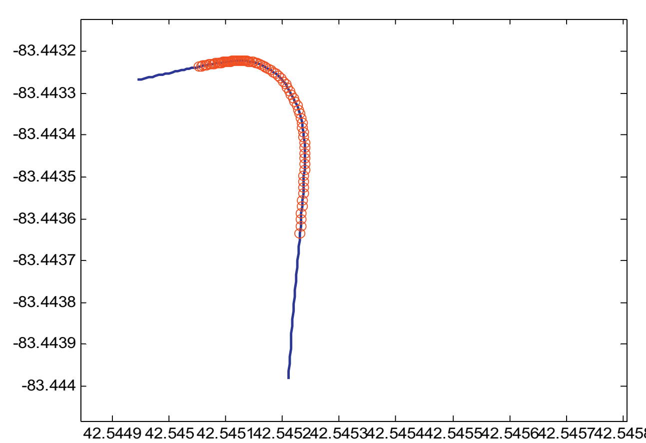

Fig. 1. GPS trace of path of a vehicle executing an approximately 90° turn; the red circles identify the part of the turn examined in the analyses. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)