

## **OCULOMETRICS: VALIDATING A NEW TECHNOLOGY FOR NON-INTRUSIVE MONITORING OF HUMAN PERFORMANCE**

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An important goal of the Space Human Factors Engineering project is to develop new technologies for monitoring human performance for training, display design testing, and spaceflight applications. Astronauts must efficiently acquire information from a variety of complex and spatially distributed displays, and rapidly make high-pressure decisions based on the information that they have managed to successfully encode. Standard perceptual monitoring techniques require interrupting the task, and thus have severely limited value in evaluating performance in applied tasks. We have developed a new technology, oculometrics, which uses eye movements to provide quantitative information about human perception, yet is non-intrusive (performance can be monitored without interrupting the task). We have performed a preliminary validation of these methods in laboratory settings by simultaneously performing both our oculometric analysis and standard, proven psychometric analysis. Our ultimate goal is to fully validate and extend oculometrics as a continuous, real-time quantitative metric of the perceptual and cognitive state of astronauts and other aerospace workers.

Humans make two types of eye movements: pursuit, the smooth tracking movements used to follow the motion of an object, and saccades, the fast, ballistic movements used to change the direction of gaze from one object of interest to another. Previously, we showed that oculometric analysis of pursuit eye movements can predict human perception of motion direction. Specifically, we found that under conditions in which humans misperceive the true direction of motion, oculometric analysis can quantitatively predict the misperception (Beutter & Stone, *Vis. Res.*, 38:1273, 1998). More recently, it has also been shown that oculometric analysis can accurately predict the effect of cognitive expectations on motion perception (Krauzlis & Adler, *Vis. Neurosci.*, 18:364, 2001), as well as the perception of ambiguous visual displays (Stone et al., *Perception*, 29:771, 2000; Beutter & Stone, *Vis. Neurosci.*, 17:139, 2000). Our current research emphasis has been on adapting and validating oculometrics as a monitor of human performance during visual search (Eckstein et al., *Perception*, 30:1389, 2001).

Oculometric analysis of search begins by analyzing eye-movement traces to determine when saccades are made and to what location they are directed. The resulting scan path is translated into a series of saccadic decisions by assigning each saccade to the nearest element location within the visual display. We are currently focusing on analyzing the first saccadic decisions and comparing them to perceptual decisions made with the same amount of visual information available. In our experiments, observers searched a display, which contained a high-noise background and a target in one of ten possible equi-eccentric element locations. The target was a blurred disk added to the gaussian white-noise background. We used five different signal-to-noise ratios, chosen so that performance ranged from close to chance to almost 100% correct. In a 'long-duration'

condition (up to 4s), observers were allowed to search the display using saccadic eye movements, and we measured the accuracy of the 1<sup>st</sup> saccadic decision. In a 'short-duration' condition, in which there was no time for a saccade, the stimulus duration was chosen to match the saccadic processing time (determined using the saccadic latencies in the long-duration condition) and we measured the accuracy of the perceptual decision. We found that the accuracy of the 1<sup>st</sup> saccadic decision was nearly identical to the perceptual accuracy thereby validating the use of oculometrics to measure perception in a detection-based search task (Stone et al., NEUROSCI 1999). We also found parallel changes in saccadic and perceptual performance when changing the search to a discrimination task with disks present at all 10 element locations and a single brighter target disk. We then developed a model based on Signal Detection Theory, which predicts both the perceptual and saccadic accuracies for both contrast detection and discrimination search tasks (Beutter et al., ARVO 2000) and extended our analysis to the 2<sup>nd</sup> search saccade (Eckstein et al., ARVO 2000).

All of the above findings indicate that oculometric analysis can be used to predict average perceptual performance for a fixed visual condition, but do not prove that the oculometric and perceptual decisions are correlated on a trial-by-trial basis. Resolving this key question is critical for demonstrating that oculometrics can be used on a moment-by-moment basis as a measure of the ongoing perceptual state. To address this, we determined if a particular instance of noise had similar effects on saccades and perception. In the above experiments, we presented the same noise sample several times so that we could measure the correlation between the saccadic and perceptual decisions made in the presence of the same noise. We found that the two decisions were indeed correlated, well above chance predictions (Beutter et al., NEUROSCI 2000). Specifically, we computed the cross-correlation between the saccadic and perceptual decisions (how frequently they were identical for the same noise image) and found that it was nearly identical to the perceptual auto-correlation (Beutter et al. VSS 2001). This shows that using oculometrics to predict the perceptual response to an image predicts the actual perceptual response to that image nearly as well as basing the prediction on previous perceptual responses to the identical stimulus image. We have also found that perceptual decisions in a motion direction task are correlated on a trial-by-trial basis with the simultaneously measured oculometric decisions (Stone & Krauzlis, ARVO 2000).

In summary, we have rigorously demonstrated that oculometrics can provide quantitative information about human visual perception without interfering with the task at hand. Currently, we are working on extending oculometric analysis in a number of ways. We are examining a number of visual search and motion processing tasks over a wide range of conditions to determine if oculometrics is a robust metric of visual performance and to support the development and testing of models of human visuomotor performance. We are also investigating the extension of oculometrics to other sensory modalities, including the measurement of auditory performance in spatial localization and tracking tasks (Krukowski et al., NEUROSCI 2001) and of human vestibular performance in self-motion perception tasks (Smith et al., NEUROSCI 2001).