



Provided by the author(s) and University of Galway in accordance with publisher policies. Please cite the published version when available.

Title	Structural connectivity and rich-club organization in recent onset psychosis
Author(s)	Forcellini, Giulia; O'Donoghue, Stefani; Kenney, Joanne; McInerney, Shane; Scanlon, Cathy; Nabulsi, Leila; McPhilemy, Genevieve; Kilmartin, Liam; O'Hora, Denis; Hallahan, Brian; Cannon, Dara M.; McDonald, Colm
Publication Date	2017-05-17
Publication Information	Forcellini, Giulia, O'Donoghue, Stefani, Kenney, Joanne, McInerney, Shane, Scanlon, Cathy, Nabulsi, Leila, McPhilemy, Genevieve, Kilmartin, Liam, O'Hora, Denis, Hallahan, Brian, Cannon, Dara A. , McDonald, Colm. Structural connectivity and rich-club organization in recent onset psychosis. Schizophrenia Research. doi: 10.1016/j.schres.2017.05.018
Publisher	Elsevier
Link to publisher's version	http://dx.doi.org/10.1016/j.schres.2017.05.018
Item record	http://hdl.handle.net/10379/6570
DOI	http://dx.doi.org/10.1016/j.schres.2017.05.018

Downloaded 2023-03-31T19:46:06Z

Some rights reserved. For more information, please see the item record link above.



Structural connectivity and rich-club organization in recent onset psychosis

Authors: Giulia Forcellini^{a*}, Stefani O'Donoghue^a, Joanne Kenney^a, Shane McInerney^{a,b,c}, Cathy Scanlon^a, Leila Nabulsi^a, Genevieve McPhilemy^a, Liam Kilmartin^d, Denis O'Hora^e, Brian Hallahan^a, Dara M. Cannon^a, and Colm McDonald^a.

Authors Affiliations: ^a Centre for Neuroimaging & Cognitive Genomics (NICOG), Clinical Neuroimaging Laboratory, NCBES Galway Neuroscience Centre, College of Medicine Nursing and Health Sciences, National University of Ireland Galway, Galway, Republic of Ireland; ^b Faculty of Medicine, Department of Psychiatry, University of Toronto, Toronto, Ontario, Canada; ^c Department of Psychiatry, University of Toronto, Toronto, Ontario, Canada; ^d College of Engineering and Informatics, National University of Ireland, Galway; ^e School of Psychology, National University of Ireland Galway, Galway, Republic of Ireland.

*Corresponding Author: Centre for Neuroimaging & Cognitive Genomics (NICOG), Clinical Neuroimaging Laboratory, NCBES Galway Neuroscience Centre, College of Medicine Nursing and Health Sciences, National University of Ireland Galway, H91 TK33 Galway, Ireland.

Phone number: +353 (0)91 750486

Email address: giuliafor.91@gmail.com

Address for correspondence:

Clinical Neuroimaging Laboratory,
202 Comerford Suite, Clinical Science Institute,
National University of Ireland Galway, Galway, Ireland

Dear Editors,

Studying psychosis in its early stages is important to better understand illness progression and any associated neuroanatomical change. Growing evidence suggests that abnormal structural connectivity may represent a biological marker of psychosis, with altered organization reported both at a prodromal and an early stage of the disorder (Schmidt et al., 2016; Zhang et al., 2015). Through the implementation of a graph theoretical approach, it is possible to investigate in detail how specific brain regions are integrated, segregated or central in the whole-brain structural network (Sporns, 2012). We addressed local graph topological properties in a number of regions previously found to be implicated in early psychosis (Ellison-Wright et al., 2008) in order to clarify the collective role of such nodes in patients at an early stage of the disorder, approximately three years after their first psychotic episode. Furthermore, we investigated the organization of rich-club structures, consisting of highly central and densely interconnected regions considered to have a key role in interregional brain communication and integration (van den Heuvel & Sporns, 2011).

Diffusion tensor imaging (DTI) datasets employing the identical acquisition parameters as per O'Donoghue et al. (2017) were obtained from 26 patients with recent onset psychosis (ROP; 17 males, mean age 31.9, SD=9), who were scanned approximately 3 years after their first presentation, and 26 healthy controls (HC; 15 males, mean age 37.9, SD=9). Participants' recruitment and more detailed clinical characteristics are outlined in Kenney et al. (2015). Network graphs were weighted by number of streamlines (NOS), fractional anisotropy (FA) and rich-club coefficients derived as outlined previously (O'Donoghue et al., 2017)

The two groups were gender matched, but significantly differed for age ($t=2.335$, $p=0.024$), with ROP being younger than HC. Symptoms severity in patients was assessed using the Positive and Negative Syndrome Scale (PANSS, total= 43 ± 13). MANCOVA tests, covaried for age and gender, were performed across groups for local graph metrics in a priori selected nodes of interest. Results are outlined in table 1. Specifically, two nodes of interest presented significant connectivity differences that survived multiple comparison correction, in NOS but not FA-weighted networks. The left amygdala revealed an increased clustering coefficient in ROP compared to HC, whereas the left anterior cingulate (ACG) presented a decrease in betweenness centrality in patients. An increase in

the clustering coefficient of the left amygdala that did not survive multiple comparison correction was evident also in FA-weighted networks.

Both groups presented a rich-club organization, with normalized weighted rich club coefficient ($\Phi_{W_{norm}}$) > 1 . However, the rich-club organization in ROP revealed subtle abnormalities in patients, with the right thalamus missing and the left middle occipital gyrus (MOG) additionally recruited relative to healthy controls. The rich clubs organization of both groups otherwise involved bilateral caudate, hippocampus, putamen, precuneus, and the left thalamus.

Applying this novel network analysis, we identified local brain topology abnormalities early in the course of psychosis, particularly affecting the limbic system. This is consistent with the regional pattern of deficits previously reported in the early stages of schizophrenia (Ellison-Wright et al., 2008). Disrupted integration of the ACG in ROP might lead to aberrant emotional and cognitive preprocessing, whereas an increase in the efficiency and integration of the amygdala may reflect an overactive response to emotional stimuli in psychosis. Furthermore, the subtle anomalies found the rich-club organization in psychotic patients might represent deficits in global brain communication already present at this stage of the disorder. Importantly, the thalamus is a key hub in global communication, and its disrupted connectivity could contribute to broader symptomatology and will be important to investigate in future studies. In contrast, the involvement of the MOG in the rich-club structure has been recently reported in bipolar patients (O'Donoghue et al., 2017), potentially representing a compensatory effect from early integration impairments.

It is important to highlight that our cohort comprises patients who experienced their first psychotic episode 3 years prior to scanning, with variable levels of recovery, and most were taking psychotropic medications. These factors, together with the clinical heterogeneity of our sample, consisting of patients with affective and non-affective psychosis, might have obscured our ability to detect topological and global abnormalities specific to schizophrenia or bipolar disorder.

This structural connectivity analysis represents a promising approach for the characterization of dysconnectivity in psychosis. Taken together, our findings indicate the existence of subtle connectivity deficits at an early stage of the disorder, specifically involving limbic structures, which might represent trait features for psychosis.

Table 1. Local connectivity differences between HC and ROP, covaried for age and gender.

Nodes		Clustering coefficient F, p		Local Efficiency F, p		Betweenness Centrality F, p	
		NOS-weighted	FA-weighted	NOS-weighted	FA-weighted	NOS-weighted	FA-weighted
Insula	Left	0.001, 0.980	0.207, 0.651	0.062, 0.805	0.335, 0.566	0.467, 0.498	0.004, 0.949
	Right	0.579, 0.450	0.115, 0.736	0.311, 0.580	0.040, 0.843	1.101, 0.300	3.638, 0.063
Anterior Cingulate	Left	0.365, 0.566	0.089, 0.766	0.094, 0.761	0.242, 0.625	10.609, 0.002**	2.633, 0.112
	Right	2.026, 0.161	0.349, 0.557	1.872, 0.178	0.278, 0.601	0.222, 0.640	0.017, 0.898
Amygdala	Left	11.040, 0.002**	4.127, 0.048*	9.122, 0.004*	3.080, .086	2.567, 0.116	1.908, 0.174
	Right	2.017, 0.162	0.006, 0.937	0.488, 0.488	0.313, 0.578	4.443, 0.041*	0.094, 0.760
Postcentral gyrus	Left	0.460, 0.501	0.000, 0.983	0.476, 0.493	0.019, 0.891	5.840, 0.020*	0.539, 0.466
	Right	0.338, 0.564	0.486, 0.489	0.103, 0.750	0.409, 0.526	0.000, 0.991	2.831, 0.099
Supramarginal gyrus	Left	0.138, 0.712	0.005, 0.944	0.062, 0.805	0.250, 0.620	1.513, 0.225	1.154, 0.289
	Right	1.452, 0.234	4.427, 0.041*	1.898, 0.175	1.604, 0.211	1.724, 0.197	0.977, 0.329
Putamen	Left	0.614, 0.437	0.186, 0.668	1.669, 0.203	0.109, 0.742	0.255, 0.616	0.104, 0.748
	Right	3.647, 0.062	0.560, 0.458	3.834, 0.056	0.107, 0.745	0.642, 0.427	0.255, 0.616
Thalamus	Left	0.020, 0.887	0.102, 0.751	0.364, 0.549	0.221, 0.640	2.181, 0.146	0.013, 0.909
	Right	1.499, 0.227	1.101, 0.299	2.102, 0.154	0.172, 0.680	0.229, 0.634	0.011, 0.917
Caudate	Left	1.382, 0.246	0.070, 0.792	2.107, 0.153	0.005, 0.946	0.394, 0.533	0.380, 0.540
	Right	1.619, 0.209	0.921, 0.342	1.393, 0.153	0.255, 0.616	2.417, 0.126	0.039, 0.843

* Significant differences that did not survive FDR correction; ** Significant differences that survived FDR correction.

REFERENCES

- Ellison-Wright, I., Glahn, D. C., Laird, A. R., Thelen, S. M., & Bullmore, E., 2008. The anatomy of first-episode and chronic schizophrenia: An anatomical likelihood estimation meta-analysis. *American Journal of Psychiatry*, 165(8), 1015–1023.
- Kenney, J., Anderson-Schmidt, H., Scanlon, C., Arndt, S., Scherz, E., McInerney, S., McFarland, J., Byrne, F., Ahmed, M., Donohoe, G., Hallahan, B., McDonald, C., Cannon, D. M., 2015. Cognitive course in first-episode psychosis and clinical correlates: A 4year longitudinal study using the MATRICS Consensus Cognitive Battery. *Schizophrenia Research*, 169(1-3), 101–108.
- O'Donoghue, S., Kilmartin, L., O'Hora D., Emsell, L., Langan, C., McInerney, S., Forde, N., Leemans, A., Jeurissen, B., Barker, G., McCarthy, P., Cannon, D.M., McDonald, C., 2017. Anatomical integration and rich-club connectivity in euthymic bipolar disorder. *Psychological Medicine*, 1-15.
- Schmidt, A., Crossley, N.A., Harrisberger, F., Smieskova, R., Lenz, C., Riecher-Rössler, A., Lang, U.E., McGuire, P., Fusar-Poli, P., Borgwardt, S., 2016. Structural network disorganization in subjects at clinical high risk for psychosis. *Schizophrenia Bulletin*, p.sbw110.
- Sporns, O., 2012. From simple graphs to the connectome: Networks in neuroimaging. *NeuroImage*, 62(2).
- van den Heuvel, M. P., & Sporns, O., 2011. Rich-Club Organization of the Human Connectome. *Journal of Neuroscience*, 31(44), 15775–15786.
- Zhang, R., Wei, Q., Kang, Z., Zalesky, A., Li, M., Xu, Y., Li, L., Wang, J., Zheng, L., Wang, B., Zhao, J., Zhang, J., Huang, R., 2015. Disrupted brain anatomical connectivity in medication-naïve patients with first-episode schizophrenia. *Brain Structure & Function*, 220(2), 1145–1159.