Driving Towards Safety: Effects on Pupil Dilation During Unexpected Driving Events

Joseph Kao[1], Leili Najmabadi[1], Andrew Gundran[2], Joe Baker[2], Hadi Hosseini[2]

Palo Alto High School[1], Department of Psychiatry and Behavioral Sciences, Stanford University[2]

Introduction

The study of neurological reactions and comprehension of physiological data related to unexpected events in various driving situations is significant to prevent the large amount of car accidents that occur around the world everyday. Approximately 1.3 million people die from car accidents annually and there is a global average of around 18 car crash deaths per 100,000 people per year, so there is a need for interactive safety systems that can be developed to distinguish this damaging problem. In this specific experiment, researchers created a driving paradigm based off an ISO (international standard) double lane change task in a driving simulator environment. Often used to evaluate handling performance of a vehicle, the ISO double lane change task involves the participant to drive down a straightaway and then change lanes according to the arrow presented at a given point. Following the lane change, the participant would navigate back to the center lane and allow the car to drive in autonomous mode until resetting to the next trial.

Fig. 1. Human subject driving the modified car, which is the system of this experiment.

Materials and Methods

- 20 healthy participants (10 female and 10 male)
- Driving paradigm
- Accelerometer
- Near infrared spectroscopy (NIRS) Head Cap
- Eyetracker
- Modified Car with Electronic Controls
- Computer with Appropriate Software
- 2 GoPros

Through triggering systems and simultaneous video capture via GoPros and a forward facing camera from eye tracking glasses, researchers were able to capture precisely when an event happened along with the participants reaction and behavior via video, brain and eye tracking data streams. The independent variable was the steering sign conditions, which includes start congruent, start incongruent, turn congruent, turn incongruent, auto congruent, and auto incongruent. The dependent variable was pupil dilation, and the control condition for the steering switch was autonomous mode, which in this case is when the car drives itself. The experiment was measured using a pseudorandomized order of trials in order to reduce bias and make the trials unpredictable. 16 Congruent (normal steering) and 16 incongruent (reversed steering) trials were conducted adding up to a total of 32 trials for each participant. An equal number of male and female participants was represented

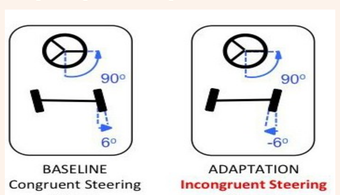

Fig 2. Comparison between Congruent and Incongruent Steering

Fig. 3. Illustration of the Accelerometer.

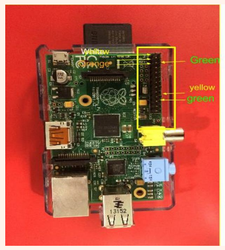

Fig 4. Illustration of the Eyetracker.

Results

All participants were able to successfully complete the driving simulator experiment. Preliminary results indicate that mean pupil diameter is similar at the beginning of the driving event when comparing congruent (mean = 3.5902 mm) versus incongruent steering (mean = 3.5874 mm). However, mean pupil diameter was larger in incongruent conditions (mean = 3.8084 mm) compared to congruent conditions (mean =3.6507 mm) at the turn event (i.e. when driver makes a decision).

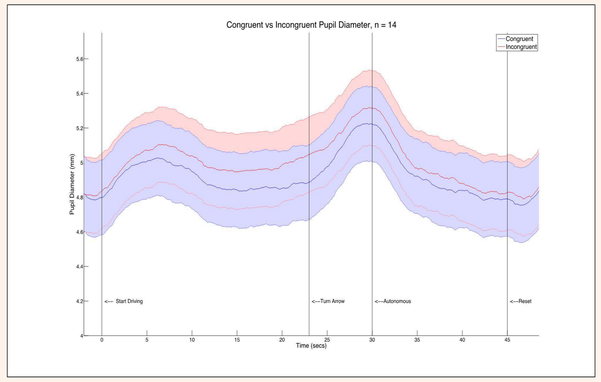

Fig. 5. Throughout the study, there were 2 bell shaped curves. The lowest points of pupil dilation occurred when the subjects started driving and when the simulation was reset. The reason behind this is that once a participant starts to drive a normally functioned car, it only takes up a bit of one's mental effort and does not require lots of stress. Observations iinfer that the pupil dilation at a turn arrow signifies a sharp increasing trend of the bell shaped curve and slowly levels off after entering autonomous mode because participants begin to relax. There is also a lag time for the pupil to reach its peak of dilation between turn arrow and autonomous mode. Both congruent and incongruent driving trials demonstrated similar patterns to each other, but the incongruent trial always had a higher pupil dilation compared to the congruent trial because of the stress level of having to instantly adapt and alter directions.

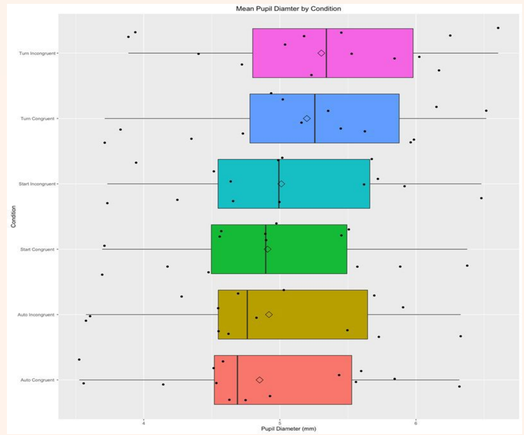

Fig. 6. The conditions of start congruent and autonomous congruent have almost identical means of pupil dilation, which are relatively lower than the means of other categories. incongruent condition had the greatest mean of pupil dilation, while the autonomous congruent condition had the least mean of pupil dilation.(Rhombus = mean; Vertical Line = median)

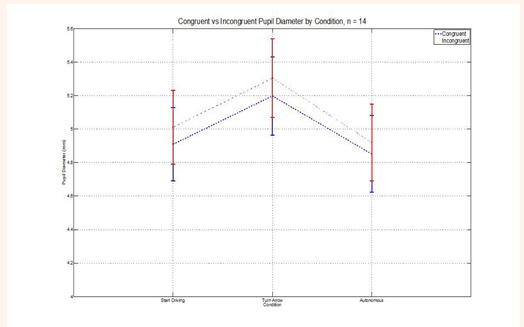

Fig. 7. The pupil dilation slowly increases after the initial start of driving occurs. Incongruent trials takes a slight edge over congruent trials in pupil diameter with a .1 mm difference. When there is a sudden turn arrow that appears, pupil dilation increases by .2 mm in both congruent and incongruent trials which results in a peak in pupil diameter. Then, it slowly decreases and levels off before the experiment shifts into autonomous mode. (Red = Incongruent Trials; Blue = Congruent Trials)

Summary/Conclusions

In conclusion, when participants have to learn and adapt in unexpected driving conditions, it elicits a higher pupillary dilation, which in return means a greater autonomous nervous response. For example, when the car travels the opposite way the wheel is turning at given times, it becomes even more difficult for the participant to maneuver the car and results in an increased amount of focus as well as stress level. Pupil size enlarges in proportion to the difficulty of the task at hand, which provides a positive correlation between the two. This supports the hypothesis because unexpected driving events can induce more of a fight or flight response that helps the body react quickly. Combined with neural activity, these findings can be used to further understand states of stress and increased mental workload that could be aided by advanced warning signs or autonomous systems. Lastly, it is important to examine closely on what the participants are specifically viewing at any critical driving moment.

Literature cited

Liu, T., Pelowski, M., Pang, C., Zhou, Y., & Cai, J. 2015. Near-infrared spectroscopy as a tool for driving research.

W.G. and Winfred, A. 1996. The five-factor model, conscientiousness, and driving accident involvement. *Journal of Personality* 64.3: 593-618.

Tsunashima,H. and K. Yanagisawa. 2009. Measurement of brain function of car driver using functional near-infrared spectroscopy (fNIRS).

Yoshino, K., Noriyuki, O., and K. Yamamoto, H. Takahashi, and T. Kato. 2013. Functional brain imaging using near-infrared spectroscopy during actual driving on an expressway. *Frontiers in Human Neuroscience*

Acknowledgments

We thank our mentors Andrew Gundran, Joe Baker, and Hadi Hosseini for helping us through our research project and letting us use the resources in the lab.

Fig 8. Picture of Stanford Psychiatry and Behavioral Sciences

For Further Information

Please contact *josephkao168@gmail.com or leilinaj@gmail.com*. More information and related projects can be obtained at *http://cibsr.stanford. edu/research.html*

Center for Interdisciplinary Brain Sciences Research