OCULOMETRIC ASSESSMENT OF BRAIN HEALTH AND OPERATIONAL PERFORMANCE

Dorion Liston[1], Quinn Kennedy[1], Collin Belanger[1], Maheen Adamson[2], Eric Seemiller[3], Jonelle Knapp[3], Marc Winterbottom[3], Steven Hadley[3]

[1]neuroFit, Mountain View, CA; [2]WRIISC WOMEN CoE, VA Palo Altho Health Care System/ Neurosurgery, Stanford School of Medicine, Palo Alto, CA;
[3]Operational Based Vision Assessment (OBVA) Laboratory, 711th Human Performance Wing, Wright-Patterson AFB, OH.

AFRL

I. Background

There is a need for quick, noninvasive, objective brain health assessments to inform best practices for maintaining and maximizing cognitive performance in military operational tasks. Oculometrics, the measurement of eye movements, may be one solution as they can quantify the health of cortical circuitry associated with perception and motor tracking. Previous work has demonstrated that oculometrics are sensitive to a wide range of neurocognitive function, from TBI (Wagner et al, 2017, MHSRS) to exceptional (Chen et al, 2021, J Vis 23:3 1-16). Below, we describe recent empirical work assessing the utility of oculometric assessment in terms of test-retest reliability of a commercial-off-the-shelf (COTS) oculometric system, as a biofeedback mechanism, and correlation with performance on an operational task.

II. Methods

Oculometric Task:

- Based on a Rashbass (1961) step-ramp tracking task, participants begin by fixating a dot in the middle of the screen. At a random time, the dot moves in a single random direction at a random speed. For each of the 45 trials, participants are instructed to track the movement of the dot with the eyes.

Oculometric Measures:

- The 5-minute task generated 10 standardized (z-scored) oculometric measures of perceptual and motor tracking responses (Liston & Stone, 2014), see Figure 2 below.

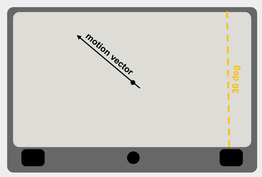


Figure 1. Oculometric task (diagram by authors).

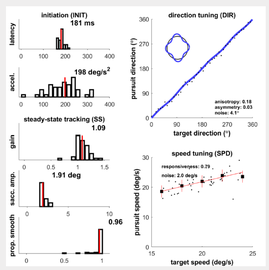


Figure 2. Oculometric Measures.

Studies

Study 1: Test-Retest Reliability. 43 participants completed the oculometric task twice on the same day and twice on different days. Bland-Altman analysis was used to measure the test-retest variability in each oculometric measure.

Study 2: Biofeedback. Eight professional baseball players completed the oculometric task approximately daily over an average of 21 days. Time series analysis was used to measure changes in performance over time.

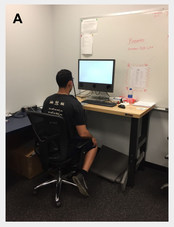
Study 3: Correlation with Operational Performance. 26 participants completed the KC-46 stereoscopic remote vision system aerial refueling and telerobotic arm tasks, and the oculometric test. Correlation analysis was used to assess the relationship between oculometric measures and operational task task performance.

III. Results: Test-Retest Reliability

Metric	Cronbach's Alpha		Intraclass Correlation Coefficient	
	Intra-	Inter-	Intra-	Inter-
Latency	0.6517	**0.7391**	0.4437	**0.5372**
Acceleration	**0.8000**	**0.7511**	**0.6527**	0.4633
Direction Anisotropy	0.1395	0.1208	-0.0637	0.0380
Direction Asymmetry	0.3929	0.2496	0.1814	0.0986
Direction Noise	**0.7998**	**0.7522**	**0.6611**	**0.5583**
Speed Slope	0.1568	0.4605	-0.0780	0.3028
Baseline Speed	0.1021	0.2431	-0.3289	0.1375
Speed Noise	**0.8100**	**0.7412**	**0.6418**	0.4189
Steady State Gain	**0.8186**	**0.7593**	**0.6714**	**0.6077**
Saccade Amplitude	**0.8050**	0.6969	**0.5736**	**0.5134**
Proportion Smooth	**0.9006**	**0.8840**	**0.8215**	**0.7774**
nFit	**0.8802**	**0.8852**	**0.7746**	**0.7506**

Table 1. The majority of the 11 oculometric measures were found to have acceptable test-retest reliability based on Cronbach's Alpha (values > 0.7) or Intraclass Correlation Coefficients (values >0.5): latency, acceleration, direction noise, speed noise, steady state gain, saccade amplitude, proportion smooth, and the summary score called nFit.The oculometric test shown here had better test-retest reliability than another commercially available oculometric test (Hollander et al, 2023).

IV. Results: Biofeedback



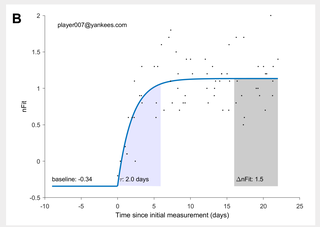


Figure 3. Biofeedback in Professional Athletes. A. A professional athlete completing the oculometric task at a baseball spring training facility (photo by authors). **B.** Filled circles plot individual oculometric summary measurements as a function of time for a single high-performance coach over a period of approximately three weeks. We fit these timeseries data with an exponential rise function, setting t0 to be the time of their first nFit measurement. This fit showed a baseline nFit score of -0.34, ΔnFit of 1.5, and τ of 2.0 days yielding a stabilization in just under a week.

V. Results: Operational Performance

Figure 4. Gripper Task.. The operator is required to perform a simulated telerobotic arm task using a 3D display. The objective is to assess operationally relevant stereoscopic remote vision system (RVS) performance in a way that can be mapped to underlying visual capabilities (photo by authors).

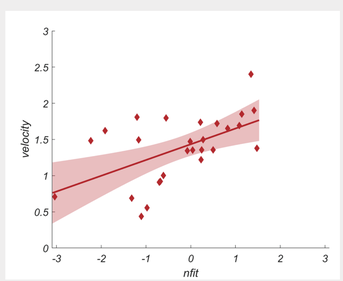


Figure 5. Correlation with Task Performance. Overall oculmetric performance correlates with speed at which subjects completed the gripper task.

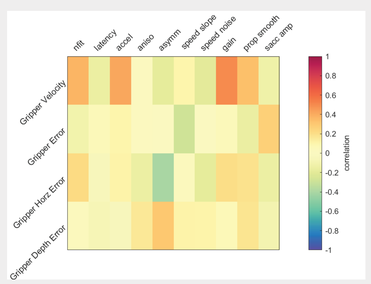


Figure 6. Correlation Matrix. Pearson's r values for corelations between individual oculometric measures and gripper task outcome measures. Bolder colors indicate stronger correlation.

VI. RESULTS: Simulated RVS Air Refueling Performance

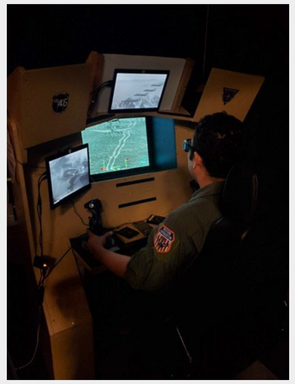


Figure 7. Simulated air refueling task (left). A Boom Operator performs a simulated KC-46 remote vision system (RVS) air refueling task in the OBVA Laboratory (photo by authors). **A KC-46 refuels a B-52 (right).** [source: https://www.dvidshub.net/image/7714934/b-52-and-kc-46-aircraft-integrate-fly-over-Caribbean]

- Oculometrics have been shown to predict simulated air refueling performance in multiple KC-46 remote vision system (RVS) human performance studies.
- Oculometrics can also be used to monitor operator state during task performance.
- The OBVA Lab is working with customers and stakeholders to examine the use of oculometrics to inform medical readiness and quantify impact of physiological stressors such as hypoxia and fatigue.

DISCUSSION

- These results suggest that oculometrics provide a reliable and objective way to help warfighters measure and monitor their brain health to maximize operational performance.
- Oculometrics provide additional data beyond traditional vision tests (e.g., visual acuity, stereo acuity) to assess medical readiness and predict operational performance.
- Oculometrics are related to athletic performance (e.g., Liu et al, 2020; Chen et al, 2021; Murray et al, 2021; Poltaski and Biberdorf, 2015) and overall health (e.g., Liston et al., 2017; Stone et al, 2019; Tyson et al, 2018; Wagner, 2017; Wong et al, 2018; Yeoh, A., et al., 2018), and is a promising technology for monitoring and maintaining Warfighter health and performance.

Figure 8. Oculometrics are linked to performance in baseball (left), cricket (center), hockey (right), and other sports (source: Wikimedia commons).

REFERENCES

Chen R, Stone LS, Li L. (2021). Visuomotor predictors of batting performance in baseball players. Journal of Vision. 21(3):3, 1-16.
Hollander et al. (2023). Reliability of Two Clinically-Oriented Eye Tracking Protocols. Presentation at the Aerospace Medical Association Annual Meeting, New Orleans, LA.
Liston, DB, & Stone, L. (2014). Oculometric assessment of dynamic motion processing. Journal of Vision, 14(14):12, 1-17.
Liston, D. B., et al. (2017). "Oculometric Assessment of Sensorimotor Impairment Associated with TBI." Optom Vis Sci 94(1): 51-59.
Liu, S., Edmunds, F. R., Burris, K., & Appelbaum, L. G. (2020). Visual and oculomotor abilities predict professional baseball batting performance. International Journal of Performance Analysis in Sport, 20(4), 683-700.
Murray, N. P., Lawton, J., Rider, P., Harris, N., & Hunfalvay, M. (2021). Oculomotor Behavior Predict Professional Cricket Batting and Bowling Performance. Frontiers in Human Neuroscience, 15, 768585.
Poltavski, D., & Biberdorf, D. (2015). The role of visual perception measures used in sports vision programmes in predicting actual game performance in Division I collegiate hockey players. J Sports Sci, 33(6), 597-608.
Rashbass, C. (1961). The relationship between saccadic and smooth tracking eye movements. J Physiol, 159:326-338.
Russi, et al (2024). Assessing eye movements to predict operational performance and readiness. Aircrew Human Performance Summit; Ft. Walton Beach, FL.
Stone LS, Tyson TL, Cravalho PF, Feick NH, Flynn-Evans EE (2019) Distinct pattern of oculomotor impairment associated with acute sleep loss and circadian misalignment. The Journal of physiology 597:4643-4660.
Tyson T, Feick N, Cravalho P, Flynn-Evans E, Stone L (2018) Increased dependence on saccades for ocular tracking with low-dose alcohol. Society for Neuroscience Abstracts: 399.320.
Wagner, et al. (2017) Oculometric screening for traumatic brain injury in veterans. Military Health System Symposium; Kissimmee, FL.
Wong, K., et al. (2018). Oculometric Assessment of Dynamic Visual Processing in Patients with Cirrhosis: A Potential Diagnostic Tool for Minimal Hepatic Encephalopathy. Digestive Disease Week. Washington, D.C. 1568.
Yeoh, A., et al. (2018). Visual Processing Impairments Detected by Oculometric Assessment Provide Evidence of Obesity-Related Neurological Dysfunction. American College of Gastroenterology. Philadelphia, PA.

Disclaimers

The views and opinions presented herein are those of the author(s) and do not necessarily represent the views of DoD or its Components. Appearance of, or reference to, any commercial products or services does not constitute DoD endorsement of those products or services. Portions of this research were carried out at the 711 HPW/RHBC Operational Based Vision Assessment (OBVA) Laboratory in accordance with IRB approved research protocols.

Cleared for public release (AFRL-2022-4874).