

Cognitive network reconstruction in opioid users compared to non-users: topological analysis of cognitive function through graph model and centrality measures

Running title: Cognitive network in opioid use disorder

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Supplementary tables and figures

		Group		Statistics
		Opioid users (n=33)	Non-user controls (n=20)	
Education level	Primary school	3	2	Fisher's exact test: 4.536 (df=1, $p = 0.549$)
	Secondary school	11	8	
	High school diploma	12	6	
	Associate's degree	0	2	
	Master's degree	7	2	
Gender	Male	32	18	Fisher's exact test: 1.133 (df=4, $p = 0.338$)
	Female	1	2	
Marital status	Single	21	6	Fisher's exact test: 5.651 (df=2, $p = 0.059$)
	Married	11	13	
	Divorced	1	1	
Age		29.94±9.19	36.05±7.75	U Mann-Whitney test: $z = -2.55$, $p = 0.011$

Table S1. Demographic data representing the statistical analyses for the level of education, gender (female to male ratio), marital status and age in the subjects with opioid use disorder and non-user controls. Fisher's exact test indicated no significant differences among the two groups in terms of each classification. U Mann-Whitney test indicated a statistically significant difference in age between the two groups [$z = -2.55$, $p = 0.011$]. Therefore, age was considered as a covariate in other analyzes. Age is shown in mean±SD. $p < 0.05$ was considered statistically significant.

Domain 1	Domain 2	Correlation coefficient	p-value
Conceptual level responses	No responses in N-Back	-0.353	0.044
Correct card selection	Wrong card selection	-0.974	0.001
Correct card selection	Other errors in WCST	-0.62	0.001
Correct card selection	Total time in WCST	-0.384	0.027
Correct card selection	No. of tries	-0.365	0.037
Correct card selection	Education level	0.454	0.008

Correct card selection	Conceptual level responses	0.729	0.001
Divided attention commission errors	Divided attention correct responses	-0.808	0.001
Divided attention commission errors	Divided attention reaction time	-0.514	0.002
Divided attention commission errors	Age	-0.377	0.03
Divided attention omission errors	Divided attention correct responses	-0.748	0.001
Failure to continue on a specific pattern	Selective attention reaction time	0.412	0.017
Failure to continue on a specific pattern	Divided attention reaction time	0.414	0.017
Failure to continue on a specific pattern	Reaction time (ms) in N-Back	0.477	0.005
Failure to continue on a specific pattern	SD. Of reaction time in N-Back	0.488	0.004
N-Back score	Divided attention commission errors	-0.381	0.029
N-Back wrong responses	Selective attention correct responses	-0.426	0.013
N-Back wrong responses	Selective attention commission errors	0.503	0.003
No responses in N-Back	N-Back score	-0.944	0.001
No. of categories completed	Wrong card selection	-0.774	0.001
No. of categories completed	Other errors in WCST	-0.714	0.001
No. of categories completed	No. of tries	-0.476	0.005
No. of categories completed	Perseverative errors	-0.456	0.008
No. of categories completed	No. of tries to complete the first level	-0.417	0.016
No. of categories completed	Correct card selection	0.752	0.001
No. of categories completed	Conceptual level responses	0.881	0.001
No. of tries	Divided attention reaction time	0.353	0.044
No. of tries	Other errors in WCST	0.451	0.008
No. of tries to complete the first level	Conceptual level responses	-0.485	0.004
No. of tries to complete the first level	Divided attention reaction time	0.366	0.036
Other errors in WCST	Conceptual level responses	-0.694	0.001
Other errors in WCST	No. of tries to complete the first level	0.4	0.021
Perseverative errors	Correct card selection	-0.79	0.001
Perseverative errors	Conceptual level responses	-0.524	0.002
Perseverative errors	Education level	-0.518	0.002
Perseverative errors	Wrong card selection	0.754	0.001
Reaction time (ms) in N-Back	Selective attention reaction time	0.433	0.012

Reaction time (ms) in N-Back	SD. Of reaction time in N-Back	0.572	0.005
Reaction time (ms) in N-Back	Divided attention reaction time	0.572	0.001
SD. Of reaction time in N-Back	Divided attention correct responses	-0.35	0.046
SD. Of reaction time in N-Back	Divided attention omission errors	0.366	0.036
Selective attention commission errors	Selective attention correct responses	-0.817	0.001
Selective attention commission errors	Divided attention correct responses	-0.681	0.001
Selective attention commission errors	Age	-0.373	0.033
Selective attention commission errors	Divided attention commission errors	0.725	0.001
Selective attention correct responses	Divided attention omission errors	-0.535	0.001
Selective attention correct responses	Divided attention commission errors	-0.526	0.002
Selective attention correct responses	Divided attention correct responses	0.681	0.001
Selective attention omission errors	Divided attention omission errors	0.537	0.001
Selective attention omission errors	Selective attention reaction time	0.541	0.001
Selective attention reaction time	Divided attention commission errors	-0.386	0.027
Selective attention reaction time	Divided attention reaction time	0.615	0.001
Total time in WCST	N-Back score	0.359	0.04
Total time in WCST	No. of tries to complete the first level	0.39	0.025
Wrong card selection	Conceptual level responses	-0.743	0.001
Wrong card selection	Education level	-0.429	0.013
Wrong card selection	Total time in WCST	0.367	0.036
Wrong card selection	No. of tries	0.404	0.02
Wrong card selection	Other errors in WCST	0.626	0.001

Table S2. Spearman correlations between each two subscales in subjects with opioid use disorder. In order to find possible functional interactions between subscales, the correlations between each two subscales were calculated by the non-parametric Spearman test. $p < 0.05$ was considered statistically significant.

Domain 1	Domain 2	Correlation coefficient	p-value
Correct card selection	Conceptual level responses	0.809	0.001
No. of categories completed	Conceptual level responses	0.857	0.001
No. of tries to complete the first level	Conceptual level responses	-0.489	0.029
Other errors in WCST	Conceptual level responses	-0.824	0.001
Perseverative errors	Conceptual level responses	-0.573	0.008
Wrong card selection	Conceptual level responses	-0.787	0.001
No. of categories completed	Correct card selection	0.868	0.001
Perseverative errors	Correct card selection	0.886	0.001
Perseverative errors	Correct card selection	-0.898	0.001
Conceptual level responses	Divided attention commission errors	-0.635	0.003
Correct card selection	Divided attention commission errors	-0.719	0.001
N-Back score	Divided attention commission errors	-0.52	0.019
No responses in N-Back	Divided attention commission errors	0.579	0.007
No. of categories completed	Divided attention commission errors	-0.723	0.001
No. of tries to complete the first level	Divided attention commission errors	0.504	0.023
Other errors in WCST	Divided attention commission errors	0.693	0.001
Perseverative errors	Divided attention commission errors	0.579	0.008
Selective attention commission errors	Divided attention commission errors	0.514	0.02
Selective attention correct responses	Divided attention commission errors	-0.577	0.008
Selective attention omission errors	Divided attention commission errors	0.448	0.048
Wrong card selection	Divided attention commission errors	0.715	0.001
Conceptual level responses	Divided attention correct responses	0.462	0.04
Correct card selection	Divided attention correct responses	0.505	0.023
Divided attention commission errors	Divided attention correct responses	-0.873	0.001
Divided attention omission errors	Divided attention correct responses	-0.902	0.001
N-Back score	Divided attention correct responses	0.519	0.019
No responses in N-Back	Divided attention correct responses	-0.569	0.009

No. of categories completed	Divided attention correct responses	0.548	0.012
Other errors in WCST	Divided attention correct responses	-0.539	0.014
Selective attention commission errors	Divided attention correct responses	-0.59	0.006
Selective attention correct responses	Divided attention correct responses	0.73	0.001
Selective attention omission errors	Divided attention correct responses	-0.601	0.005
Total time in WCST	Divided attention correct responses	-0.477	0.033
Wrong card selection	Divided attention correct responses	-0.523	0.018
Divided attention commission errors	Divided attention omission errors	0.578	0.008
Selective attention commission errors	Divided attention omission errors	0.533	0.015
Selective attention correct responses	Divided attention omission errors	-0.712	0.001
Selective attention omission errors	Divided attention omission errors	0.611	0.004
Total time in WCST	Divided attention omission errors	0.554	0.011
No. of tries to complete the first level	Divided attention reaction time	-0.475	0.034
Selective attention commission errors	Divided attention reaction time	-0.452	0.045
Selective attention reaction time	Divided attention reaction time	0.707	0.001
No. of categories completed	Education level	0.444	0.05
No. of tries	Education level	-0.469	0.037
Correct card selection	N-Back score	0.528	0.017
No responses in N-Back	N-Back score	-0.969	0.001
No. of categories completed	N-Back score	0.475	0.034
Perseverative errors	N-Back score	-0.56	0.01
Wrong card selection	N-Back score	-0.505	0.023
Correct card selection	No responses in N-Back	-0.546	0.013
No. of categories completed	No responses in N-Back	-0.503	0.024
No. of tries to complete the first level	No responses in N-Back	0.447	0.048
Perseverative errors	No responses in N-Back	0.526	0.017
Wrong card selection	No responses in N-Back	0.521	0.019
Correct card selection	No. of tries	-0.452	0.045
No. of categories completed	No. of tries	-0.696	0.001
Perseverative errors	No. of tries	0.51	0.022
Wrong card selection	No. of tries	0.72	0.001

Correct card selection	No. of tries to complete the first level	-0.625	0.003
No. of categories completed	No. of tries to complete the first level	-0.586	0.007
Other errors in WCST	No. of tries to complete the first level	0.671	0.001
Wrong card selection	No. of tries to complete the first level	0.602	0.005
Correct card selection	Other errors in WCST	-0.788	0.001
No. of categories completed	Other errors in WCST	-0.949	0.001
No. of tries	Other errors in WCST	0.769	0.001
Perseverative errors	Other errors in WCST	0.589	0.006
Wrong card selection	Other errors in WCST	0.896	0.001
No. of categories completed	Perseverative errors	-0.706	0.001
N-Back score	SD. Of reaction time in N-Back	-0.528	0.017
Perseverative errors	SD. Of reaction time in N-Back	0.457	0.043
Reaction time (ms) in N-Back	SD. Of reaction time in N-Back	0.734	0.001
Wrong card selection	SD. Of reaction time in N-Back	0.689	0.001
N-Back score	Selective attention commission errors	-0.495	0.026
No responses in N-Back	Selective attention commission errors	0.514	0.002
Selective attention commission errors	Selective attention correct responses	-0.662	0.001
Selective attention omission errors	Selective attention correct responses	-0.906	0.001
Reaction time (ms) in N-Back	Selective attention reaction time	0.457	0.043
Correct card selection	Wrong card selection	-0.944	0.001
No. of categories completed	Wrong card selection	-0.931	0.001

Table S3. Spearman correlations between each two subscales in non-user controls. In order to find possible functional interactions between subscales, the correlations between each two subscales were calculated by the non-parametric Spearman test. $p < 0.05$ was considered statistically significant.

Subscale	Groups	Mean	Standard deviation	Mean Square	F (df=1)	p-value	Partial eta squared (η_p^2)
No. of categories completed	Case	2.67	1.708	7.554	1.996	0.164	0.038
	Control	3.4	2.257				
Perseverative errors	Case	7.42	4.191	18.263	0.773	0.383	0.015
	Control	6.25	5.711				
Correct responses	Case	32.58	7.408	47.127	0.787	0.379	0.016
	Control	34.35	8.093				
Wrong responses	Case	27.64	7.822	204.397	2.546	0.117	0.052
	Control	23.45	10.405				
No. of tries	Case	59.91	.384	41.898	7.452	0.009**	0.0171
	Control	57.8	3.833				
Other errors	Case	19.91	4.996	72.274	2.456	0.123	0.060
	Control	17.2	5.961				
Total time (s)	Case	261.85	102.087	28011.381	3.594	0.064	0.081
	Control	224.5	62.016				
No. of tries to complete the first level	Case	18.61	16.641	0.648	0.002	0.962	0.002
	Control	17.85	16.503				
Conceptual level responses	Case	2.91	2.887	27.655	3.505	0.067	0.090
	Control	4	2.828				
Failure to continue on a specific pattern	Case	0.36	.742	0.658	1.637	0.207	0.032
	Control	0.15	.366				
Wrong responses	Case	9.94	9.483	77.358	0.891	0.350	0.033
	Control	6.8	8.847				
No response	Case	31.94	28.673	34.014	0.037	0.848	0.002
	Control	29.55	32.157				
Score (Correct responses)	Case	78.12	27.297	213.964	0.227	0.636	0.011
	Control	83.65	35.040				
Reaction time (ms)	Case	607.79	161.807	22229.480	0.925	0.341	0.039
	Control	662.95	140.561				
Selective attention commission errors	Case	6.0779	1.61807	151.316	2.481	0.122	0.180
	Control	6.6295	1.40561				
Selective attention omission errors	Case	8.67	9.993	39.390	0.738	0.394	0.017
	Control	3.25	2.863				
Selective attention	Case	4.42	8.295	345.113	2.453	0.124	0.096
	Control	3	5.068				

correct responses							
Selective attention reaction time (ms)	Case	154.91	14.139	4162.980	0.745	0.392	0.015
	Control	161.75	6.488				
Divided attention commission errors	Case	467	83.851	505.862	1.528	0.222	0.130
	Control	451.15	54.119				
Divided attention omission errors	Case	29.36	21.402	3412.432	11.270	0.002**	0.184
	Control	19.2	12.722				
Divided attention correct responses	Case	29.94	18.979	6671.125	7.902	0.007**	0.170
	Control	14.2	14.406				
Divided attention reaction time (ms)	Case	108.58	31.325	5.360	0.001	0.982	0.088
	Control	134.6	24.106				

Table S4. The multivariate generalized linear model (MGLM) was used to compare the dependent variables of subscales in different tasks between the opioid users and non-users. This model provides a regression analysis and analysis of variance for multiple dependent variables by one or more factor variables or covariates. Mean, standard deviation, level of significance (p-value) and partial et-squared (η_p^2) as the measure for effect size are shown. $p < 0.05$ was considered statistically significant.

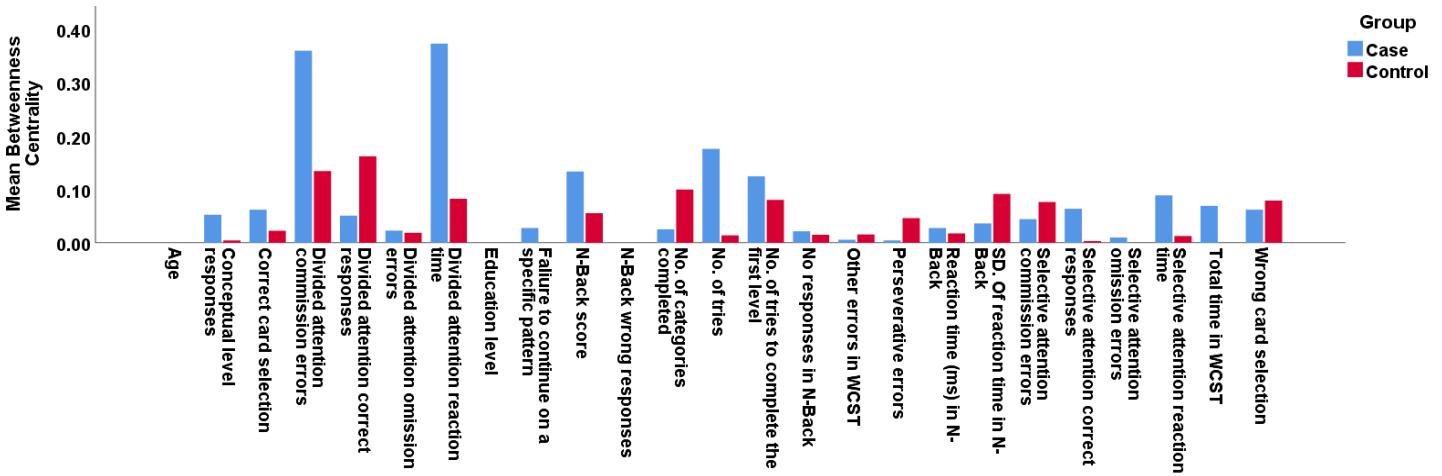


Fig S1. Comparison of the betweenness centrality (C_B) of different test subscales as cognitive network nodes between the subjects with opioid use disorder and non-user controls.

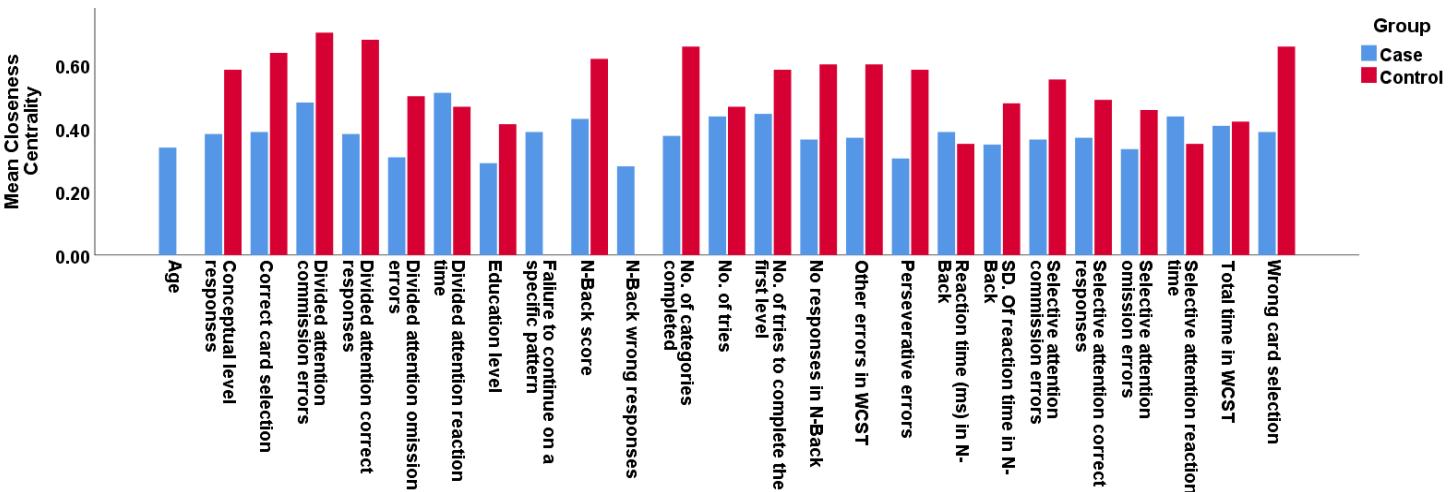


Fig S2. Comparison of the closeness centrality (CC) of different test subscales as cognitive network nodes between the subjects with opioid use disorder and non-user controls.

Group	Interactions	Correlation coefficient	Betweenness centrality	Weight	p-value
Case	No. of tries (interacts with) Divided attention reaction time	0.353	124.2868	43.87324	0.044
Case	Selective attention commission errors (interacts with) Divided attention commission errors	0.725	49.47619	35.87024	0.001
Case	No. of tries to complete the first level (interacts with) Divided attention reaction time	0.366	92.20707	33.74779	0.036
Case	Selective attention reaction time (interacts with) Divided attention reaction time	0.615	45.46544	27.96125	0.001
Case	Reaction time (ms) in N-Back (interacts with) Divided attention reaction time	0.572	42.20353	24.14042	0.001
Case	Selective attention omission errors (interacts with) Selective attention reaction time	0.541	42.1321	22.79347	0.001
Case	Total time in WCST (interacts with) N-Back score	0.359	57.30568	20.57274	0.04
Case	Failure to continue on a specific pattern (interacts with) Divided attention reaction time	0.414	42.20353	17.47226	0.017
Case	Wrong card selection (interacts with) No. of tries	0.404	39.69877	16.0383	0.02
Case	Reaction time (ms) in N-Back (interacts with) SD. Of reaction time in N-Back	0.572	23.65591	13.53118	0.005
Case	Failure to continue on a specific pattern (interacts with) SD. Of reaction time in N-Back	0.488	23.65591	11.54408	0.004
Case	N-Back wrong responses (interacts with) Selective attention commission errors	0.503	22.38095	11.25762	0.003
Case	Correct card selection (interacts with) Education level	0.454	21.8	9.8972	0.008

Case	Selective attention omission errors (interacts with) Divided attention omission errors	0.537	16.79877	9.020939	0.001
Case	Wrong card selection (interacts with) Total time in WCST	0.367	24.51951	8.99866	0.036
Case	Perseverative errors (interacts with) Wrong card selection	0.754	10.68495	8.056452	0.001
Case	No. of tries (interacts with) Other errors in WCST	0.451	16.66667	7.516668	0.008
Case	Other errors in WCST (interacts with) No. of tries to complete the first level	0.4	18.23333	7.293332	0.021
Case	Total time in WCST (interacts with) No. of tries to complete the first level	0.39	17.73333	6.915999	0.025
Case	SD. Of reaction time in N-Back (interacts with) Divided attention omission errors	0.366	18.16897	6.649843	0.036
Case	Correct card selection (interacts with) Conceptual level responses	0.729	7.7	5.6133	0.001
Case	No. of categories completed (interacts with) Conceptual level responses	0.881	5.5	4.8455	0.001
Case	Reaction time (ms) in N-Back (interacts with) Selective attention reaction time	0.433	10.40476	4.505261	0.012
Case	Failure to continue on a specific pattern (interacts with) Selective attention reaction time	0.412	10.40476	4.286761	0.017
Case	Selective attention correct responses (interacts with) Divided attention correct responses	0.681	6.238095	4.248143	0.001
Case	No. of categories completed (interacts with) Correct card selection	0.752	4.533333	3.409066	0.001
Case	Wrong card selection (interacts with) Other errors in WCST	0.626	5.366667	3.359534	0.001
Case	Failure to continue on a specific pattern (interacts	0.477	2	0.954	0.005

	with) Reaction time (ms) in N-Back				
Case	No. of categories completed (interacts with) Other errors in WCST	-0.714	2.5	-1.785	0.001
Case	Correct card selection (interacts with) Wrong card selection	-0.974	2	-1.948	0.001
Case	Perseverative errors (interacts with) Education level	-0.518	4.4	-2.2792	0.002
Case	Selective attention commission errors (interacts with) Age	-0.373	8	-2.984	0.033
Case	Correct card selection (interacts with) Other errors in WCST	-0.62	5.366667	-3.32733	0.001
Case	No. of categories completed (interacts with) Wrong card selection	-0.774	4.533333	-3.5088	0.001
Case	Other errors in WCST (interacts with) Conceptual level responses	-0.694	6	-4.164	0.001
Case	Selective attention commission errors (interacts with) Selective attention correct responses	-0.817	5.166667	-4.22117	0.001
Case	Wrong card selection (interacts with) Conceptual level responses	-0.743	7.7	-5.7211	0.001
Case	No. of categories completed (interacts with) Perseverative errors	-0.456	13.47849	-6.14619	0.008
Case	Perseverative errors (interacts with) Conceptual level responses	-0.524	13.55161	-7.10104	0.002
Case	SD. Of reaction time in N-Back (interacts with) Divided attention correct responses	-0.35	22.47619	-7.86667	0.046
Case	Selective attention commission errors (interacts with) Divided attention correct responses	-0.681	11.7381	-7.99365	0.001
Case	Perseverative errors (interacts with) Correct card selection	-0.79	10.68495	-8.44111	0.001

Case	Wrong card selection (interacts with) Education level	-0.429	21.8	-9.3522	0.013
Case	Correct card selection (interacts with) Total time in WCST	-0.384	24.51951	-9.41549	0.027
Case	No. of categories completed (interacts with) No. of tries to complete the first level	-0.417	23.65591	-9.86451	0.016
Case	No. of categories completed (interacts with) No. of tries	-0.476	21.55591	-10.2606	0.005
Case	N-Back wrong responses (interacts with) Selective attention correct responses	-0.426	25.61905	-10.9137	0.013
Case	Conceptual level responses (interacts with) No responses in N-Back	-0.353	32.20046	-11.3668	0.044
Case	Divided attention omission errors (interacts with) Divided attention correct responses	-0.748	15.46851	-11.5704	0.001
Case	Selective attention correct responses (interacts with) Divided attention omission errors	-0.535	22.70661	-12.148	0.001
Case	Selective attention reaction time (interacts with) Divided attention commission errors	-0.386	37.47619	-14.4658	0.027
Case	Correct card selection (interacts with) No. of tries	-0.365	39.69877	-14.4901	0.037
Case	Divided attention commission errors (interacts with) Age	-0.377	40	-15.08	0.03
Case	No. of tries to complete the first level (interacts with) Conceptual level responses	-0.485	33.25115	-16.1268	0.004
Case	Selective attention correct responses (interacts with) Divided attention commission errors	-0.526	58.4447	-30.7419	0.002
Case	No responses in N-Back (interacts with) N-Back score	-0.944	39.53379	-37.3199	0.001
Case	N-Back score (interacts with) Divided attention commission errors	-0.381	98.17281	-37.4038	0.029

Case	Divided attention commission errors (interacts with) Divided attention correct responses	-0.808	47.96851	-38.7586	0.001
Case	Divided attention commission errors (interacts with) Divided attention reaction time	-0.514	112.9071	-58.0342	0.002
Control	Reaction time (ms) in N-Back (interacts with) SD. Of reaction time in N-Back	0.734	42.7619	31.38723	0.001
Control	Selective attention reaction time (interacts with) Divided attention reaction time	0.707	38.57143	27.27	0.001
Control	Wrong card selection (interacts with) SD. Of reaction time in N-Back	0.689	30.23175	20.82968	0.001
Control	No. of categories completed (interacts with) Education level	0.444	34.4	15.2736	0.05
Control	Divided attention commission errors (interacts with) Divided attention omission errors	0.578	17.80159	10.28932	0.008
Control	Perseverative errors (interacts with) SD. Of reaction time in N-Back	0.457	21.52698	9.83783	0.043
Control	No. of categories completed (interacts with) Divided attention correct responses	0.548	17.85574	9.784946	0.012
Control	Selective attention correct responses (interacts with) Divided attention correct responses	0.73	12.46032	9.096034	0.001
Control	Wrong card selection (interacts with) No. of tries	0.72	12.29281	8.850823	0.001
Control	Selective attention omission errors (interacts with) Divided attention commission errors	0.448	19.61111	8.785777	0.048
Control	Perseverative errors (interacts with) Divided attention commission errors	0.579	15.00812	8.689701	0.008
Control	Wrong card selection (interacts with) Divided attention commission errors	0.715	10.27796	7.348741	0.001

Control	N-Back score (interacts with) Divided attention correct responses	0.519	13.57381	7.044807	0.019
Control	Selective attention commission errors (interacts with) Divided attention omission errors	0.533	12.5381	6.682807	0.015
Control	No. of tries to complete the first level (interacts with) Divided attention commission error	0.504	13.20794	6.656802	0.023
Control	Wrong card selection (interacts with) No. of tries to complete the first level	0.602	10.93571	6.583297	0.005
Control	Reaction time (ms) in N-Back (interacts with) Selective attention reaction time	0.457	13.90476	6.354475	0.043
Control	No. of tries (interacts with) Other errors in WCST	0.769	7.701961	5.922808	0.001
Control	Selective attention commission errors (interacts with) Divided attention commission errors	0.514	11.44379	5.882108	0.02
Control	Other errors in WCST (interacts with) No. of tries to complete the first level	0.671	8.710317	5.844623	0.001
Control	Other errors in WCST (interacts with) Divided attention commission errors	0.693	7.803361	5.407729	0.001
Control	Correct card selection (interacts with) Divided attention correct responses	0.505	10.35574	5.229649	0.023
Control	No responses in N-Back (interacts with) Selective attention commission errors	0.514	9.359477	4.810771	0.002
Control	Total time in WCST (interacts with) Divided attention omission errors	0.554	8.5	4.709	0.011
Control	Perseverative errors (interacts with) No. of tries	0.51	9.175163	4.679333	0.022
Control	Conceptual level responses (interacts with) Divided attention correct responses	0.462	9.690476	4.477	0.04

Control	Wrong card selection (interacts with) Other errors in WCST	0.896	4.84127	4.33778	0.001
Control	No. of categories completed (interacts with) Conceptual level responses	0.857	5.019048	4.301324	0.001
Control	No. of categories completed (interacts with) N-Back score	0.475	8.817647	4.188382	0.034
Control	Perseverative errors (interacts with) Correct card selection	0.886	4.646825	4.117087	0.001
Control	Perseverative errors (interacts with) No responses in N-Back	0.526	6.72479	3.53724	0.017
Control	Perseverative errors (interacts with) Other errors in WCST	0.589	5.93254	3.494266	0.006
Control	No. of tries to complete the first level (interacts with) No responses in N-Back	0.447	6.729365	3.008026	0.048
Control	Correct card selection (interacts with) N-Back score	0.528	5.517647	2.913318	0.017
Control	No responses in N-Back (interacts with) Divided attention commission errors	0.579	4.904762	2.839857	0.007
Control	Wrong card selection (interacts with) No responses in N-Back	0.521	5.244631	2.732453	0.019
Control	Selective attention omission errors (interacts with) Divided attention omission errors	0.611	4.3	2.6273	0.004
Control	No. of categories completed (interacts with) Correct card selection	0.868	3	2.604	0.001
Control	Correct card selection (interacts with) Conceptual level responses	0.809	3.019048	2.44241	0.001
Control	Other errors in WCST (interacts with) Conceptual level responses	-0.824	2.4	-1.9776	0.001
Control	Correct card selection (interacts with) No responses in N-Back	-0.546	3.689076	-2.01424	0.013

Control	Correct card selection (interacts with) Other errors in WCST	-0.788	2.619048	-2.06381	0.001
Control	Selective attention correct responses (interacts with) Divided attention omission errors	-0.712	3	-2.136	0.001
Control	Wrong card selection (interacts with) N-Back score	-0.505	4.406536	-2.2253	0.023
Control	Perseverative errors (interacts with) N-Back score	-0.56	4.931139	-2.76144	0.01
Control	Selective attention omission errors (interacts with) Selective attention correct responses	-0.906	3.3	-2.9898	0.001
Control	No. of categories completed (interacts with) No responses in N-Back	-0.503	6.189076	-3.11311	0.024
Control	Correct card selection (interacts with) Wrong card selection	-0.944	3.555556	-3.35644	0.001
Control	No. of categories completed (interacts with) Other errors in WCST	-0.949	3.619048	-3.43448	0.001
Control	Divided attention commission errors (interacts with) Divided attention correct responses	-0.873	4.071429	-3.55436	0.001
Control	No. of tries (interacts with) Education level	-0.469	7.6	-3.5644	0.037
Control	No. of tries to complete the first level (interacts with) Conceptual level responses	-0.489	7.376984	-3.60735	0.029
Control	No responses in N-Back (interacts with) N-Back score	-0.969	3.733333	-3.6176	0.001
Control	Perseverative errors (interacts with) Conceptual level responses	-0.573	6.33254	-3.62855	0.008
Control	Correct card selection (interacts with) No. of tries	-0.452	8.937255	-4.03964	0.045
Control	Wrong card selection (interacts with) Conceptual level responses	-0.787	5.24127	-4.12488	0.001
Control	Perseverative errors (interacts with) Correct card selection	-0.898	4.646825	-4.17285	0.001

Control	Conceptual level responses (interacts with) Divided attention commission errors	-0.635	6.619048	-4.2031	0.003
Control	No responses in N-Back (interacts with) Divided attention correct responses	-0.569	7.97619	-4.53845	0.009
Control	No. of categories completed (interacts with) Perseverative errors	-0.706	6.446825	-4.55146	0.001
Control	N-Back score (interacts with) Divided attention commission errors	-0.52	8.771429	-4.56114	0.019
Control	Correct card selection (interacts with) Divided attention commission errors	-0.719	6.684314	-4.80602	0.001
Control	No. of categories completed (interacts with) Wrong card selection	-0.931	5.355556	-4.98602	0.001
Control	Correct card selection (interacts with) No. of tries to complete the first level	-0.625	8.824603	-5.51538	0.003
Control	No. of categories completed (interacts with) No. of tries	-0.696	7.937255	-5.52433	0.001
Control	Other errors in WCST (interacts with) Divided attention correct responses	-0.539	11.47479	-6.18491	0.014
Control	Selective attention commission errors (interacts with) Selective attention correct responses	-0.662	9.538095	-6.31422	0.001
Control	N-Back score (interacts with) Selective attention commission errors	-0.495	14.59757	-7.2258	0.026
Control	Wrong card selection (interacts with) Divided attention correct responses	-0.523	15.85812	-8.2938	0.018
Control	No. of categories completed (interacts with) No. of tries to complete the first level	-0.586	14.8246	-8.68722	0.007
Control	Selective attention commission errors (interacts with) Divided attention correct responses	-0.59	14.77059	-8.71465	0.006
Control	No. of categories completed (interacts with)	-0.723	12.18431	-8.80926	0.001

	Divided attention commission errors				
Control	Selective attention omission errors (interacts with) Divided attention correct responses	-0.601	14.78889	-8.88812	0.005
Control	Selective attention correct responses (interacts with) Divided attention commission errors	-0.577	16.30159	-9.40602	0.008
Control	Divided attention omission errors (interacts with) Divided attention correct responses	-0.902	11.46032	-10.3372	0.001
Control	N-Back score (interacts with) SD. Of reaction time in N-Back	-0.528	24.11429	-12.7323	0.017
Control	Selective attention commission errors (interacts with) Divided attention reaction time	-0.452	33.77143	-15.2647	0.045
Control	Total time in WCST (interacts with) Divided attention correct responses	-0.477	33.5	-15.9795	0.033
Control	No. of tries to complete the first level (interacts with) Divided attention reaction time	-0.475	38.8	-18.43	0.034

Table S5. Analytical characteristics of the links for different test subscales in opioid users

and non-user controls. Mathematical parameters such as betweenness centrality (C_B), interaction effects between each two subscales and their correlation coefficient as well as the level of significance (p -value) are provided. Weight of each link in the interactive network reconstruction is calculated by multiplication of C_B and the correlation coefficient. Descending weight measures is set as the table order. $p < 0.05$ was considered statistically significant.