Can We Discriminate Safe and Unsafe Visual Scanning in Multitask Driving Conditions?

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Introduction

Traffic accidents are a major public health concern with 1.2 million fatalities occurring every year and with millions more individuals getting injured [1]. More than 90% of the accidents are, at least partially, caused by the driver [2]. Figure 1 shows the overrepresentation of younger and older drivers among these crashes. The overrepresentation of younger drivers [1] can be explained by an increased willingness to take risk, poor anticipation of hazards, and insufficiently learned lateral and longitudinal vehicle control [3]. Figure 1 also shows the overrepresentation of elderly drivers which is caused by decline of cognitive and physical abilities [4] such as visual impairment (e.g., glaucoma).

Generic predictors of crash risk exist (e.g., age, gender). However, detailed knowledge about how drivers control their vehicle and combine various subtasks related to driving does not exist. Combining the visual scanning, vehicle control and decision making tasks makes the driving task complex. Drivers not only control the vehicle but also anticipate oncoming events (e.g., hazards, traffic) and combine the driving task with other tasks (navigating, cell phone use). Driving is predominantly a visual task [6] and individual differences in visual scanning behavior are found as a function of increasing driving experience [7], visual impairment [8] and environmental complexities [9]. For example, novice drivers have less visual attention to latent hazards compared to experienced drivers [10] and show visual scanning strategies that rely less on top down mechanisms of visual attention [11].

In our research, we aim to distinguish safe from unsafe drivers based on their visual scanning behavior. In this paper we will demonstrate two examples of visual scanning behaviors: (a) when using an in-vehicle system and (b) when performing a highway driving task, both in a driving simulator. Using these results the differences of drivers visual scanning in (multitask) driving and the applicability of non-intrusive eye tracker hardware in driver behavior research will be demonstrated.

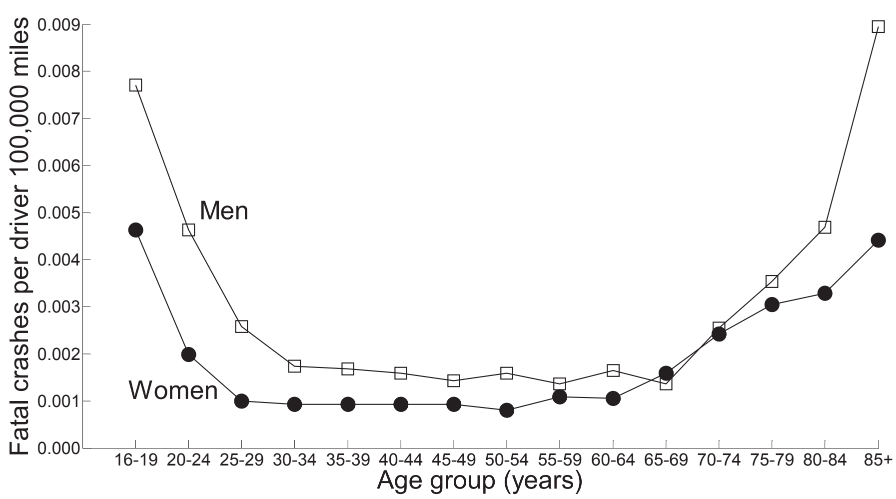

Figure 1. Fatal accident involvement per driver 100,000 miles as a function of age [5].

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Methods

The driving simulator used in these studies is the Green Dino [12] driving simulator which is used for initial driver training in the Netherlands. This medium fidelity, fixed-base driving simulator provides a 180 degree horizontal field of view. A high field of view increases perceptual fidelity and is assumed to result in more realistic scanning behavior. The simulator controls were based on controls from a real car and steering feel was passively calibrated with respect to on-road vehicles [13]. This driving simulator has previously been used for research of training and assessment of student drivers [14]. Head motion and gaze direction was measured in both studies with a remote mounted eye-tracker system using infrared illumination. Cameras were mounted outside of the visual scenery in the driving simulator and calibration took place for each individual participant.

Results

The visual scanning of novice drivers using a concurrent lane position feedback system [15] is shown in figure 2. This feedback system allowed learner drivers to improve their lane keeping performance by using the feedback on their momentary lateral position error presented on their vehicle dashboard. The figure shows how drivers directed their gaze at the feedback area for longer periods of time.

In figure 3 the difference in visual scanning patterns are shown for two inexperienced drivers during a traffic-free highway driving task. One driver showed a small variance in horizontal fixations, with most fixations aimed at the roadway. A second driver showed large horizontal variance in fixations and shorter fixation times indicative of increased visual scanning of the roadway and its surroundings.

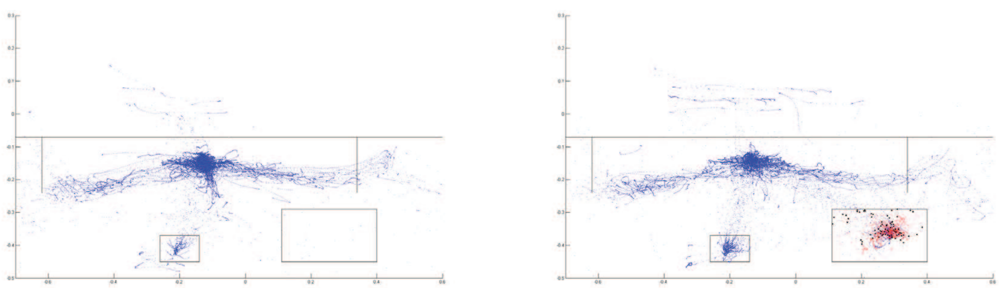

Figure 2. Raw gaze data for a rural road driving task. Gaze is mainly directed to the road ahead and the swirls left and right indicate looking into corners. Gaze pattern of a novice driver showing extensive use of an in-vehicle system (right).

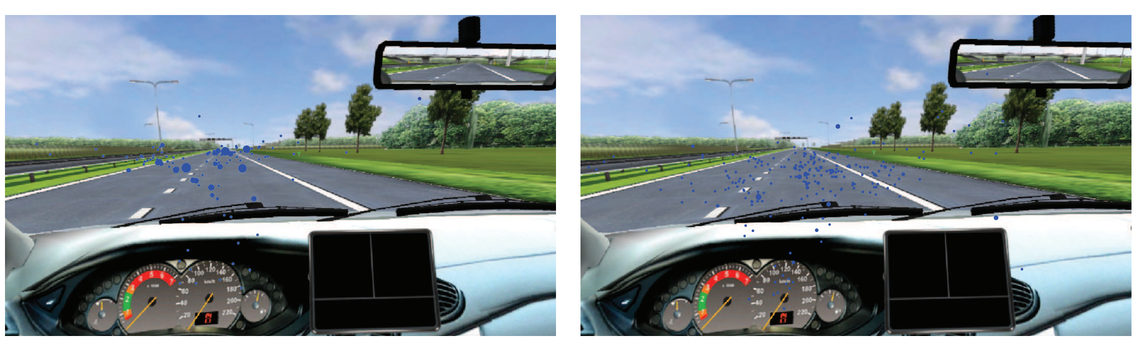

Figure 3. Visualization of fixations during a highway driving task, fixation duration is indicated by the dot size. Fixation pattern of two inexperienced drivers showing differences in visual scanning.

Discussion

Using driving simulators and high-end eye-tracking hardware, we have shown to be able to discriminate the differences in visual attention while using an in-vehicle system and the different fixation patterns of drivers performing the same task, showing the variability between drivers. In future work we will relate driving simulator measures of both the vehicle (e.g., lane position) and driver performance (e.g., steering activity) with gaze direction based metrics (e.g., fixation patterns) and measures of driver workload (e.g., heart rate variability). With these relations we aim to distinguish safe drivers from unsafe drivers and apply this knowledge in driver support systems, driver training and assessment.

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