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Using Virtual Reality Driving Simulation to Model the Dynamics of Driver Peripheral Vision

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Using Virtual Reality Driving Simulation to Model the Dynamics of Driver Peripheral Vision

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1 Introduction

During driving, relevant stimuli such as a jaywalking pedestrian or a speed limit sign often first appear outside of the central region of our gaze but we are still able to perceive and respond to them. To characterize this phenomenon, psychology researchers commonly use a construct known as the Functional Field of View (FFoV) — the region of our field of view in which stimuli can be processed during a single fixation [1]. Essentially, if a new stimulus occurs outside their FFoV, drivers cannot perceive it without additional eye or head movements. The FFoV consists of both foveal and peripheral vision. However, most of today’s gaze-based driver awareness models only account for foveal vision [3], which would lead to underestimation of driver situational awareness (SA) and hence, redundant assistive alerts or interventions. Considering the important role that the FFoV plays in maintaining situational awareness while driving [5], peripheral blind spots in the FFoV caused by saccadic suppression should be modeled and mitigated by intelligent driver assistance systems.

To that end, last year, we proposed an experiment to model the FFoV with the following objectives:

1. *Design experimental procedure for peripheral detection task (PDT) during driving:* Participants were asked to respond to peripheral targets (red orbs) that appear briefly in the periphery of their vision. The targets are very conspicuous, so missed targets indicate blind spots in the FFoV, allowing us to model its spatial extent and temporal dynamics.

2. *Gather data in virtual reality driving simulation:* We collected data during a Driving Task (DT) and a Non-Driving Task (NDT) to isolate the differences in FFoV caused by driving.

3. *Analyze data and build predictive model:* Our data analysis showed that while drivers missed more peripheral targets in the first second of a new fixation, their
eccentricity did not significantly change with an increase in fixation duration. Since we could not find an effect of fixation duration and missed target eccentricity, we did not build a predictive model.

2 Results and Impact

In the work described above, we studied the shape and dynamics of the FFoV during active driving using a peripheral detection task in a virtual reality (VR) driving simulator ([4]) with licensed drivers in urban driving settings ([1]). We found evidence that supports a vertically asymmetric (upward-inhibited) shape of the FFoV in our active driving task, similar to previous work in non-driving settings. During the Driving Task, the distribution of misses was centered at a higher pitch (vertical, $7^\circ$ difference) eccentricity in the driver’s FoV than the distribution of hits. This difference was statistically significant. However, we find that this asymmetry disappears when the same peripheral detection task is conducted in the Non-Driver setting which suggests a task-based modulation of the FFoV.

Finally, we also examine the dynamic nature of the FFoV. Our data indicates that drivers’ peripheral target detection ability is inhibited right after saccades but recovers once drivers fixate for some time.

Missed peripheral stimuli were observed to be overall more eccentric than hits during the driving task: mean eccentricity for hits and misses are $25.89^\circ$ and $32.90^\circ$ respectively. Further, we examined the distribution of OFDs for hits and misses. Misses tended to have shorter associated OFDs (0.41s on average) than hits (0.69s). Both differences were found to be statistically significant. Moreover, we observed that 81.5% of all misses occurred within 0.5s of fixation onsets, while only 62.1% of all onsets fell within that period (89.5% misses/80% onsets within 1s).

The findings of the FFoV’s task-dependent nature as well as systematic asymmetries and inhibitions have implications on tuning downstream applications such as gaze-based intelligent driving assistance systems.

Together, these data indicate that missed peripheral targets are most likely to occur in the first second of a new fixation. For example, an assistance system can track when a person is saccading unusually frequently and raise the cautiousness levels of the system during and right after driver saccades since drivers may be more likely to miss stimuli entering their peripheral FoV in these periods.

A research paper describing this work was accepted as an oral presentation at the IEEE Intelligent Vehicles Symposium ’23 [2] as well as an extended abstract at CogSci ’23.

3 Where could this lead?

This line of research should be viewed in the broader context of gaze-based driving assistance systems. Driver gaze allows us to make inferences about driver internal states such as situational awareness and intent, which can be then used to model their perceptions of the environment/other agents and ultimately forecast driver behavior. If we can do this accurately, we can predict when driver internal perceptions do not match reality and can predict when future driver actions may lead to dangerous situations.
4 List of publications/presentations

The following publications acknowledged the Link Foundation’s support:


References


How did the Fellowship make a difference?

It was also a validating accomplishment to receive the fellowship recognizing the work we have done in driving simulation. The Fellowship was helpful in providing additional flexibility while choosing project directions that may be more difficult with more traditional funding sources and allowed me to spend some of my time maintaining an open-source implementation of our VR driving simulation software\(^1\) which has since been used by many other groups for their research, true to the mission of the Link Foundation.

\(^1\)https://github.com/HARPlab/DReyeVR/