ECE 791/792 Project Proposal

Improvement and evaluation of the cognitive load estimation technique

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Courses involved: ECE 633, ECE 634, ECE 647, ECE 714, ECE 955

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General problem definition

Today, a rising number of in-car electronic devices draw away the driver's attention from the road. This can lead to hazardous situations. The drivers' cognitive state could be monitored to prevent these situations. One of the least intrusive methods for assessing cognitive load is measuring pupil diameter change using remote eye tracking. Because of the effect of task evoked pupillary response (TEPR), the pupil will dilate when a person is faced with a challenging cognitive task. But the pupil's diameter will also change due to change in lighting conditions (pupillary light reflex). The problem we are facing is decoupling the effects of illumination and cognitive load on pupil diameter.

Background

Palinko and Kun have proposed the method for decoupling the effects of illumination and cognitive load on pupil diameter. They verified the model shown in Figure 1. They showed that by predicting the pupil reaction due to illumination, the cognitive load can be estimated.

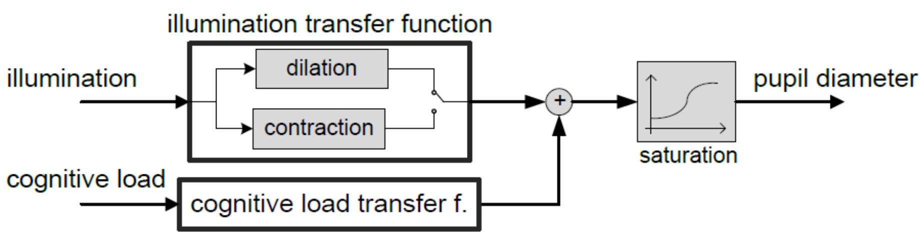

Figure 1. Pupil response model

In their study, Palinko and Kun evaluated the estimation process in the case where driver was supposed to look in the center of one of the different colored trucks (Figure 2).

Figure 2. scene from the experiment conducted by Palinko and Kun

Prediction was done by averaging over a large number of pupil responses for different subjects and only the shape of the response was evaluated. For quantitative measurement of the cognitive load, it is important to predict not only the shape of the response, but also the correct amplitude.

Specific problem

By varying the vehicles size the illumination perceived by the driver and the pupil reaction changes. In this project, estimation procedure given by Palinko and Kun will be improved and the effect of the vehicle's size on the cognitive load estimation process will be evaluated.

Specific design objectives

The goal of this project is to design and conduct a series of experiments to evaluate a simple approach to disambiguation of effects of illumination and cognitive load on pupil diameter under three different lighting conditions as a consequence of different sizes of the vehicles. The proposed hypothesis is cognitive load effect on pupil size would be more pronounced in case of a smaller vehicle compared to the bigger vehicle.

For three different sizes of the vehicles, cognitive load will be estimated. The quality of the cognitive load estimate will be quantitatively evaluated.

Palinko and Kun noticed the variations of pupil size when there should be no changes (steady state of the isolated illumination effect). Tracked data and prediction of the pupil reaction in this case are shown in Figure 3. This could be happening due to noise introduced by eye tracker device and unconscious eye movements of the participant. In this project, the eye tracker noise will be filtered by the low pass filter. The cut-off frequency will be determined by correlating the pupil diameter of the left and the right eye at different frequencies.

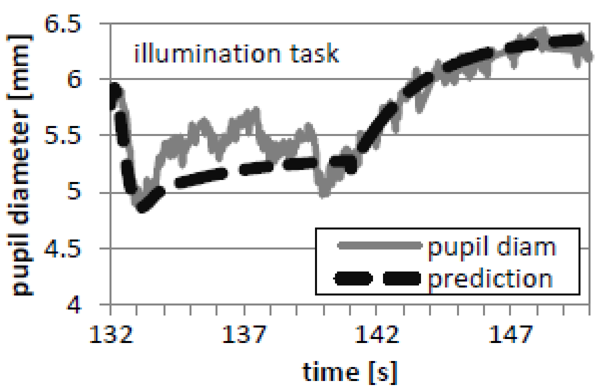

Figure 3. Pupil diameter for an illumination task and the prediction (from DA 2011 paper)

The gaze direction will be tracked for two reasons, for eliminating the gaze angle lag and evaluation of variations of pupil size due to unconscious eye movement.

Data acquisition

Between-subjects experiments with three conditions: large, medium and small trucks will be analyzed. DA 2011 experiment will be used as a large trucks set-up and two additional experiments would be conducted. Participants will be given three tasks (same as in DA 2011):

1. Cognitive task with varying cognitive load and constant lighting: participants were listening to a voice counting from 1 to 18 repeatedly. Participants were told that every sixth number might be out of order and are instructed to push the button if they detect an out-of-order number. A new number was read every 1.5 seconds, thus cognitive load (and pupil diameter) increased every 6x1.5 sec = 9 seconds.
2. Visual task with constant cognitive load and varying lighting: participants were instructed to follow a visual target which switched location between a white, a gray and a black truck. The light reaching the participant's eye varied as the participant's gaze moved from one truck to another. Participants held their gaze on a truck for 9 seconds, allowing the pupil diameter enough time to settle.
3. Combined task with varying cognitive load and lighting: Participants completed the cognitive and visual tasks in parallel.

There will be at least six participants per condition to avoid order effects.

Implementation

Estimating the start point for changes in illumination:

The target subjects are supposed to look at changes during the experiment. Some time is needed for subjects to perceive the visual information and process it. This leads to the gaze angle lagging behind the change of target location. This time varies between subjects but it is not always the same even for one subject. Eye tracker measures the gaze direction and this information could be used to correct the difference in time between change of target location and the illumination change perceived by subject. Figure 4 shows a gaze lagging example.

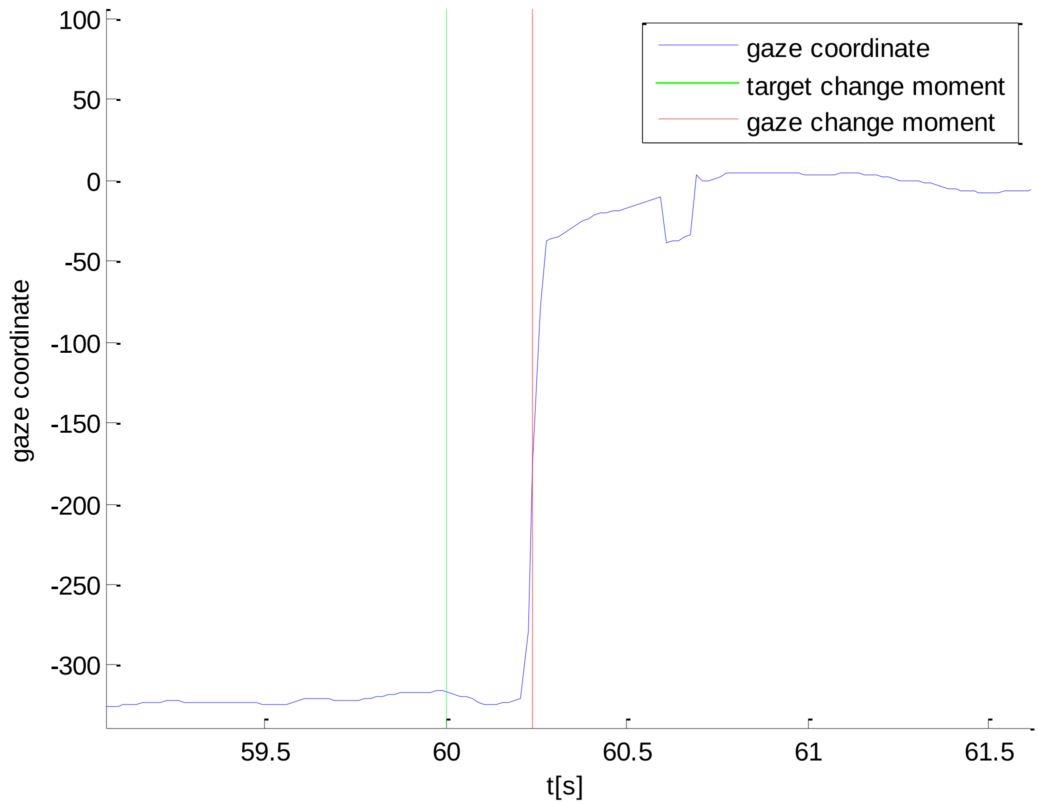

Figure 4. The gaze change time (red) determined by analyzing the gaze direction (blue) is different than the target change time (green)

As for two successive targets subject is looking at the static image, the illumination conditions do not change. If the transition period between two targets is considered to be short enough (Figure 4) the time when gaze is directed towards midpoint between two targets locations is defined to be the time when the illumination changes. The probability of gaze lag time having a certain value is shown in Figure 5. The histogram is made by analyzing data from 13 subjects who participated in the DA 2011 experiment. Mean value for the gaze lag is $t_L = 0.41$.

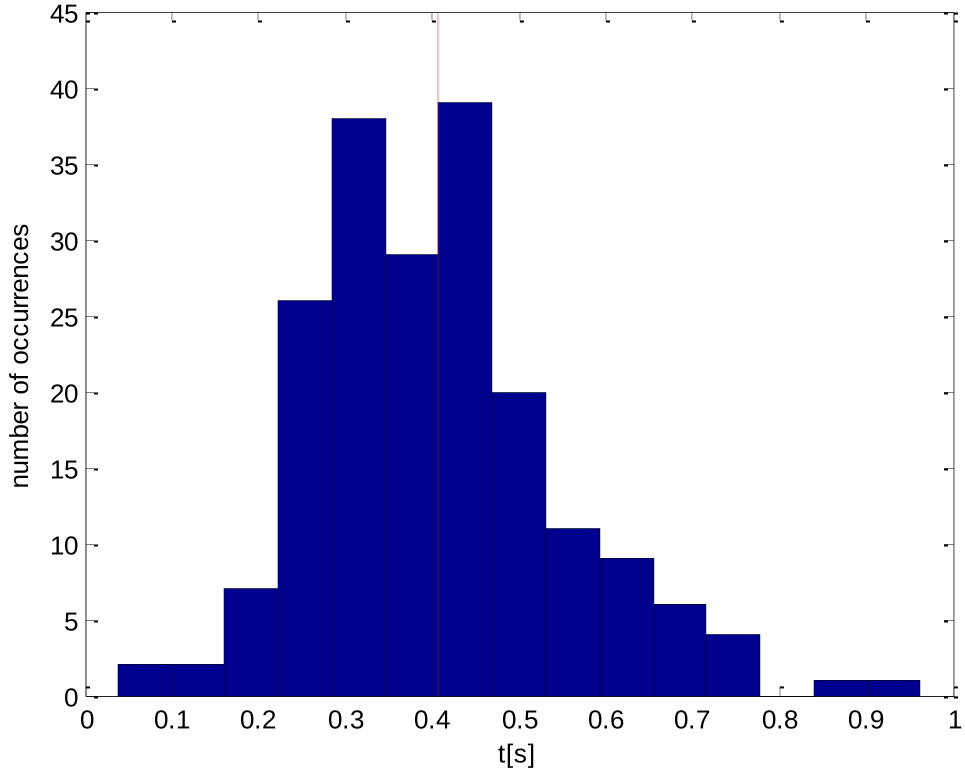

Figure 5. Gaze time lag histogram

Gaze lags for two subjects during experiment are shown in Figure 6.

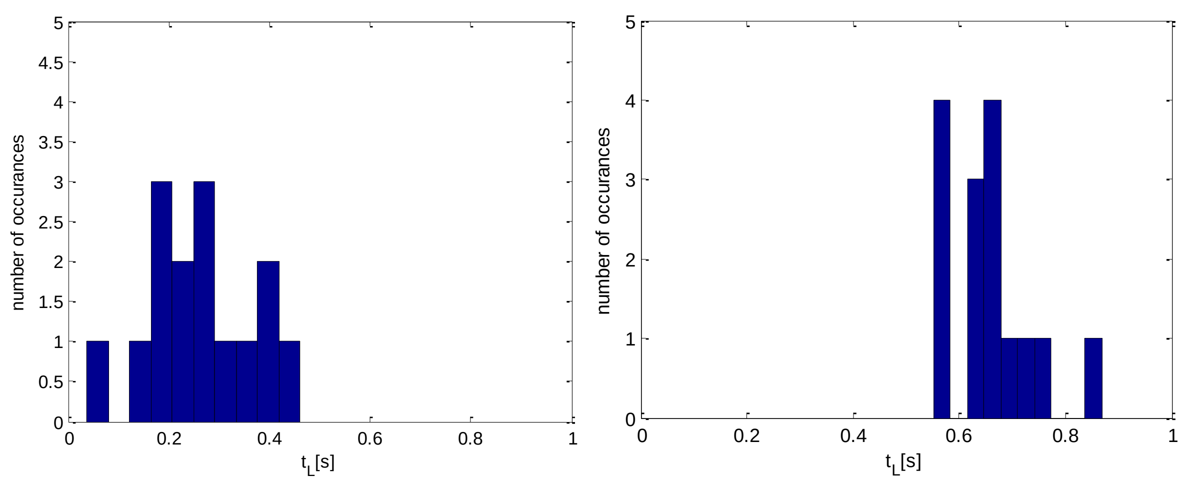

Figure 6. Gaze lags for two different subjects

From figures 5 and 6 it is evident that not considering gaze lag could result in estimation process errors.

Prediction preparations

By averaging pupil responses for transitions from one illumination condition to another, we can visualize the dilation and contraction mechanisms. The average responses with gaze lag correction for illumination and combined task are shown in Figure 7 and 8 respectively.

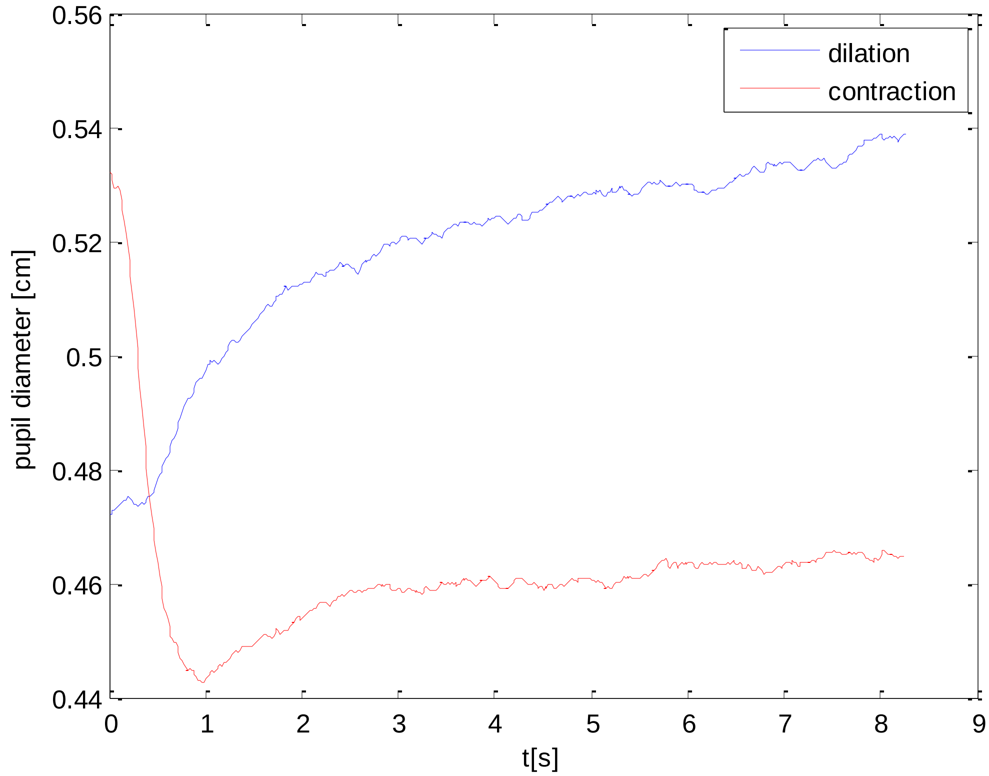

Figure 7. Illumination task averaged response with gaze lag correction

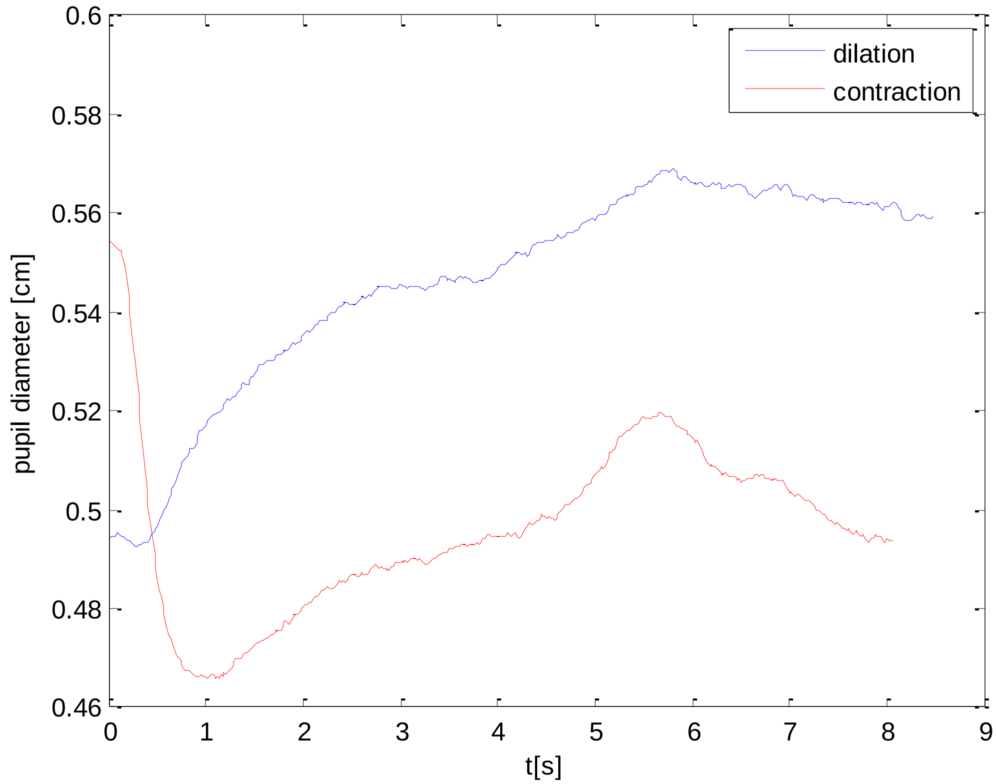

Figure 8. Combaned task averaged pupil response with gaze lag correction

Evaluation of cognitive load estimate:

Responses on Figure 7. will be used to determine the transfer function for illumination task (Figure 1). For illumination conditions in combined task, pupil's light reaction will be predicted and subtracted from the measured pupil size. This represents the estimate of the cognitive load and it will be quantitatively evaluated by comparing the estimate with the measurements for the cognitive task.

Evaluation of target location tracking:

By analyzing the participant's gaze angle, the participant's ability to track target location would be evaluated and approaches to correct for any discrepancies in gaze location and target location will be designed. These discrepancies might result in differences between expected and actual illumination of the pupil, and the affect on the pupil size will be evaluated.

Project’s timeline

The project’s timeline is shown in Figure 9.

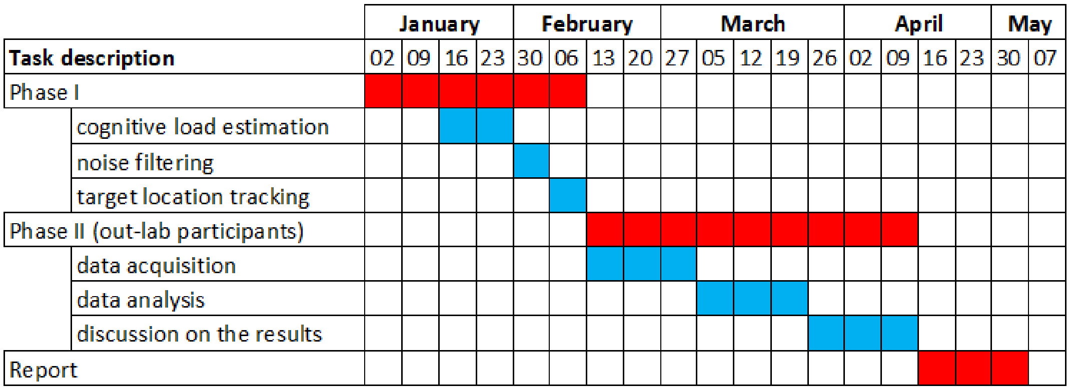

Figure 9. Project’s timeline

References

Palinko O., Kun A.L. (2011). Exploring the influence of light and cognitive load on pupil diameter in driving simulator studies. *Proceedings of Driving Assessment Conference.*