An Examination of the Oculomotor Behavior Metrics within a Suite of Digitized Eye Tracking Tests

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***Abstract*— Eye tracking has recently been used to examine oculomotor behavior (OMB) for visual and neurological health and wellness with promise in determining characteristics of healthy eyes and in turn a healthy brain. Recent research has demonstrated that human eye movements reflect individual and group differences, however, clinical evaluations of eye movements often lack test-retest reliability. The purpose of this study was to examine the reliability of oculomotor behavior metrics in healthy individuals, to determine the normative values through cluster analysis, and to compare oculomotor behavior metrics by age groups in a suite of digitized eye tracking tests. A large sample of 2993 participants completed RightEye tests. These tests demonstrated acceptable or higher reliability on 85% of the eye movement metrics and the clustering analysis distinguished 5 distinct age groups. Furthermore, group differences were found between age clusters. Overall, the findings represent the reliability of a computerized oculomotor behavior measure and the importance to consider individual and group characteristics for clinical applications as well as applied settings.**

***Index Terms*— Vision testing, cluster analysis, smooth pursuit, saccades, reliability, normative data, eye tracking,**

I. Introduction

Vision is the most dominant sensory system in humans with specific characteristics and capabilities. The purpose of eye movements is to move salient information into the fovea to see it clearly. Oculomotor behavior (OMB) is broadly composed of smooth pursuits, saccades, and fixations[1]. Given that eye movements are important aspect of OMB, there is a need to incorporate reliable and accurate measures of OMB into clinical practice and in research. As such, the purpose of this project is to test the reliability of Righteye OMB metrics in a large sample of healthy individuals, to determine the normative values of OMB metrics for healthy individuals, and to compare OMB metrics by age.

Deficits in the oculomotor system can result in lower visual acuity, changes in visual perception, and reduced visual stability[2]. The oculomotor system can be an indicator of the neurological status of an individual[3,4]. With the proper measurement of eye movements, scientists and clinicians could utilize OMB to indicate certain neurological diseases. Also, eye movement measurement may indicate current disease state and efficacy of therapy even when other measures (such as magnetic resonance imaging (MRI)) fail to indicate a deficit[5].

Given the factors that influence OMB and the current standards of assessment, there is a need for objective and reliable measures of OMB. Leigh & Zee[2], in their classic textbook, describe the clinical examinations of saccades, smooth pursuit, gaze behavior, and eye-head movements among others. Typically, these clinical evaluations involve a "bedside" approach and instruction which include 'follow the tip of my finger' and require the physician to detect the salient characteristics of OMB by the naked eye[6]. A current limitation of eye movement research is a lack of data examining the reliability of oculomotor metrics[7]. Therefore, this study has three main purposes. The first purpose was to examine the reliability of OMB metrics from the RightEye tests in a large sample of healthy individuals and to determine the normative values of OMB metrics for healthy individuals, and to cluster these normative values by age.

II. Method

A. Participants

For the normative data analysis, 2993 participants completed the RightEye tests. Participants were between the ages of 5-62 years (M = 20.87, SD = 12.45); 2030 were males (67.85%), 962 were females (32.15%). Of the 2993 participants, 61.63% were white, 6.85% black, 8.32% Hispanic, 0.20% Native American and 8.96% opted not to report ethnicity.

To establish test-retest reliability, a subset (n = 201) completed RightEye tests twice (i.e., Trial1 and Trial2) on two separate days. These participants were between the ages of 5-62 years (M = 25, SD =17.47); 108 were males (53.73%), 93 were females (46.27%). Of the 201 participants, 66.67% were white, 3% black, 1.5 % Hispanic, and 28.83% opted not to report ethnicity.

B. Apparatus

Stimuli were presented using the RightEye tests on NVIDIA 24-inch 3D Vision monitor fitted with an SMI 12" 120 Hz remote eye tracker connected to an Alienware gaming system, and a Logitech (model Y-R0017) wireless keyboard and mouse. The participants were seated in a stationary (non-wheeled) chair

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that could not be adjusted in height. They sat in from of a desk in a quiet, private testing room. Participants' heads were unconstrained.

The accuracy of the SMI eye tracker was 0.4 degrees within the desired headbox of 32cm x 21cm at 60cm from the screen. For standardization of testing, participants were asked to sit in front of the eye tracking system at an exact measured distance of 60cm (ideal positioning within the headbox range of the eye tracker). A nine-point calibration was conducted with points spanning the computer screen.

C. Oculomotor Tasks

Five RightEye oculomotor tests are described below. From these 5 tests, 54 different metrics of digitized oculomotor behaviors were assessed.

Circular smooth pursuit test (CSP). In the CSP test, participants were instructed to track a target stimulus, a black dot of 0.2 degrees' diameter at a 10-degree radius at a rate of 0.4Hz, in a clockwise direction, for 15 seconds. The 0.4 Hz = 1 revolution / 0.4 revolutions per sec = 2.5 sec. To find linear velocity, we multiply the angular velocity with the radius which is 10 degrees: $(2^{o}\pi)/(2.5\text{ sec})*10\text{ deg}=25.13\text{ deg/sec}$. The CSP test provides measures of time on target percentages, saccade percentages, latent smooth pursuit, and smooth pursuit target accuracy.

Horizontal smooth pursuit test (HSP). In the HSP test, participants were asked to focus on a dot (same size and speed as the CSP test) on the screen and follow the dot horizontally across the screen for 25 seconds, moving to the far right, then to the far left, and back to the center. The stimuli moved in a sinusoidal way from the left to right and right to left in a straight line. For a participant to be considered "on target," they were required to follow the stimuli within an error of 2.4 degrees. A participant could also be ahead or behind a stimulus and can still be labeled as 'following' if they are within an error of 4.8 degrees. The HSP test also provides measures of fixation percentages, saccade percentages, latent smooth pursuit, and smooth pursuit target accuracy.

Vertical smooth pursuit test (VSP). The protocol for the VSP test was the same as the protocol for the HSP test. However, the VSP test was in a vertical plane.

Horizontal saccades test (HS). In the HS test, participants were asked to look at a countdown of 3, 2, 1 in the center of the screen before moving their eyes back and forth between 2 dots. Their goal was to "target each dot" on the left and right of the screen as quickly and accurately as possible. The dots on the screen turned green when the participants' eyes hit the targets. The test lasted 10 seconds. The HS test provides measures of fixation percentages, saccade percentages, and target accuracy

Vertical saccades test (VS). The protocol for the VS test was the same as that for the HS test. However, the VS test was in a vertical plane.

D. Procedure

Participants were recruited through advertisements placed on the internet, social media, bulletin boards, and word of mouth. The nature of the study was explained to the participants, and all participants were provided a written University Approved informed consent to participate. Following informed consent, participants were asked to complete a pre-screening questionnaire and an acuity vision screening where they were required to identify four shapes at 4mm in diameter. If any of the pre-screening questions were answered positively and any of the vision screening shapes were not correctly identified, then the participant was excluded from the study. Participants were excluded from the study if they reported past head injury, any neurological condition, or static visual acuity of greater than 20/400. Participants were also excluded if they were unable to pass a 9-point calibration sequence.

E. Data Analysis

Given the three aims of this study, we conducted several statistical analyses. First, the reliability of RightEye Test was evaluated using Cronbach's Alpha (CA). The CA indicates the relative reliability and is interpreted using the following criteria CA > .9 specifies excellent reliability above .7 indicates acceptable, and less than .6 represents poor reliability[8]. The alpha level was set at $p<.05$ for all statistical test.

Second, to describe the normative features of the data, we performed exploratory data analysis and conducted model-based clustering using expectation–maximization (EM) algorithm analysis. We chose this approach because it has several advantages over k-means or hierarchical clustering approaches. First, both k-means and hierarchical approaches are mainly heuristics thus not model-based and not well suited for inference[9]. Second, a model-based approach uses a density function with an associated weight that will 'suggest' the optimal number of clusters. Lastly, the model approach is based on the Bayesian Information Criterion (BIC) values which help to determine the most appropriate clusters. Third, we examined group differences including age clusters and gender with a series of five multivariate ANOVAs, one for each test (CSP, HSP, VSP, HS, and VS).

III. Results

A. Test-Retest Reliability Analysis

All fifty-four eye tracking variables from trials 1 and 2 were analyzed using R (statistical package) reliability procedure. Tables I-V presents the means and standard deviations for trials 1 and 2, the Cronbach's Alpha correlations between the Trial 1 and Trial 2, and associated the test-retest reliability decisions. Eighty-five percent of eye tracking variables demonstrated Acceptable (.7) to Excellent (.9) test-retest reliability. Eight synchronization eye tracking variables were demonstrated poor reliability (<.6).

B. Cluster Analysis

The model-based clustering using EM algorithm analysis created five distinct age group: 5-8, 9-16, 17-28, 29-52, and 53-62. Further, we conducted stability testing to establish that the data sample used for cluster analysis that is representative of the entire population. The stability testing involved sub-sampling 10 individuals from the experimental population for each age group. These sub-samples were then compared against the entire population norm to assess cluster solution (See Figure 1). The comparison of the sample norms and the population norms showed the cluster solution was appropriate in numbers and quality (Calinski-Harabasz Index = 16.61 with average inter-cluster distance = 56.73).

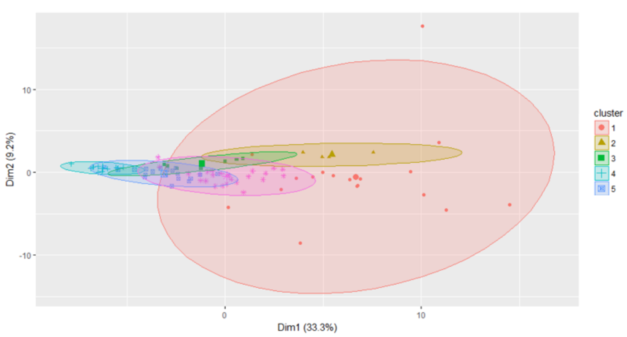

Fig. 1 Five Cluster Solution

C. Group Differences

To provide a descriptive indication of the strength of our cluster solution, we conducted a MANOVA on the multivariate effect of the cluster membership (Age) for each test (CSP, HSP, VSP, HS, and VS). All five MANOVAs revealed a significant multivariate effect on cluster membership thus indicating reasonable support for our cluster solution.

1) CSP Test

The MANOVA for the CSP Test revealed a significant multivariate effect on cluster membership, Wilks' Lambda = .829, $F(64, 11{,}374) = 8.69$, $p < .0001$. Descriptive CSP statistics for the five clusters were evaluated by separate one-way analysis of variance. The follow-up ANOVAs revealed significant Age Cluster differences for all circular smooth pursuit variables ($p < .001$). Tukey post hoc analysis for CSP variables indicated there were no significant differences between Age Clusters 17-28 and 29-52 however, these clusters were significantly different from Age Clusters 5-8, 9-16, and 53-62 for E/T VR Error, Fixation (%), On-Target SP, Saccade

TABLE I
Test-Retest Reliability for Circular Smooth Pursuit

Variable	Trial 1 Mean	Trial SD	Trial 2 Mean	Trial 2 SD	CA	Decision
E/T VR (°) (Left)	14.92	3.13	14.89	2.84	0.9	Acceptable
E/T VR (°) (Right)	14.71	2.49	14.75	2.46	0.9	Acceptable
Fixation (%) (Left)	5.12	6.3	5.6	6.84	0.8	Acceptable
Fixation (%) (Right)	5.3	6.23	5.54	6.86	0.7	Acceptable
Sync X (0-1) (Left)	0.88	0.08	0.87	0.08	0.6	Poor
Sync X (0-1) (Right)	0.88	0.08	0.88	0.08	0.6	Poor
On-Target SP (Left)	62.05	22.56	62.72	24.13	0.7	Acceptable
On-Target SP (Right)	61.01	22.25	61.52	21.48	0.7	Acceptable
Saccade (%) (Left)	5.94	5.29	5.47	5.01	0.8	Acceptable
Saccade (%) (Right)	5.74	5.16	5.44	5.18	0.8	Acceptable
Latent SP (%) (Left)	13.85	14.15	13.77	14.56	0.9	Acceptable
Latent SP (%) (Right)	13.99	13.72	13.93	13.12	0.9	Acceptable
SP (Left) (%)	87.46	12.88	88.26	11.33	0.7	Acceptable
SP (Right) (%)	87.83	11.67	88.38	10.77	0.7	Acceptable
Predictive SP (%) (Left)	5.23	8.45	5.09	8.25	0.9	Acceptable
Predictive SP (%) (Right)	6.77	9.6	6.36	9.52	0.9	Acceptable
Sync Y (0-1) (Left)	0.85	0.09	0.86	0.08	0.5	Unacceptable
Sync Y (0-1) (Right)	0.85	0.08	0.85	0.07	0.4	Unacceptable

E/T VR (°) = eye/target velocity error, SP = Smooth pursuit

TABLE II
Test-Retest Reliability for Horizontal Smooth Pursuit

Variable	Trial 1 Mean	Trial 1 SD	Trial 2 Mean	Trial 2 SD	CA	Decision
E/T VR (°) (Left)	18.91	5.27	18.57	5.14	0.7	Acceptable
E/T VR (°) (Right)	18.84	5.03	18.59	4.87	0.7	Acceptable
Fixation (%) (Left)	8	6.63	7.84	6.71	0.8	Acceptable
Fixation (%) (Right)	7.64	6.27	8.26	6.09	0.7	Acceptable
Sync X (0-1) (Left)	0.95	0.07	0.96	0.06	0.3	Unacceptable
Sync X (0-1) (Right)	0.95	0.07	0.96	0.05	0.3	Unacceptable
Saccade (%) (Left)	4.95	5.23	4.63	5.16	0.8	Acceptable
Saccade (%) (Right)	4.92	5.2	4.74	5.36	0.9	Acceptable
SP (Left) (%)	86.54	10.79	86.38	11.34	0.9	Acceptable
SP (Right) (%)	87.05	9.57	86.6	9.74	0.8	Acceptable

TABLE III
Test-Retest Reliability for VERTICAL Smooth Pursuit

Variable	Trial 1 Mean	Trial SD	Trial 2 Mean	Trial 2 SD	CA	Decision
E/T VR (°) (Left)	23.17	9.2	22.4	9.82	0.9	Acceptable
E/T VR (°) (Right)	23.11	8.96	22.45	9.79	0.8	Acceptable
Fixation (%) (Left)	23.37	11.38	22.03	11.68	0.7	Acceptable
Fixation (%) (Right)	23.38	11.65	22.61	11.87	0.7	Acceptable
Saccade (%) (Left)	24.6	8.54	25.09	9.27	0.7	Acceptable
Saccade (%) (Right)	25	9.24	25.38	10.13	0.7	Acceptable
SP (Left) (%)	50.21	12.95	51.55	12.99	0.7	Acceptable
SP (Right) (%)	50.06	13.3	51.1	12.81	0.7	Acceptable
Sync Y (0-1) (Left)	0.73	0.08	0.73	0.07	0.4	Unacceptable
Sync Y (0-1) (Right)	0.73	0.08	0.73	0.07	0.4	Unacceptable

TABLE IV
Test-Retest Reliability for Horizontal SACCADES

Variable	Trial 1 Mean	Trial SD	Trial 2 Mean	Trial 2 SD	CA	Decision
Fixation (#) (Left)	17.75	9.76	20.22	8.58	0.7	Acceptable
Fixation (#) (Right)	17.45	9.39	20.1	8.49	0.7	Acceptable
On-Target (#) (Left)	2.57	2.84	2.88	2.86	0.9	Acceptable
On-Target (#) (Right)	2.15	2.65	2.28	2.61	0.9	Acceptable
Saccade (#) (Left)	18.29	9.53	21.04	8.08	0.7	Acceptable
Saccade (#) (Right)	18.38	9.18	21.15	8.18	0.7	Acceptable
All Bandwidths (#) (Left)	9.42	7.07	10.91	6.55	0.7	Acceptable
All Bandwidths (#) (Right)	8.91	6.31	10.63	6.42	0.7	Acceptable

TABLE V
Test-Retest Reliability for VERTICAL SACCADES

Variable	Trial 1 Mean	Trial SD	Trial 2 Mean	Trial 2 SD	CA	Decision
Fixation (#) (Left)	16.01	6.56	17.76	6.66	0.8	Acceptable
Fixation (#) (Right)	15.21	6.9	16.45	6.76	0.8	Acceptable
On-Target (#) (Left)	3.73	3.87	3.92	4.09	0.7	Acceptable
On-Target (#) (Right)	3.87	4.04	3.84	4.06	0.8	Acceptable
Saccade (#) (Left)	16.49	6.72	17.92	6.91	0.7	Acceptable
Saccade (#) (Right)	16.51	6.8	18.06	7.54	0.7	Acceptable
All Bandwidths (#) (Left)	7.25	5.26	8.18	5.26	0.7	Acceptable
All Bandwidths (#) (Right)	7.31	4.86	7.97	5.36	0.7	Acceptable

(%), Latent SP, and Predictive SP. Age Cluster 5-8 significantly differed from each Age Cluster (i.e., 9-16; 17-28; 29-52; and 53-62) for all CSP variables.

2) HSP Test

Similarly, the MANOVA for the HSP Test demonstrated a significant multivariate effect on cluster membership, Wilks' Lambda = .729, $F(32, 7889.837) = 15.845$, $p < .0001$. The follow-up ANOVAs for HSP further supported our cluster solution as significant Cluster differences were found for all HSP variables ($p < .001$). Age Clusters 17-28, 29-52, and 53-62 did not differ for E/T VR, Saccade %, and SP %, however, were significantly different for the remaining Age Clusters (i.e., 5-8, 9-16). Age Cluster 5-8 differed on all clusters for all HSP variables except Fixation %. In this case, Age Cluster 5-8 was not significantly different from Clusters 5-8, 9-16, and 53-62.

3) VSP Test

Likewise, the MANOVA for the VSP Test also showed a significant multivariate effect on cluster membership, Wilks' Lambda = .739, $F(32, 7528.43) = 20.11$, $p < .0001$. The follow-up ANOVAs for VSP also supported our cluster solution as significant Age Cluster differences were found for all VSP variables ($p < .001$) and Tukey's Post Hoc test demonstrated the same findings as the HSP Test.

4) HS Test

For the Horizontal Saccade Test, the MANOVA revealed a significant multivariate effect on cluster membership, Wilks' Lambda = .851, $F(32, 10{,}486.01) = 14.684$, $p < .0001$. Our Cluster solution was support by significant follow-up ANOVA for all HS variables ($p < .001$). Post Hoc test revealed Cluster 5-8 and Cluster 17-28 were significantly different from Clusters 9-16, 29-52, and 53-62 on Fixation %, On-target %, Saccade %, and All Bandwidths.

5) HS Test

Lastly, the Vertical Saccade Test revealed a significant multivariate effect on cluster membership, Wilks' Lambda = .817, $F(32, 7972.35) = 12.956$, $p < .0001$. Similar to the other analyses, follow-up ANOVAs for each VS test demonstrated support for our Cluster solution as all VSP variables were significantly different ($p < .0001$). Post Hoc test revealed the Age Cluster 5-8 was significantly different on all variables. Age Cluster 17-28 differed from the all Age Clusters on All Bandwidths, Saccade, and Fixation %.

fee.

IV. Conclusion

The purposes of this study were to use an empirical, data-driven approach to examine the reliability of RightEye Neuro Vision and to determine the normative values of OMB metrics for healthy individuals, and to cluster these variables by age through cluster analysis.

A. Reliability of RightEye Tests

Eighty-five percent of variables resulted in acceptable or higher reliability. Synchronization was the only unreliable metrics within smooth circular pursuit and vertical pursuit. Synchronization analysis, in this study, is modeled by separating the horizontal (x-axis) and vertical (y-axis) components of the eye position in relation to the same components of the target's position, as proposed by Contreras, et al[3]. However, there are no known tests of reliability for synchronization in previous literature, and thus questions group differences usually found using synchronization metrics via this method. Future experiments should analyze all eye movement metrics tested for reliability and explore other methods of quantifying synchronization such as that outlined by Samadini and colleagues[10]. The remaining tests, including circular smooth pursuit, horizontal smooth pursuit, vertical smooth pursuit, vertical saccade, and horizontal saccade, demonstrated strong reliability and potentially represents an acceptable alternative to standard bedside clinical assessment.

B. Cluster analysis.

The cluster analysis represents a robust method to demonstrate distinct groups by age. We observed 5 distinct clusters which indicate the need to consider age ranges in an oculomotor test. The MANOVAs for circular, vertical, and horizontal smooth pursuit, horizontal saccades, and vertical saccades revealed a significant multivariate effect on cluster membership for Age, thus indicating reasonable support for our cluster solution. Follow-up analysis indicated a majority of the eye tracking variables represent distinct differences for Age. Most measurements demonstrate a curvilinear relationship with peaks occurring for the 17-28 age groups and 29-58 age groups (See Figures 2, 3, 4 and 5 as examples). The results are in-line research indicating saccadic control increases from ages 3-14 and saccade latencies decrease until age 15[11]. In addition, other investigators have noted age-related declines in smooth pursuit and saccades[12] and the underlying age-related changes to the oculomotor nerve[13].

C. Conclusion

Overall, the results demonstrated the RightEye reliable, and the clustering method presented here represents a robust method to demonstrate distinct differences in eye tracking variables by Age. Findings represent the sensitivity OMB measures and the importance to consider individual and group characteristics for clinical applications as well as applied settings. Future studies should also consider normative values for OMB variables to enhance interpretation of findings. Furthermore, group analysis indicates the need to consider individual characteristics in eye tracking research.

Appendix

Descriptive Statistics Circular Smooth Pursuit, Horizontal Smooth Pursuit, Vertical Smooth Pursuit, Horizontal Saccade, Vertical Saccades Clustered by Age.

A. *Circular Smooth Pursuit*

	5 - 8				9 - 16				17 - 28				29 - 52				53 - 62			
Test	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper
E/T VR (°) (Left)	17.45	5.18	16.81	18.09	15.62	3.7	15.32	15.91	14.26	1.84	14.1	14.42	14.38	2.91	14.06	14.69	15.11	1.9	14.74	15.48
E/T VR (°) (Right)	17.56	5.13	16.93	18.18	15.84	4.08	15.51	16.16	14.39	2	14.22	14.56	14.36	1.85	14.16	14.56	15.1	1.74	14.76	15.44
Fixation (%) (Left)	8.65	8.98	7.54	9.75	6.26	8.05	5.62	6.91	4.23	5.95	3.72	4.73	3.93	4.05	3.5	4.37	5.39	5.75	4.26	6.52
Fixation (%) (Right)	9.01	9.5	7.85	10.18	6.55	8.02	5.91	7.19	4.35	6.01	3.83	4.86	4.13	3.98	3.71	4.56	5.4	5.39	4.35	6.46
Sync X (0-1) (Left)	0.86	0.08	0.85	0.87	0.88	0.08	0.87	0.89	0.9	0.05	0.89	0.9	0.89	0.05	0.89	0.9	0.89	0.07	0.87	0.9
Sync X (0-1) (Right)	0.85	0.09	0.84	0.86	0.88	0.08	0.88	0.89	0.9	0.05	0.9	0.9	0.9	0.06	0.89	0.9	0.9	0.05	0.89	0.91
On-Target SP (Left)	56.75	21.23	54.15	59.36	63.64	21.8	61.9	65.38	67.35	20.09	65.63	69.06	64.31	20.98	62.07	66.55	62.53	21.81	58.25	66.8
On-Target SP (Right)	54.06	20.45	51.55	56.57	61.24	21.07	59.56	62.93	65.54	19.61	63.86	67.21	63.37	19.92	61.24	65.5	59.16	18.9	55.45	62.86
Saccade (%) (Left)	8.94	6.76	8.11	9.77	6.4	5.48	5.96	6.84	4.61	4.46	4.22	4.99	5.47	5.8	4.85	6.09	6.46	5.07	5.46	7.45
Saccade (%) (Right)	8.74	6.57	7.93	9.54	6.46	6.11	5.97	6.95	4.48	4.91	4.06	4.9	5.12	5.04	4.59	5.66	6.49	5.49	5.42	7.57
Latent SP (%) (Left)	13.54	13.31	11.9	15.17	14.36	14.98	13.17	15.56	16.89	15.43	15.58	18.21	20.47	18.17	18.53	22.41	17.06	18.51	13.44	20.69
Latent SP (%) (Right)	14.44	13.88	12.73	16.14	14.76	14	13.64	15.88	17.14	15.84	15.79	18.49	20.47	17.26	18.63	22.32	17.32	14.19	14.54	20.1
SP (Left) (%)	82.41	12.44	80.88	83.94	87.34	11.11	86.45	88.23	91.17	8.24	90.47	91.87	90.58	8	89.73	91.44	88.15	8.55	86.48	89.83
SP (Right) (%)	82.25	12.84	80.67	83.83	86.99	11.46	86.07	87.9	91.18	8.53	90.45	91.91	90.74	7.61	89.93	91.56	88.1	8.33	86.47	89.73
Predictive SP (%) (Left)	11.54	12.33	10.03	13.05	8.93	12.02	7.97	9.89	6.88	10.47	5.99	7.77	5.7	10.1	4.62	6.78	8.47	11.78	6.16	10.78
Predictive SP (%) (Right)	13.02	11.88	11.57	14.48	10.63	13.55	9.55	11.71	8.42	12.03	7.4	9.45	6.85	10.57	5.72	7.98	11.42	14.29	8.62	14.22
Sync Y (0-1) (Left)	0.84	0.07	0.83	0.85	0.86	0.07	0.86	0.87	0.87	0.07	0.87	0.88	0.86	0.08	0.85	0.87	0.85	0.08	0.84	0.87
Sync Y (0-1) (Right)	0.83	0.07	0.82	0.84	0.85	0.08	0.84	0.85	0.86	0.07	0.85	0.86	0.86	0.06	0.85	0.86	0.85	0.07	0.83	0.86

B. *Horizontal Smooth Pursuit*

	5 - 8				9 - 16				17 - 28				29 - 52				53 - 62			
Test	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper
E/T VR (°) (Left)	24.29	8.44	23.26	25.33	20.14	6.63	19.61	20.67	16.97	2.92	16.72	17.22	17.06	3.56	16.68	17.44	17.74	2.91	17.17	18.31
E/T VR (°) (Right)	24.31	8.13	23.32	25.31	20.14	6.37	19.63	20.64	17.15	3.7	16.84	17.47	17.2	3.75	16.8	17.6	17.56	2.53	17.06	18.06
Fixation (%) (Left)	10.07	9.77	8.87	11.27	8.87	7.85	8.24	9.49	6.91	5.55	6.44	7.39	7.26	4.81	6.75	7.78	8.08	6.14	6.88	9.29
Fixation (%) (Right)	10.34	8.68	9.27	11.41	8.94	7.91	8.3	9.57	7.13	5.93	6.62	7.63	7.21	5.11	6.66	7.75	8.41	6.44	7.15	9.67
Sync X (0-1) (Left)	0.94	0.06	0.93	0.95	0.96	0.06	0.95	0.96	0.97	0.02	0.97	0.97	0.97	0.02	0.97	0.97	0.97	0.02	0.96	0.97
Sync X (0-1) (Right)	0.94	0.06	0.93	0.95	0.96	0.06	0.95	0.96	0.97	0.02	0.97	0.97	0.97	0.03	0.97	0.97	0.97	0.02	0.97	0.97
Saccade (%) (Left)	10.7	10.56	9.4	11.99	6.27	7.53	5.67	6.87	3.64	5.62	3.16	4.12	3.93	4.08	3.49	4.36	6.13	10.52	4.07	8.19
Saccade (%) (Right)	10.6	10.77	9.28	11.92	6.32	8.08	5.68	6.97	3.63	5.83	3.13	4.12	3.97	4.28	3.51	4.43	5.4	7.67	3.89	6.9
SP (Left) (%)	79.23	15.53	77.32	81.14	84.87	12.37	83.88	85.85	89.45	8.9	88.69	90.21	88.81	7.49	88.01	89.61	85.78	12.33	83.37	88.2
SP (Right) (%)	79.06	14.85	77.24	80.88	84.74	12.44	83.75	85.73	89.25	9.32	88.45	90.04	88.83	7.79	87.99	89.66	86.2	10.86	84.07	88.32

C. *Vertical Smooth Pursuit*

	5 - 8				9 - 16				17 - 28				29 - 52				53 - 62			
Test	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper
E/T VR (°) (Left)	35.33	14.5	33.55	37.11	26.76	13.59	25.68	27.85	19.42	8.05	18.73	20.1	20.32	7.57	19.51	21.13	22.7	8.94	20.95	24.46
E/T VR (°) (Right)	35.27	14.09	33.55	37	27.17	14.69	26	28.34	19.76	12.72	18.67	20.84	20.26	7.6	19.45	21.08	22.23	8.56	20.55	23.9
Fixation (%) (Left)	28.24	12.51	26.7	29.77	26	11.88	25.05	26.95	20.16	10.35	19.28	21.04	20.06	8.76	19.13	21	19.49	9.4	17.64	21.33
Fixation (%) (Right)	28.28	13.33	26.65	29.92	25.92	12.02	24.96	26.88	20.76	10.24	19.89	21.63	20.22	9.07	19.25	21.19	20.49	9.05	18.71	22.26
Saccade (%) (Left)	26.72	11.35	25.33	28.11	24.2	8.68	23.51	24.9	24.4	9.52	23.59	25.21	26.46	9.31	25.46	27.45	28.32	11.16	26.13	30.51
Saccade (%) (Right)	26.6	11.35	25.2	27.99	24.42	9.58	23.66	25.18	23.96	9.85	23.12	24.8	26.24	9.61	25.21	27.27	26.69	12.79	24.18	29.19
SP (Left) (%)	45.11	12.35	43.59	46.62	49.79	12.26	48.81	50.77	55.44	12.04	54.41	56.47	53.52	10.83	52.37	54.68	52.09	10.97	49.94	54.24
SP (Right) (%)	45.14	12.85	43.57	46.72	49.65	12.46	48.65	50.64	55.28	12.15	54.25	56.32	53.56	11.28	52.36	54.77	52.74	11.21	50.54	54.94
Sync Y (0-1) (Left)	0.69	0.1	0.68	0.7	0.71	0.08	0.7	0.71	0.74	0.06	0.73	0.74	0.74	0.06	0.73	0.74	0.73	0.06	0.72	0.74
Sync Y (0-1) (Right)	0.69	0.1	0.68	0.7	0.7	0.08	0.7	0.71	0.74	0.06	0.73	0.74	0.74	0.06	0.73	0.74	0.73	0.06	0.71	0.74

D. *Horizontal Saccades*

	5 - 8				9 - 16				17 - 28				29 - 52				53 - 62			
Test	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper
Fixation (#) (Left)	12.77	10.14	11.53	14.02	16.31	7.87	15.68	16.94	20.88	9.28	20.09	21.67	16.18	7.6	15.37	16.99	15.58	7.86	14.04	17.12
Fixation (#) (Right)	12.42	7.74	11.47	13.37	16.15	7.4	15.56	16.74	20.73	9.14	19.95	21.5	16.25	7.82	15.41	17.09	15.58	7.9	14.03	17.13
On-Target (#) (Left)	2.14	2.2	1.87	2.41	3.06	2.98	2.83	3.3	3.7	3.47	3.41	4	2.9	3.17	2.57	3.24	2.95	3	2.36	3.54
On-Target (#) (Right)	2.04	2.37	1.75	2.33	2.78	2.68	2.56	2.99	3.43	3.27	3.15	3.71	2.89	2.95	2.57	3.2	2.69	3.11	2.08	3.3
Saccade (#) (Left)	13.85	9.7	12.66	15.05	17.2	7.62	16.6	17.81	21.48	9.02	20.72	22.25	17	7.39	16.21	17.79	16.35	7.46	14.89	17.81
Saccade (#) (Right)	13.63	7.22	12.74	14.51	17.21	7.3	16.62	17.79	21.49	9.06	20.72	22.26	16.91	7.26	16.13	17.68	16.35	7.2	14.94	17.76
All Bandwidths (#) (Left)	5.78	3.9	5.3	6.26	8.23	5.22	7.82	8.65	11.2	6.51	10.65	11.76	8.83	5.63	8.23	9.43	8.07	5.3	7.03	9.11
All Bandwidths (#) (Right)	5.69	3.63	5.25	6.14	8.22	4.96	7.82	8.61	10.83	6.35	10.29	11.37	9.02	5.75	8.4	9.63	7.81	5.82	6.67	8.95

E. *Vertical Saccades*

	5 - 8				9 - 16				17 - 28				29 - 52				53 - 62			
Test	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper	Mean	SD	CL Lower	CL Upper
Fixation (#) (Left)	11.44	4.74	10.85	12.02	15.05	6.1	14.56	15.53	19.88	7.23	19.27	20.5	16.74	6.41	16.05	17.42	15.98	7.09	14.59	17.37
Fixation (#) (Right)	11.53	4.74	10.95	12.12	15.03	6.28	14.53	15.53	19.84	7.02	19.24	20.44	16.63	6.26	15.96	17.3	16.12	8.05	14.54	17.7
On-Target (#) (Left)	2.13	2.28	1.85	2.41	3.13	3.04	2.88	3.37	4.59	4.24	4.23	4.95	4.12	3.8	3.71	4.53	3.77	4.18	2.95	4.59
On-Target (#) (Right)	2.12	2.37	1.83	2.41	3.11	3.04	2.87	3.36	4.48	4.26	4.12	4.85	4.34	4.11	3.9	4.78	4.17	4.44	3.3	5.04
Saccade (#) (Left)	12.97	4.82	12.38	13.56	16.22	5.88	15.75	16.69	20.91	6.99	20.31	21.51	17.72	5.98	17.08	18.36	16.81	6.98	15.44	18.18
Saccade (#) (Right)	13.05	4.63	12.48	13.61	16.15	6.16	15.66	16.65	20.95	6.9	20.36	21.53	17.65	6.03	17.01	18.3	16.87	7.41	15.42	18.32
All Bandwidths (#) (Left)	4.9	3.3	4.49	5.3	7.17	4.51	6.81	7.53	10.01	5.59	9.53	10.48	8.05	4.86	7.53	8.57	7.44	4.3	6.6	8.28
All Bandwidths (#) (Right)	4.92	3.27	4.52	5.32	6.92	4.47	6.56	7.27	10.02	5.5	9.56	10.49	8.01	4.72	7.5	8.51	7.12	4.74	6.19	8.05

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