Assessing Eye-Movement Performance and Executive Function After Concussion

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Introduction

When normal functioning is disturbed by a concussion, individuals may experience a range of post concussion symptoms (PCS); consequently individuals who have had a concussion may have difficulty performing normal eye movements (Webb et al., 2018).

Located in the frontal cortex and brainstem regions, the frontal eye field is responsible for saccadic movements, smooth pursuit (SP), and multiple object tracking (MOT). The eye movement circuit which includes the frontal cortex may be vulnerable to concussion (Lappi, 2016).

Individuals who have prolonged PCS often experience difficulties with concentration, feelings of disorientation, and headaches that may be associated to poor eye-movement performance and executive functioning (Heitger et al., 2009).

Aims

Understand the possible role that executive dysfunction may play in the cognitive and eye-movement performance problems experienced by individuals with concussions.

Evaluate the extent to which executive functioning and eye movement performance varies with symptom severity and time since injury. Do these tests track the resolution of concussion?

Participants

Humans who have experienced a concussion (C; *n* = 20) or orthopedic injury (OC; *n* = 19) within the past three years, and healthy controls (HC; *n* = 21)

Table 1 - Demographic Information

Measure Mean (SD)	Concussion (C), n=20	Injury Control (IC), n=20	Healthy Control (HC), n=20	C-IC p-level	C-HC p-level
Sex (nF/nM)	15/5	10/10	14/6	.108	.731
Age	22.0 (2.71)	22.85 (1.95)	21.05 (3.26)	.263	.324
Years of Education	15.4 (1.5)	16.4 (1.0)	14.85 (1.66)	.013	.279
Days Since Injury	617.2 (355.5)	349 (270.1)	NA	.011	NA

Table 2 – Injury Data

	Concussion N=20	Injury Control N=20
Type of Injury		
Concussion	20	0
Bone	0	7
Soft Tissue	0	13
Method of Injury		
Motor Vehicle Accident	2	1
Sports	13	11
Other	5	8

Method

A brief neuropsychological battery: the SCAT5 Symptom Eval Questionnaire, BECK depression questionnaire, WAIS-IV Digit Symbol, WAIS-IV Verbal Fluency, WAIS-IV Coding, and Trail Making.

Eye-Movement Performance Tasks:

Anti Saccades – measures ability to adjust to an unpredictable change in target location to the left or right and near or far distance from the central fixation point over 48 trials.

- P's directed their saccade in the opposite direction and mirror distance of the target. Reaction time (RT), correct direction, and number of eye movements to target were measured.

Smooth Pursuit (SP) – measures ability to track a smooth moving target.

- Ps followed a target following a sinusoidal path at two different speeds. Tracking lag time was measured.

Multiple Object Tracking (MOT) – measures ability to track a number of moving targets amongst distractors for 3-second periods.

- Ps were presented with 10 circles on the screen, one to five were identified as targets. All of the items moved randomly for three seconds. When they stop, P's used the mouse to identify the original targets in their new location. Percent accuracy was measured.

References

Heitger, M, H., et al. (2009). *Brain*, *132*(10), 2850-2870. doi:10.1093/brain/awp181
Lappi, O. (2016). *Neuroscience and Behavioral Reviews*, 69, 49-68. 10.1016/j.neubiorev.2016.06.006
Webb, B., Humphreys, D., & Heath, M. (2018). *J Neurotrauma*, *35*(16), 1874-1881. doi:10.1089/neu.2018.5673

Results

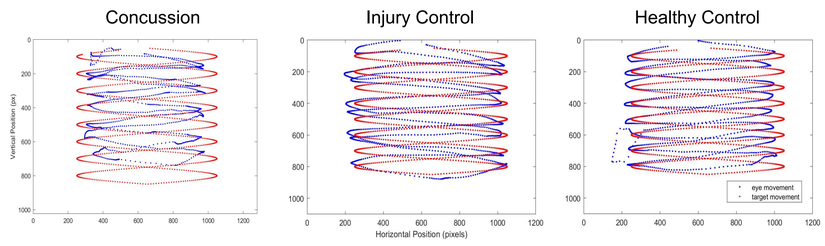
Table 3 – Neuropsychological Test Results

Measure - Mean (SD)	Concussion N=20	Injury Control N=20	Healthy Control N = 20	C-IC p-level	C-HC p-level
SCAT5 Symptom Questionnaire					
Number of symptoms	**9.25 (6.4)**	**5.45 (5.6)**	**3.5 (4.7)**	**.068**	**.001**
Symptom Severity (Total)	**20.5 (22.4)**	**11.7 (13.3)**	**8.5 (13.6)**	**.027**	**.023**
Beck Depression Inventory					
Total Score	8.1 (7.7)	6.1 (6.5)	6.3 (7.5)	.184	.227
WAIS-IV (T Score)					
Digit Span	8.1 (3.1)	58.3 (2.2)	7.9 (2.1)	.332	.430
Verbal Fluency	**27.0(20.5)**	**50.5 (27.2)**	**41.8 (22.6)**	**.002**	**.019**
Coding	10.9 (2.7)	10.5 (2.1)	10.7 (1.8)	.411	.324
Trail Making (Z-Score)	.57 (1.1)	.53 (.91)	.52 (1.1)	.491	.491

Neuropsychology Test Results:
Reports of symptom severity, number of symptoms, and verbal fluency distinguished the concussed participants from injury controls and healthy controls.

Table 4 – Measures of Eye-Movement Performance

Measure - Mean (SD)	Concussion N=20	Injury Control N=20	Healthy Control N = 20	C-IC p-level	C-HC p-level
Anti Saccades					
Reaction Time (RT; ms)	267.6 (7.0)	262.8 (7.0)	254.4 (7.0)	.305	.085
Correct Direction (%)	67.4	67	65.7	.495	.495
Two Eye-Movements (%)	**67.3**	**62.5**	**55.8**	**<.001**	**<.001**
Smooth Pursuit (SP)					
Tracking Lag Time (ms)	**223**	**212**	**176**	**.292**	**.005**
Multiple Object Tracking (MOT)					
Four-Target Accuracy (%)	67.1	68.4	63.9	.426	.491



Eye-Movement Performance Results:
Anti saccade % two-movement trials and smooth-pursuit lag time distinguished concussed participants from controls.

Do test results reflect the presence of concussion? If so, performance will vary with symptom severity and time since injury (after we account for depression).

Do measures of symptom severity and time since injury account for neuropsychological test performance?

Table 5 – Neuropsychological Hierarchical Regression

Test	Concussion N = 20 Partial r (*p*)	Injury Control N=20 Partial r (*p*)	Healthy Control N=20 Partial r (*p*)
Depression			
Verbal Fluency	No relationship found.	No relationship found.	-0.4 *(<.001)*
Coding	No relationship found.	No relationship found.	-0.54 *(.014)*
Symptom Severity			
Verbal Fluency	No relationship found.	No relationship found.	0.4 *(.002)*
Coding	No relationship found.	No relationship found.	-0.55 *(.002)*
Time Since Injury	No relationship found.	No relationship found.	N/A

Tests of executive functioning on verbal and coding tasks varied with severity of healthy control Ps' depression scores and concussion-related symptom reporting.

Do measures of symptom severity and time since injury account for eye-movement test performance (after accounting for depression)?

Table 6 – Neuropsychological and Eye-Movement Performance Hierarchical Regression

Test	Concussion N = 20 Partial r (p)	Injury Control N=20 Partial r (p)	Healthy Control N=20 Partial r (p)
Anti Saccades			
Reaction Time	-0.57 (*.009*)	No relationship found.	No relationship found.
Symptom Severity	No relationship found.	No relationship found.	No relationship found.
Time Since Injury			
Lag Time	No relationship found.	0.64 (*.005*)	N/A

Eye-movement performance on reaction time in anti saccades varied with depression scores in healthy controls. Smooth pursuit lag time varied with time since injury in injury controls

Conclusions

Concussed participants differed on symptom severity from injury controls and healthy controls, suggesting lingering concussion side effects up to three years post injury.

Concussed participants were more sensitive to verbal fluency than injury controls and healthy controls, however this does not support evidence of cognitive deficits in executive functioning.

When faced with an anti-saccade task, concussed participants needed to perform two eye-movements to complete the task more often than controls, indicating greater levels of uncertainty about the direction or distance that needed to be covered.

Concussed participants had more difficulty tracking a target using smooth-pursuit eye-movements than healthy controls.

These findings add to the evidence that concussed participants show persistent eye-movement performance difficulties up to three years post injury.

Eye-movement performance and symptom severity assessment should be included in brain injury and recovery evaluation beyond the typical recovery period.