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Special Interest Group on Human-Computer Interaction

12-13-2015

Does Pupillary Data Differ During Fixations and Saccades? Does it Carry Information About Task Demand?

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ABSTRACT

Pupillometry can serve as a reliable measure of cognitive effort. However, exploring pupil data is a relatively new phenomenon in IS research. In this study, we argue that a user's pupil data may carry different information during saccades and fixations. Moreover, we explore the relationship between task demand and pupil data. Fixation refers to relatively steady gazes during which the eyes take "foveal snapshots" of stimuli. Saccades refer to ballistic eye movements between fixations. Pupil data refers to changes in pupil dilation/constriction as well as variation in such changes. Fixations and saccades represent two different types of eye movement events. The former is used to collect visual information to send to our brain for processing, the latter is used to scan our visual field for the next fixation event (Djamasbi 2014). Because pupil dilation is an involuntary reaction that has been shown to represent cognitive activity (Buettner et al. 2015), we tested to see whether pupil information during fixations and saccadic eye movements are different. We also tested to see whether pupil data during fixation and saccades carry information about task demand. In order to do so, we examined the relationship between subjective perception of task demand and objective measure of pupil data.

Eighteen engineering graduate students, who participated in our study, completed 10 GRE math questions in 5 minutes. We used Tobii X300, Tobii Studio version 3.2.3, and IV-T filter with 30 deg/sec saccadic velocity threshold to collect their eye movement data. We measured subjective experience of task demand via the NASA Task Load Index (TLX), which has 5 dimensions: Mental Demand, Physical Demand, Time Demand, Performance, Effort, and Frustration (Lin and Imamiya 2006). Our t-tests showed that the mean value of pupil dilation during fixation (3.07852) was slightly larger than the mean value of pupil dilation during saccades (3.07763). These differences, however, were not significant. We measured pupil dilation variation as standard deviation in pupil dilation (Iqbal et al. 2005). Our t-tests showed that pupil dilation variation during fixation (0.16639) was significantly ($p=0.016$) smaller than pupil dilation variation during saccade (0.16866). We tested the relationship between subjective experience of task demand (TLX items) and pupil dilation and pupil variation during saccades and fixations via regression analysis. The results showed a significant relationship between task demand and pupil variation (in saccades: $R^2=0.25$, $p=0.035$, $B=51.08$, in fixations: $R^2=0.24$, $p=0.041$, $B=51.64$), however; the results did not show any significant relationship between task demand and pupil dilation. The effect size for the significant results was rather large and slightly larger for fixation ($f^2= 0.33$) than for saccades ($f^2= 0.31$). The unstandardized coefficient (B) was also slightly larger for fixation as compared to saccades.

In summary, our analysis showed that pupil dilation was not significantly different between fixations and saccades. However, we found a significant difference in pupil variation between these two eye movement events. Our results also showed that pupil variation had a strong significant correlation with the Time Demand dimension of TLX. We did not find the same relationship between TLX and pupil dilation data in our study. These results suggest that pupil data during saccades and fixations can be different, and that may be useful in some studies to consider. The results also suggest that pupil dilation variation may be more sensitive in terms of revealing differences between fixation and saccadic eye movements. Because our results indicate that pupil data may carry information about a user's subjective experience of task environment, they provide a new direction for using pupillometry in studying user experience.

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