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Final Report

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Driver attention to the roadway is paramount to safety. Therefore, the debate on driver distraction is largely concerned with maximizing the time a driver's eyes are focused on the road (NHTSA, 2013; Green, 2004). The demands visual-manual interfaces place on driver's visual attention are relatively overt. Previous research (Harbluk, Noy, Trbovich, & Eizenman, 2007; Sodhi, Reimer, & Llamazares, 2002; Victor, Harbluk, & Engström, 2005) has shown that many cognitive activities impact the allocation of visual attention as well. Although a driver's eyes overtly remain oriented towards the road during periods of heightened cognitive activity, a more central concentrated scan path appears. Numerous studies have reported a decrease in reaction time associated with increased cognitive activates (Engström, Aust, & Viström, 2010; Strayer & Drews, 2004).

Previous research has investigate the impact of a variety of cognitive activities on driver attention (Harbluk, Noy, Trbovich, & Eizenman, 2007; Sodhi, Reimer, & Llamazares, 2002; Victor, Harbluk, & Engström, 2005; Recarte and Nunes 2000; Recarte and Nunes 2003; Nunes and Recarte 2002). As discussed in Reimer (2009) and Reimer, Mehler, Wang and Coughlin (2012), these efforts argue for the investment in additional effort to assess the sensitivity of gaze concentration to different levels of cognitive workload. In addition, little investment has been made in understanding the impact of driver age on these phenomena. As part of multiple field and simulation studies described in detail in the publications listed below, this research shows that changes in cognitive workload induced through the delayed digit (n-back) task have a differential impact on gaze concentration. Age per see does not moderate these effects. In essence, the impact of a cognitive activity on gaze concentration relates significantly to the level of demand associated with the activity. As a result of this effort and other NE-UTC research (MITR22-7 & MITR23-5), the n-back task has been utilized by NHTSA, OEM's, and many international laboratories as a cognitive benchmark task. Tom Ranney (NHTSA, 2011), in his report on driver distraction, commented that the most difficult demand level studied (2-back) should be considered as a first stage threshold for an acceptable dose of cognitive demand produced by an in-vehicle system. For further information on this research please see:

Reimer, B. (2009). Cognitive Task Complexity and the Impact on Drivers' Visual Tunneling. *Transportation Research Record*, 2138, 13-19. Also appeared in (2009) Proceedings of The Transportation Research Board 88th Annual Meeting, Washington, DC.

Abstract: Cognitive distractions have been shown to affect drivers adversely and are a leading cause of accidents. Research indicates that drivers alter how they allocate their visual attention while engaging in secondary cognitive tasks. To evaluate the potential impact of secondary cognitive tasks on the allocation of drivers' visual attention and on vehicle control, drivers were presented with increasingly complex forms of an auditory cognitive task while driving an instrumented vehicle. Measures of vehicle performance and eye gaze were assessed. Consistent with theories of visual tunneling, gaze distributions were significantly smaller while drivers performed certain levels of the secondary task; peripheral vision was thereby reduced. During the most difficult level of the secondary task, gaze dispersion was smaller than during any other level of the task. Changes in visual attention may provide earlier indications of cognitive distraction than changes in vehicle control, the latter of which were observed only during the most difficult level of the secondary task. Observed changes in vertical eye position suggest that drivers compensate for moderate cognitive demands by increasing their sight distance before further incremental increases in workload exceeded their abilities. In summary, the workload of a secondary cognitive task affected drivers' visual attention. A low to moderate increase in workload was detectable as a change in gaze before vehicle control suffered. Gaze restriction appears related to the degree of cognitive workload. This work shows that visual attention is a potential method of detecting changes in driver state associated with cognitive workload.

Wang, Y., Reimer, B., Mehler, B., Zhang, J., Mehler, A., & Coughlin, J.F. (2010). The Impact of Repeated Cognitive Tasks on Driving Performance and Visual Attention. In G. Salvendy (Ed.) *Advances in Human Factors, Ergonomics, and Safety in Manufacturing and Service Industries* (pp. 668-678). CRC

Press. Also appeared in (2010) Proceedings of The 3rd International Conference on Applied Human Factors and Ergonomics, Miami, FL.

Abstract: This study assesses the degree to which three demand levels of an auditory delayed digit recall task impact visual attention, pupil diameter and simulated driving performance. Changes in horizontal gaze dispersion and reduced lateral variation during the dual task periods indicate a more centralized allocation of visual attention during periods of heightened cognitive load. This pattern was consistent across the first and second presentations of each task. At the highest demand level, pupil diameter increased significantly over other dual task periods and single task driving. Pupil diameter was moderately impacted by task repetition, suggesting some habituation to the novelty of the task. The overall results indicate that pupil diameter was a more sensitive measure of changes in workload with repeated task exposure than visual attention and driving performance measures in the context of the simulation. In an on-road study with the same secondary task, gaze became significantly more centralized as the level of cognitive workload increased. Although this level of discrimination was not replicated here, taken together, the results further highlight the usefulness of gaze dispersion as an indicator of cognitive workload.

Reimer, B., Mehler, B., Wang, Y. & Coughlin, J.F. (2012). A Field Study on The Impact of Variations in Short Term Memory Demands on Drivers' Visual Attention and Driving Performance Across Three Age Groups. *Human Factors*, 54(3), pp. 454-468.

Abstract: *Objective:* To assess sensitivity of visual attention and driving performance for detecting changes in driver cognitive workload across different age groups. *Background:* The literature shows mixed results concerning the sensitivity of gaze concentration metrics to variations in cognitive demand. No studies appear showing how age impacts gaze allocation during cognitive demand. *Method:* Recordings of drivers' gaze and driving performance under three levels of cognitive demand were captured under actual driving conditions in individuals in their 20s, 40s and 60s. *Results:* Gaze concentration increased with task difficulty through the low and moderate levels of demand and then appeared to level out at the high demand level. At the moderate difficulty level, gaze concentration increased by 2.4cm (≈ 2 degrees) from the reference period. The degree of gaze concentration with added cognitive demand is not related to age in the relatively healthy drivers studied. Driving performance measures did not show a consistent relationship to the objective demand level. *Conclusion:* Gaze concentration appears at low levels of cognitive demand prior to the appearance of marked decrements in driving control. There is no compelling evidence from this study that driving performance measures can be used to index differences in workload prior to capacity saturation. *Application:* Drivers' awareness of vehicle surroundings is incrementally impacted by increases in cognitive demand. The development of more advanced driver support systems should consider gaze concentration as a measure of driver cognitive workload. This is particularly relevant in light of the added benefits of gaze measurements for detecting visual demand.

Other publications supported through this project include:

Zhao, N., Reimer, B., Mehler, B., D'Ambrosio, L.A. & Coughlin, J.F. (2012). Self-Reported and Observed Risky Driving Behaviors among Frequent and Infrequent Cell Phone Users. *Accident Analysis and Prevention*. <http://dx.doi.org/10.1016/j.aap.2012.07.019>.

Lavallière, M., Reimer, B., Mehler, B., D'Ambrosio, L., Wang, Y., Teasdale, N. & Coughlin, J.F. (2011). The Effect of Age and Gender on Visual Search During Lane Changing. Proceedings of the 6th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design. Lake Tahoe, CA, pp. 621-628.

Reimer, B., Mehler, B., Wang, Y. & Coughlin, J.F. (2010). The Impact of Systematic Variation of Cognitive Demand on Drivers' Visual Attention across Multiple Age Groups. Proceeding of the 54th Annual Meeting of the Human Factors and Ergonomics Society. San Francisco, CA, pp. 2052-2056.