Oculometric Assessment of Dynamic Visual Processing

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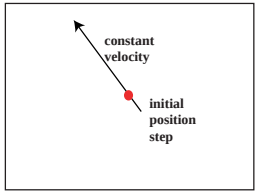
I. Introduction

Eye movements are the most frequent (~3 per second), shortest-latency (~150-250 ms), and biomechanically simplest (1 joint, no inertial complexities) voluntary motor behavior in primates, providing a model system to assess sensorimotor disturbances arising from trauma, fatigue, aging, or disease states (e.g., Diefendorf and Dodge, 1908). We developed a 15-minute behavioral tracking protocol consisting of randomized step-ramp radial target motion to assess several aspects of the behavioral response to dynamic visual motion, including pursuit initiation, steady-state tracking, direction-tuning, and speed-tuning thresholds. This set of oculomotor metrics provide valid and reliable measures of dynamic visual performance (Stone and Krauzlis, 2003; Krukowski and Stone, 2005; Stone et al, 2009; Liston and Stone, 2014), and may prove to be a useful assessment tool for functional impairments of dynamic visual processing.

II. Methods

Radial step-ramp tracking task:

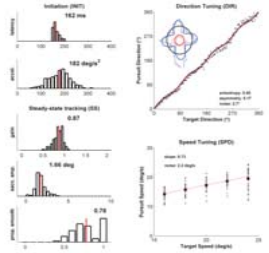
Observers (41 normal, 2 glaucoma patients, and one retinitis pigmentosa patient sampled twice) were asked to pursue a small spot that made an initial step (4 deg) back from a central fixation location, then moved through the original fixation location in a directionally-randomized radial (Krukowski and Stone, 2005) step-ramp Rashbass (1961) tracking task



Task Parameters (Liston and Stone, 2014):

Trials per experiment	180
Stimulus direction	2-360°, in 2° steps
Target speed	16, 18, 20, 22, 24 deg/s
Foreperiod	truncated exponential 200-5000 ms

High spatial, temporal, directional and speed uncertainty minimizes expectation and prediction.



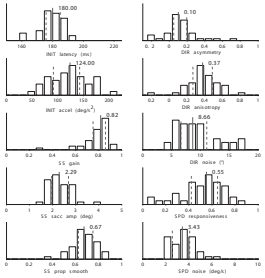
Oculomotor metrics:

Our automated analysis returns ten metrics quantifying the latency and acceleration of smooth **pursuit initiation** (INIT, first 100 ms following pursuit onset), **steady-state tracking** (SS, 400-700 ms following motion onset) gain, saccade amplitude, and the proportion of eye displacement consisting of smooth movements, **direction-tuning** (DIR) anisotropy and noise, and **speed-tuning** (SPD) slope and noise.

Impairment vector:

By normalizing each metric across our 41-observer baseline data set, deviations from the mean can be quantified in z-scores. For a given condition, the "impairment vector" is the distance between the average vector for the patient population and the mean of the normal population. The projection of an indivdual's vector onto the impiarment vector yields a linear detection index that quantifies severity.

III. Baseline population data



Initiation

median latency:	180 ms
median acceleration:	124 deg/s^2

Steady-state tracking

gain:	0.82
saccade amplitude:	2.31
proportion smooth:	67 %

Direction-tuning

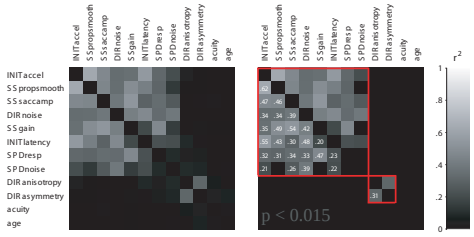
vertical-horizontal asymmetry:	0.10
cardinal-oblique anisotropy:	0.37
noise:	8.66º

Speed-tuning

slope:	0.55
noise:	3.43 deg/s

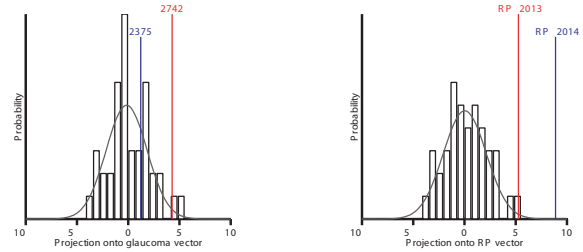
The median oculometric values in our 41-subject population were generally consistent with previously-reported values. Speed thresholds were elevated likely due to high uncertainty and lack of training.

IV. Correlation analysis



Across our 41-subject baseline population, any two metrics share approximately one quarter of their variance, on average ($r^2 = 0.23$; 0.0 to 0.62). The two metrics quantifying the pursuit oblique effect anisotropy were somewhat correlated with one another ($r^2 = 0.31$), but were completely uncorrelated with the set of eight other metrics (mean $r^2 = 0.03$, $p>0.05$). All ten of our measures were uncorrelated with both visual acuity and age

V. Preliminary clinical assessment



For the very few patients examined thus far, we observed a clear ability of our task and metrics to detect functional impairments with respect to our baseline population. We also found that our test can track changes in impairment severity over time.

VI. Conclusions

Our baseline values were generally consistent with previously-reported values.

A correlation analysis of our set of ten metrics revealed two statistically-unrelated groups of metrics: one small group comprised of the amplitude and anisotropy of pursuit direction-tuning, and one larger group containing the remaining eight metrics with modest albeit significant correlations.

Using the power afforded by our multidimensional measures, we computed linear detection indices for glaucoma and retinitis pigmentosa. For a few preliminary cases, we have observed detectable clinical impairments.

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