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A Comprehensive Safety Analysis for Gaze Fixation of Drivers to Outside Scene

Abhijit Sarkar

Virginia Tech Transportation Institute, Blacksburg, VA 24060, USA

ABSTRACT

Driver distraction is one of the major contributing factors for crashes and near crashes. Research shows that driver distraction for as small as 2 seconds can result in safety critical events. Unfortunately, there are limited research in understanding the effects of outside objects in driver distraction. In this work we mainly concentrate on gaze fixation to objects that are located outside the vehicle. We used crash/ near crash (CNC) events, as well as baseline (BL) driving events from SHRP2 naturalistic driving study (NDS) to understand gaze fixation patterns. We selected a total of 666 events from CNC and 446 events from BL events. To reduce variability, these events are selected for cases where the driver gaze is fixated through the right windshield. We performed statistical analysis on both the sets of events for gaze fixation. When comparing between CNC and BL, the drivers mostly struggle to perceive information of dynamic objects in the scene, information from billboards and intersection scene, as well as for driving tasks while changing lanes, maneuvering to avoid other objects including pedestrians, taking a turn.

Keywords: Driver distraction, Crash analysis, Statistical analysis, Human factors, Roadway objects, Traffic safety analysis

INTRODUCTION

Driver distraction is one of the major reasons for traffic related crashes and fatalities. Driving is a complex task where a driver needs to process a driving scene to navigate safely from one point to another. However, drivers are often distracted with tasks not directly related to driving. These distractions can be visual, cognitive, auditory, or a combination of them. In this work, we mainly focus of visual distraction. Research has demonstrated that distraction due to cell phone interactions, passenger interaction, reaching for objects, are some of the major inside distractions that can lead to safety critical events (Dingus et al,2016, Hanowski, 2011).

However, this does not eliminate the role of outside distraction. Before the wide use of cellphones and smartphones, analysis (Stutts et al, 2001) showed that almost 30% of the crashes are caused by distraction by outside objects and events. Recently, study of naturalistic crash/near crash (CNC) and baseline (BL) events (Dingus et al,2016) showed that extended gaze to outside object significantly increases crash risk. Taxonomy of visual distraction

Figure 1: Object saliency for roadway scene. This shows that the saliency of any scene is generally targeted to the objects present in the scene. Higher intensity refers to higher value of saliency (Cornia et al, 2018).

often suggests four groups of distractions that may attract a driver's attention (Regan, Lee, and Yong, 2008): Built roadway (road curvature, surface, signs), situational entities (moving vehicles, pedestrians, weather, etc.), natural environments (Tree and vegetation, hills, lake, sky etc.), and built environment (buildings, billboards, advertisements etc.). However, research performing quantitative analysis in understanding, duration gaze fixation, scan pattern, effect of object distance in distraction by each of the objects are limited. This paper aims to address the question of duration and patterns of gaze fixation.

Gaze Fixation to Outside Objects

Gaze fixation refers to events where a person looks at a certain object or scene for significantly longer period. As the driver travels through a complex scene with multiple stimuli for distraction, it is difficult to predict what outside object or event distract a driver at a given instance. One possible way to predict such distractions is through understanding the visual saliency of an outside scene (As shown in Figure 1). Visual saliency provides us with an estimated probability of locations that can attract human attention. However, as drivers' primary task is to look at objects and places related to safe maneuver, the saliency map does not provide a full explanation all the time. Therefore, we need to perform analysis through real world driving data to understand role of objects that may attract human attention. In this paper we focus on analysis of events from naturalistic driving data where gaze fixation was observed.

METHOD AND MATERIAL

SHRP2 NDS

The SHRP2 NDS is largest collected naturalistic data available for public use (Dingus et al, 2015). It contains data from real world drivers and records kinematic behavior of the vehicle including speed, acceleration, and gyro; positions and relative speed of the surrounding objects using radar data. It also contains video of forward roadway and inside cabin looking at drivers' face. The SHPR2 NDS dataset also contains crash and near crash events

(A total of ~9000 events), and baseline driving events (A total of ~ 32000 events). All these events are annotated by human annotators. One of the annotations is the gaze location of the drivers for all those events. The gaze annotation provides a frame-by-frame annotation of driver gaze in multiple gaze locations including, rear-view mirror, forward, left mirror, right windshield, left windshield, etc. We have used these gaze annotation data to select gaze fixation cases.

Event Analysis of CNC/BL

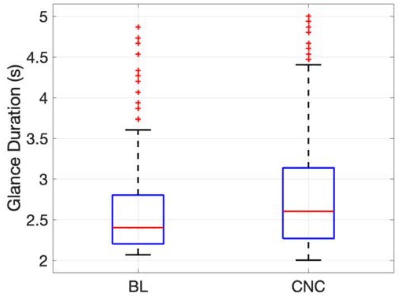
We select a total of 666 events from CNC and 446 events from BL events. To reduce variability, these events are selected for cases where the driver gaze is fixated through the right windshield. The fixation duration is chosen between 2 seconds and 5 seconds. The lower value of 2 seconds was chosen for two reasons, first to guarantee fixation to object, and secondly, any distraction more than 2 seconds are known to be critical for roadway safety (Klauer et al, 2006). The higher limit of 5 seconds was chosen as cases with more that 5 second often belong to events where the ego vehicle is stationary (at a signaled intersection for example). After the initial choice of events, we further annotated all the gaze fixation events manually using both the forward and driver face video. The annotations mainly focus on type of fixated object (car, pedestrian. Billboard etc.), ego vehicle motion (going straight, changing lane etc.), fixated object motion (fixed on the roadside, moving right to left etc.), driving environment (city, intersection, highway), exact timing of gaze fixation start and end, and use of head and eyeglance. The use of head and eyeglance annotates, if there was any visible head movement of the driver, or the driver only used eyeglance. After manual annotations we found a total of 617 valid CNC event and 410 valid BL events. The analysis is based on these finally selected events.

RESULT AND DISCUSSION

We performed statistical analysis on both the sets of events. Here is the summary of the analysis:

- **Object of fixation:** For CNC, the top five fixated objects are: light vehicles on road (39%), tree/ vegetation (16%), traffic sign (15%), intersection (7%), and building (6%). For BL, the top categories are light vehicles (30%), Traffic sign (18%), buildings (17%), intersection (11%), and other locations (11%). Billboard appears in both the cases CNC (1.3%) and BL (2.4%) cases.
- **Head movement:** For CNC, 73% events show visible head movement of the drivers compared to 66% events in the BL. Most of the cases with visible head movement in CNC, the driver was looking at other vehicles (56% cases). Out of those cases, the vehicles were changing lanes (25%), Turning left or right (19%), Going straight at constant speed (12%), stopped at a traffic lane (8%). For BL cases on the other hand, the drivers had visible head movement while looking at buildings, and intersections. It is interesting to see that.

Table 1. Comparison of duration of gaze fixations in CNC and BL events. Q1, Q2, and Q3 refers to first, second, and third quartile.



Event	Q3	Q2	Q1
BL	2.80	2.40	2.20
CNC	3.14	2.60	2.67

Table 2. The glance duration comparison for BL and CNC for billboards, cars, and intersection. All numbers are in seconds. Q1, Q2, Q3 represent 25 percentile, median, and 75 percentiles.

	BL			CNC		
	Billboard	Car	Intersection	Billboard	Car	Intersection
Q1	2.27	2.23	2.18	2.87	2.29	2.2
Q2	2.3355	2.4	2.4	**3.07**	2.6	2.5
Q3	2.74	2.8	2.67	**3.47**	**3.07**	**3.27**

- **Gaze fixation duration:** Average gaze fixation time of drivers to objects are high for CNC compared to BL as shown in Table 1 especially, they have higher range in distribution (0.3 second higher). We can assume that higher value of gaze fixation signifies higher distraction.
- **Gaze fixation duration, by object type:** The difference is especially high for billboards, and intersection related crashes. As shown in Table 2, drivers spend more time perceiving a billboard information during CNC cases. Similarly, they also spend higher amount of time perceiving an intersection.
- **Gaze fixation duration for ego motion:** Driver distraction is especially high when they are turning, negotiating with vulnerable road users, maneuvering to avoid objects.
- **Gaze fixated object position:** We noticed that for baseline events, the driver was mostly looking at stationary objects (89% time). This is compared to 44% time in CNC cases. In most of the cases in CNC, the driver was looking at movement of other roadway objects (Cars, pedestrians, SUV etc.).

Discussion

We have analyzed events from crashes, near crashes, and baseline events. our analysis shows that during CNC events, drivers' gazes are more fixated to roadway objects and their movements. In comparison, drivers gaze fixation was more towards roadside or stationary objects during BL events. In other words, fixation to dynamics of the roadway objects contributes more to safety critical events compared to the roadside objects. this conclusion can be explained through recent theories from driver modeling (Markkula, 2014;

Engström et al, 2017). A driver uses a prediction-correction model to safely maneuver the vehicle. A driver accumulates evidence from the roadway scene, then processes the information, and decides to apply break, accelerator, or steering input. Now, for any static object, the information from the object does not change over time. This is true especially for objects like buildings, road sign, or stopped vehicles. This can be even simplified for traverse through a known neighborhood. In contrary, for any dynamic roadway objects, whose trajectory and kinematics is changing over time, a driver needs to continuously update their input to the evidence accumulation model (Markkula et al, 2016; Sarkar et al, 2021) and update the maneuver decision. Clearly, this requires more cognitive involvement for a driver which may affect their attention to overall driving performance. This can even escalate when a driver is negotiating path with another vehicle, taking a turn, or another vehicle cuts in front of them. Stationary objects can also demand more cognitive attention from a driver if the driver needs to process additional information from the static object. Our result shows that one such object can be billboards which requires a driver to perceive information by processing text and graphics.

CONCLUSION

In this study, we presented a comprehensive summary of the gaze fixation and their relative contribution in road safety. We have analyzed events from CNC and BL where driver gaze was fixated to outside object through the right windshield. We have performed statistical analysis to understand the gaze fixation duration as a function of object class, object maneuver, object location in the scene, and ego motion. We believe that our result will specifically help practitioners and safety researchers to understand what objects from outside may create distraction and results in increasing risk of crashes and near crashes.

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