Supplemental Material
Major Study Analyses Excluding (*n* = 3) Subjects Who Failed the MSVT at Baseline
        Tables S1 and S2 present the two major set of findings from the main body of the manuscript (those reported in Tables 3 and 5), but this time excluding the three subjects who failed the MSVT at pre-season baseline examinations. The concussed *versus* control group effect sizes (Cohen's d) across measures and time points were highly similar when excluding these subjects (Table S1 below) as compared to what was reported using the entire sample (Table 3), with the mean difference in effect sizes between the two analyses = 0.00. Similarly, the sensitivity values reported in Table S2 below closely mirror those reported from the full study sample (Table 5). For example, excluding these subjects resulted in a mean increase in sensitivity (across 1+ and 2+ criteria and all time points) for ANAM, Axon, and ImPACT (all concussed athletes) of 0.0, 0.9, and 0.03, respectively, while the corresponding false positive rates increased by a mean of 0.03, 4.5, and 0.1, respectively.

Table S1
Concussed vs. Control Group Effect Sizes (Cohen's d), Excluding Subjects with Failed Baseline MSVT

	BL	24-hr	Day 8	Day 15	Day 45
SCAT3 Symptom Severity	-.07	**-1.52**	**-.40**	-.13	.23
ANAM					
Composite	-.18	**-.84**	-.33	-.30	-.21
SRT	-.04	**-.58**	-.18	-.12	-.10
CDS	-.06	**-.61**	-.26	-.17	-.19
PRO	-.32	**-.68**	-.35	-.26	.03
MTH	-.19	-.19	-.02	-.22	-.09
M2S	-.32	**-.89**	**-.47**	**-.40**	-.36
CDD	.06	**-.66**	-.10	-.16	-.36
SR2	.08	**-.64**	-.27	-.15	-.02
GNG	-.13	-.30	-.22	.03	.18
Mean	*-.12*	*-.60*	*-.25*	*-.19*	*-.13*
Axon					
PS Speed	-.07	**-.53**	-.12	-.11	-.03
AT Speed	-.09	**-.72**	**-.41**	-.22	-.08
LN Acc.	-.22	**-.51**	**-.39**	-.12	-.28
WM Speed	-.07	**-.51**	-.25	.01	.00
Mean	*-.11*	*-.57*	*-.29*	*-.11*	*-.10*
ImPACT					
VERM	.02	**-.76**	**-.40**	-.18	-.18
VISM	-.21	**-.76**	-.17	-.21	-.26
VMS	-.27	**-.80**	-.31	-.29	-.21
RT	.08	**-.70**	-.24	-.23	-.18
Mean	*-.10*	*-.76*	*-.28*	*-.23*	*-.21*

Note. Bolded where $p < .05$ after adjustment for multiple comparisons. Comparisons are all scaled such that negative values reflect worse performance in the concussed group. BL = baseline; SRT = Simple reaction time; CDS = code substitution-learning; PRO = procedural reaction time; MTH = mathematical processing; M2S = matching to sample; CDD = code substitution-delayed; SR2 = simple reaction time 2; GNG = go no-go; PS= processing speed; AT = attention; LN acc. = learning accuracy; WM = working memory; VERM = verbal memory composite; VISM = visual memory composite; VMS = visual motor speed composite; RT = reaction time composite.

Table S2

Percentage of Concussed (All), Asymptomatic Concussed (Sx-), and Non-Injured Controls With 1 or More (1+) and 2 or More (2+) Significant Declines According to Reliable Change Index (RCI) Criteria

	24 hr			Day 8			Day 15			Day 45		
	Concussed		Control	Concussed		Control	Concussed		Control	Concussed		Control
	All	Sx-	(false +)	All	Sx-	(false +)	All	Sx-	(false +)	All	Sx-	(false +)
ANAM												
1+ decline	47.6	42.9	25.5	31.0	28.6	29.9	35.4	30.8	27.9	25.7	26.1	25.3
2+ decline	31.0	0.0	6.4	10.7	7.1	14.0	7.6	6.2	11.5	11.4	11.6	8.0
Axon												
1+ decline	63.9	42.9	27.5	38.0	30.6	31.4	26.9	22.0	26.5	26.8	27.3	25.0
2+ decline	38.9	0.0	8.8	15.5	8.3	7.0	9.0	8.0	10.8	14.3	14.5	8.3
ImPACT												
1+ decline	68.6	58.3	29.3	49.4	40	43.4	47	45.5	40.8	39.0	38.2	40.0
2+ decline	34.9	16.7	4.1	8.4	5.0	6.6	10.8	9.1	10.8	6.5	6.6	4.8

Note. Symptom-free (Sx-) *n*s at 24-hr were small (7 for ANAM, 8 for Axon, and 13 for ImPACT). Symptomatic *n*s were small at day 45 (2 for ANAM; 1 for Axon/ImPACT). The number of neurocognitive RCIs available for each CNT was 7 for ANAM, 5 for Axon, and 4 for ImPACT. ImPACT uses 80% confidence intervals around RCIs, whereas ANAM and Axon use 90% CIs.

Effect of Test Order on CNT Findings

   Test-retest reliability. Below are the stability coefficients for the baseline vs. first follow-up time points ($M = 198$ day test-retest interval) presented separately by tests administered as the 1st or 2nd CNT during the testing sessions. There was not a consistent advantage for tests administered first or second in terms of stability over time. The median difference in reliability for each subtest for Order 1 – Order 2 was .05 (for both Pearson rs and ICCs). Nine of 17 indices showed higher Pearson reliability coefficients (10 of 17 for ICCs) for Order 1 vs. 2.

Table S3

Test-Retest Reliability by Order of CNT Administration

	Order 1 Pearson r	Order 2 Pearson r	Order 1 ICC	Order 2 ICC
ANAM				
Composite	.62	.74	.61	.72
SRT	.18	.44	.18	.43
CDS	.67	.78	.66	.75
PRT	.46	.61	.44	.57
MTH	.75	.70	.74	.68
M2S	.55	.63	.56	.63
CDD	.62	.64	.57	.55
SR2	.42	.49	.42	.49
GNG	.13	.44	.13	.42
Axon				
PS Speed	.70	.24	.67	.13
AT Speed	.69	.42	.68	.42
LN Acc.	.62	.41	.49	.30
WM Speed	.78	.73	.78	.73
ImPACT				
VERM	.63	.41	.62	.31
VISM	.51	.46	.51	.46
VMS	.83	.54	.81	.53
RT	.70	.44	.70	.44

Effects of order on CNT performance and Concussed vs. Control group differences.
To examine the effect of test order on CNT performance as well as interactions between
Group and Order, we performed a series of ANOVAs (separately by each CNT
measure/composite score) with Group, Order, and Group x Order as predictors. Baseline
performance primarily provided an opportunity to examine overall Order effects, while
the 24-hr time point was selected given that any interactions between Order and Group
should be maximal when concussed athletes were more acutely injured. The Table below
summarizes the findings of these analyses. Across all measures at Baseline, 2 of 17 CNT
indices had significantly different performance (unadjusted *p*-values) between Order 1
and 2 in opposite directions: ANAM SR2 performance was better for Order 1 than 2, and
ImPACT VMS was better for Order 2 than 1. Across time points, no Group x Order
interactions were present. Similarly, group effect sizes were not systematically different
by order: the median difference between Order 1 and 2 in the Concussed vs. Control
group difference (Cohen's *d*) was .11 at 24 hr (favoring Order 1), with 10 of 17 CNT
producing bigger Concussed vs. Control group differences for CNTs administered 1st,
and 7 indices producing bigger group effect sizes when administered 2nd.

Table S4
*Unadjusted p-values from Concussion Group x CNT Order ANOVAs at Baseline and 24-
hr Post-Injury*

	Group	Order	Group x Order
	p	*p*	*p*
ANAM			
Composite BL	.136	.061	.639
Composite 24-hr	**< .001**	.690	.652
SRT BL	.645	.264	.297
SRT 24-hr	**< .001**	.917	.426
CDS BL	.657	.738	.925
CDS 24-hr	**< .001**	.434	.718
PRO BL	**.014**	.152	.902
PRO 24-hr	**< .001**	.640	.757
MTH BL	.129	.242	.455
MTH 24-hr	.144	.785	.347
M2S BL	**.014**	.149	.872
M2S 24-hr	**< .001**	.495	.235
CDD BL	.778	.536	.540
CDD 24-hr	**< .001**	.959	.882
SR2 BL	.905	**.018**	.885
SR2 24-hr	**< .001**	.830	.521
GNG BL	.486	.377	.645
GNG 24-hr	**.039**	.500	.670
AXON			
PS Speed BL	.743	.524	.904

PS Speed 24-hr	**.001**	.228	.179
AT Speed BL	.619	.186	.431
AT Speed 24-hr	**< .001**	.266	.978
LN Acc. BL	.184	.978	.573
LN Acc. 24-hr	**.001**	.425	.221
WM Speed BL	.602	.670	.490
WM Speed 24-hr	**.001**	.707	.474
IMPACT			
VERM BL	.914	.666	.038
VERM 24-hr	**< .001**	.539	.965
VISM BL	.099	.050	.304
VISM 24-hr	**< .001**	.524	.396
VMS BL	.037	**.017**	.905
VMS 24-hr	**< .001**	.053	.925
RT BL	.599	.392	.993
RT 24-hr	**< .001**	.606	.973

Table S5

Group Comparisons for ANAM by Subscale and Time

	Concussed N = 104		Control N = 113		Group x Time	Group
	M	*SD*	*M*	*SD*	*p*	*p*
Composite					< .001	
BL	.31	1.02	.48	1.02		.350
24-hr	-.46	1.59	.67	1.10		**< .001**
Day 8	.44	1.44	.88	1.19		.067
Day 15	.43	1.17	.80	1.26		.095
Day 45	.64	1.15	.90	1.27		.291
SRT					< .001	
BL	242.32	29.22	243.45	28.47		.864
24-hr	220.82	50.33	244.52	30.10		**< .001**
Day 8	248.37	37.40	254.60	32.05		.317
Day 15	248.01	32.42	252.32	37.97		.532
Day 45	243.45	32.62	246.68	29.39		.634
CDS					.004	
BL	59.26	11.08	59.91	12.01		.776
24-hr	54.63	11.38	61.42	10.85		**< .001**
Day 8	60.38	11.89	63.41	11.04		.143
Day 15	61.97	10.54	63.97	13.46		.350
Day 45	64.60	10.84	66.75	11.85		.339
PRO					< .001	
BL	100.17	14.91	104.58	12.63		.077
24-hr	97.22	21.65	109.27	12.97		**< .001**
Day 8	102.89	19.13	109.06	16.50		.051
Day 15	103.76	16.12	107.66	14.32		.169
Day 45	107.72	15.39	107.23	18.53		.914
MTH					.342	
BL	21.48	5.47	22.53	5.56		.311
24-hr	20.21	6.26	21.48	6.80		.287
Day 8	24.88	7.76	25.05	6.87		.921
Day 15	23.68	7.44	25.18	6.07		.241
Day 45	24.99	7.25	25.62	7.39		.698
M2S					.001	
BL	37.82	11.36	41.69	12.50		.077
24-hr	31.28	11.17	41.97	12.75		**< .001**
Day 8	35.79	12.92	42.21	14.09		**.004**
Day 15	34.23	10.98	39.17	13.51		**.023**
Day 45	36.67	11.85	41.83	16.18		.067
CDD					< .001	
BL	55.15	14.82	54.38	12.71		.776

24-hr	51.31	15.59	61.17	14.27		**< .001**
Day 8	52.21	14.65	53.60	13.49		.610
Day 15	53.74	14.01	56.22	15.89		.350
Day 45	57.66	14.29	62.74	13.66		.067
SR2					< .001	
BL	240.34	35.04	237.82	30.78		.705
24-hr	212.98	54.31	241.80	33.67		**< .001**
Day 8	236.75	47.21	248.19	37.23		.136
Day 15	237.83	41.84	243.79	38.14		.412
Day 45	234.99	36.99	235.64	35.75		.940
GNG					.073	
BL	3.40	1.43	3.58	1.46		.527
24-hr	3.63	1.44	4.06	1.39		.081
Day 8	4.01	1.55	4.35	1.52		.235
Day 15	3.94	1.52	3.88	1.60		.877
Day 45	3.84	1.47	3.57	1.43		.350

Note. Bolded where $p < .05$ after adjustment for multiple comparisons. All scores (except GNG, which reflect d-prime) represent throughput scores (a combination of reaction time and accuracy where higher scores reflect better performance). BL = baseline; SRT = Simple reaction time; CDS = code substitution-learning; PRO = procedural reaction time; MTH = mathematical processing; M2S = matching to sample; CDD = code substitution-delayed; SR2 = simple reaction time 2; GNG = go no-go.

Table S6
Group Comparisons for Axon by Subscale and Time

	Concussed N = 93		Control N = 91		Group x Time	Group
	M	*SD*	*M*	*SD*	*p*	*p*
PS Speed					.001	
BL	106.87	6.25	107.25	5.47		.776
24-hr	98.49	12.35	104.29	9.36		**.003**
Day 8	103.70	10.03	104.78	6.76		.551
Day 15	104.73	7.57	105.52	6.54		.610
Day 45	104.76	6.37	104.92	6.55		.949
AT Speed					< .001	
BL	107.87	5.02	108.38	5.86		.690
24-hr	102.04	10.00	108.18	6.51		**< .001**
Day 8	105.50	8.43	108.38	5.21		**.033**
Day 15	106.97	5.61	108.24	5.89		.287
Day 45	106.66	5.88	107.15	6.20		.711
LN Acc.					.202	
BL	98.86	7.08	100.35	6.54		.291
24-hr	99.60	10.74	104.81	9.46		**.004**
Day 8	104.19	12.60	108.55	9.18		**.041**
Day 15	105.74	12.06	107.18	11.14		.556
Day 45	107.73	9.65	110.60	11.21		.194
WM Speed					< .001	
BL	105.35	5.79	105.77	6.74		.776
24-hr	102.30	7.92	105.98	6.55		**.004**
Day 8	105.51	7.22	107.18	6.44		.229
Day 15	107.53	5.97	107.49	6.27		.967
Day 45	106.96	6.31	106.98	6.39		.963

Note. Bolded where $p < .05$ after adjustment for multiple comparisons. Descriptive statistics reflect Axon standard scores ($M = 100$; $SD = 10$). BL = baseline; PS= processing speed; AT = attention; LN Acc. = learning accuracy; WM = working memory.

Table S7

Group Comparisons for ImPACT by Composite Score and Time

	Concussed N = 112		Control N = 126		Group x Time	Group
	M	*SD*	*M*	*SD*	*p*	*P*
VERM					< .001	
BL	85.77	10.01	85.56	10.04		.921
24-hr	79.90	14.24	88.98	9.29		**< .001**
Day 8	85.93	10.53	89.84	8.97		**.013**
Day 15	87.07	10.75	88.94	10.33		.311
Day 45	87.30	10.86	89.11	9.77		.330
VISM					< .001	
BL	76.83	12.80	79.54	12.76		.256
24-hr	70.79	14.52	80.61	11.13		**< .001**
Day 8	75.04	13.19	77.23	12.29		.317
Day 15	74.58	13.94	77.39	13.17		.241
Day 45	74.33	13.95	77.86	13.05		.157
VMS					< .001	
BL	38.95	7.22	40.76	6.14		.136
24-hr	36.60	7.90	42.03	5.69		**< .001**
Day 8	40.09	7.19	42.07	5.66		.067
Day 15	41.29	6.70	43.16	6.24		.089
Day 45	41.48	6.22	42.78	6.24		.264
RT					< .001	
BL	.56	.07	.56	.06		.698
24-hr	.63	.13	.56	.07		**< .001**
Day 8	.57	.08	.55	.06		.173
Day 15	.56	.07	.55	.06		.192
Day 45	.55	.06	.54	.06		.324

Note. Bolded where $p < .05$ after adjustment for multiple comparisons. BL = baseline; VERM = verbal memory composite; VISM = visual memory composite; VMS = visual motor speed composite; RT = reaction time composite.

Table S8

Percentage of Concussed (All), Asymptomatic Concussed (Sx-), and Non-Injured Controls with Significant Declines (From Baseline) on Reliable Change Index (RCI)

	24 hr			Day 8			Day 15			Day 45		
	Concussed		Control	Concussed		Control	Concussed		Control	Concussed		Control
	All	Sx-	All	All	Sx-	All	All	Sx-	All	All	Sx-	All
ANAM												
SRT	20.2	0.0	9.8	4.8	3.6	6.4	6.3	4.6	9.6	10.0	10.1	4.6
CDS	14.3	0.0	0.9	7.1	5.4	5.5	3.8	3.1	5.8	0.0	0.0	2.3
PRO	20.2	14.3	2.7	7.1	7.1	5.5	5.1	4.6	5.8	5.7	5.8	6.9
MTH	6.0	14.3	2.7	2.4	3.6	1.8	1.3	1.5	0.0	0.0	0.0	0.0
M2S	20.2	14.3	8.0	10.7	8.9	10.1	10.1	9.2	12.5	7.1	7.2	10.3
CDD	21.4	0.0	0.9	13.1	12.5	12.8	11.4	7.7	9.6	7.1	7.2	3.4
SR2	23.8	0.0	7.2	8.3	3.6	8.3	7.6	7.7	3.8	10.0	10.1	6.9
Axon												
PS Speed	48.6	28.6	18.9	23.6	13.5	20.9	17.6	13.7	16.9	19.3	19.6	19.4
AT Speed	30.1	0.0	3.3	9.7	8.1	7.0	5.9	3.9	2.4	14.0	14.3	4.2
LN Acc.	6.8	12.5	2.2	13.9	16.2	1.2	5.9	5.9	4.8	1.8	1.8	2.8
WM Speed	26.0	12.5	3.3	8.3	2.7	7.0	4.4	5.9	6.0	5.3	5.4	4.2
ImPACT												
VERM	37.9	7.7	8.0	17.9	18.0	11.3	15.5	14.1	15.0	16.7	15.6	11.4
VISM	25.3	23.1	8.0	17.9	13.1	20.2	21.4	19.2	23.3	15.4	15.6	19.0
VMS	24.4	0.0	4.8	7.2	3.3	6.5	8.4	9.1	4.2	3.9	3.9	4.8
RT	39.5	38.5	13.6	18.1	15.0	13.7	16.9	15.6	10.8	10.4	10.5	10.5

Criteria for Each Subtest of ANAM, Axon, and ImPACT

Note. Symptom-free (Sx-) *n*s at 24-hr were small (7 for ANAM, 8 for Axon, and 13 for ImPACT). Symptomatic *n*s were small at day 45 (2 for ANAM; 1 for Axon/ImPACT). SRT = Simple reaction time; CDS = code substitution-learning; PRO = procedural reaction time; MTH = mathematical processing; M2S = matching to sample; CDD = code substitution-delayed; SR2 = simple reaction time 2; GNG = go no-go; PS= processing speed; AT = attention; LN acc. = learning accuracy; WM = working memory; VERM = verbal memory composite; VISM = visual memory composite; VMS = visual motor speed composite; RT = reaction time composite.