Assessment of attentional shift under varied visual perceptual complexity: A multi-modal fNIRS and pupillometry study

Jan Lawrence Watson[1], Efecan Yilmaz[2], Cengiz Acartürk [2], Murat Perit Çakır [2,3], Hasan Ayaz[1,4,5,6,7]

[1] School of Biomedical Engineering, Science and Health Systems, Drexel University, Philadelphia, PA USA
[2] Graduate School of Informatics, Middle East Technical University, Ankara, Turkey
[3] METU TAF Modeling & Simulation R&D Center, Middle East Technical University, Ankara, Turkey
[4] Drexel Solutions Institute, Drexel University, Philadelphia, PA, USA
[5] Department of Psychology, College of Arts and Sciences, Drexel University, Philadelphia, PA, USA
[6] Department of Family and Community Health, University of Pennsylvania, Philadelphia, PA USA
[7] Center for Injury Research and Prevention, Children's Hospital of Philadelphia, Philadelphia, PA USA

The establishment of ocular and neural metrics for the classification of attentional state in realistic environments has the potential to expand attention research through the detection of distraction in real-world tasks that demand acute focus to the external environment. In this study, we investigated pupil diameter changes simultaneously with prefrontal cortex hemodynamic activity under varying levels of perceptual complexity when attention was either externally focused to the outside world or distracted by internal thought processes. For the pilot phase, a total of five (3 female, mean age = 24 years) English speaking participants were recruited and presented with a visual shape search task that assessed attentional state under varying visual perceptual complexity. To rule out the possibility of verbal thought suppression caused by familiarity with the English alphabet, Hebrew characters were used as symbols in the task. The experimental protocol contained four blocks (2 high visual complexity/ 2 low visual complexity) that were counterbalanced across subjects to prevent order effect. In the low visual complexity condition, one symbol appeared whereas in the high visual complexity condition, four symbols appeared within the stimulus display. Each of the shape search task was preceded with an interfoveal fixation point in the center of the screen (500 ms duration) and then immediately by an interfoveal stimulus display consisting of six shapes to form a circle (100 ms duration). Participants were then asked to identify a target (either 'ח' or 'ג') when it appeared within the stimulus display. Additionally, "thought probes" at the end of each block were implementedto stratify conditions of externally directed cognition (EDC) and internally directed cognition (IDC). For neurophysiological measures, remote eye tracking and functional near-infrared spectroscopy (fNIRS) were utilized to monitor participants' pupillary and prefrontal hemodynamic responses, respectively. Consistent with our hypotheses, both tonic pupil diameter (PD) as well as average oxygenated hemoglobin levels at the medial prefrontal cortex (optode 5 and optode 7) increased in instances of IDC compared to EDC. Additionally, the differences between EDC and IDC conditions exhibited a significant difference when attentional resources were fully allocated in the high perceptual complexity condition. These results suggest the potential of a neuroimaging and oculometry based attentional state assessment under differing levels of perceptual complexity and also demonstrates that fNIRS and eye-tracking based pupillometry can be used for the detection of internal distraction in real-world environments via mobile sensors.

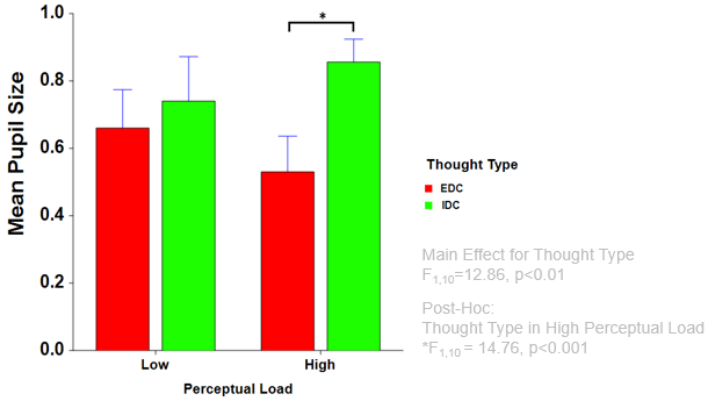

Figure 1. Comparison of mean pupil sizes between self-reported EDC and IDC thought types in low and high perceptual complexity conditions in the 1000ms interval preceding the appearance of a thought probe. Whiskers represent SEM.

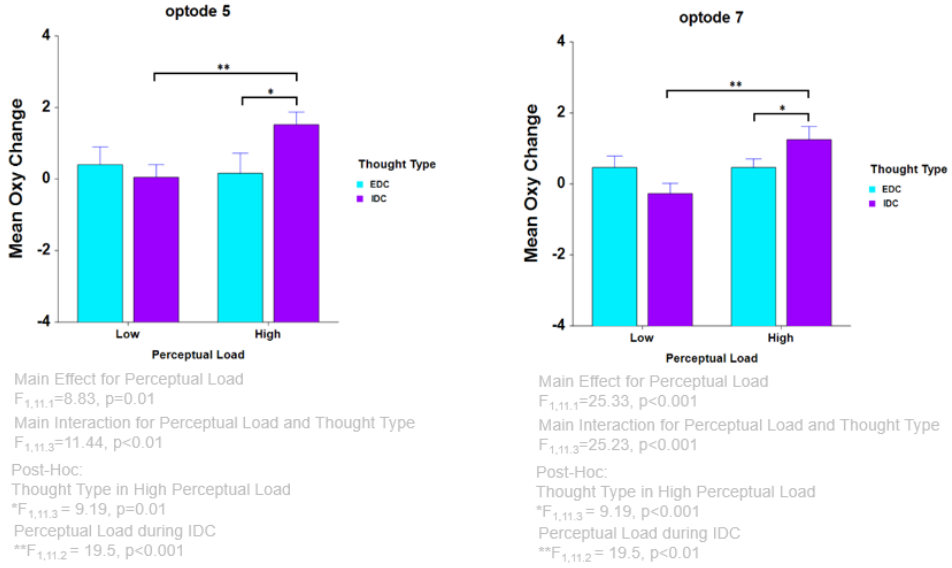

Figure 2. fNIRS optode 5 (left) and optode 7 (right) at the right medial prefrontal cortex. Both optode locations show a comparison of mean ΔOxy (ΔHbO-ΔHbR) during the 10 second time interval preceding the appearance of a thought probe in both low and high perceptual load conditions for EDC and IDC thought types. Whiskers represent SEM.