Changes in the structure of spontaneous speech predict the disruption of hierarchical brain organization in first-episode psychosis

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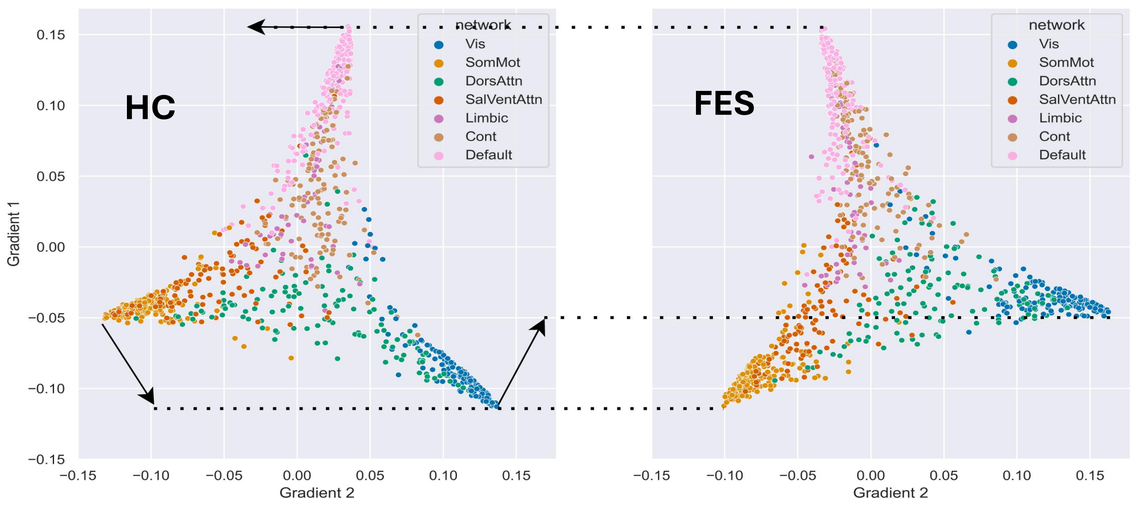
Motivation and materials

Psychosis implicates changes across a broad range of cognitive functions, which are cortically organized in a hierarchy ranging from primary sensorimotor (unimodal) to higher-order association cortices. Language has long been documented as undergoing structural changes in psychosis. We hypothesized that these changes as revealed in spontaneous speech may act as readouts of alterations in the configuration of this unimodal-to-transmodal axis. We employed 7T resting-state fMRI and spontaneous speech elicited by picture description tasks from 29 first-episode schizophrenia (FES) with 29 matched controls to investigate such hypothesis.

Gradient construction

FC matrix → Threshold 90% → Sparsified → affinity = cos<ROI_i, ROI_j> → Affinity → Diffusion Mapping

1. Large-scale cortex-wise gradient

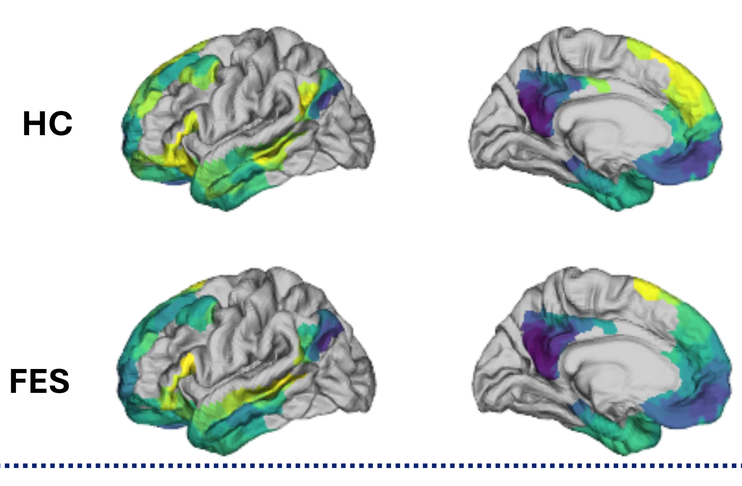


G1: Visual/Somatomotor -> Default mode

G2: Visual -> Somatomotor

SMN-DMN * VN-DMN * VN-SMN

2. Gradient within the semantic network



G1: Frontal-parietal cortex -> Medial cortex

Semantic G1 *

Language structure

Transcripts → Utterance division → List of utterances

Transcripts → Part of speech (Noun, verbs, adjectives) → List of Lexical categories

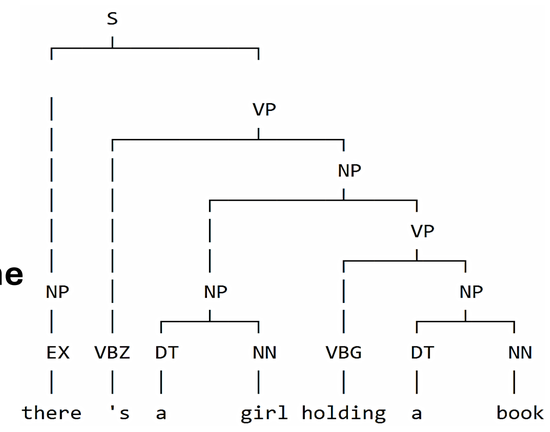
Constituency parser → Language models

1. Syntactic structure of sentence

Quantity:
- Number of words
- Number of nodes
- Number of phrases per word

Syntactic depth:
The number of edges between the S node and each word
- Maximum depth
- Averaged depth
- Approximate entropy: predictability

Predicate-argument:
- Number and length of noun phrases (NP) and nested NPs
- Number and length of verb phrases (VP) and nested VPs



In FES:
- Sentence length as a covariate
- More phrases per word
- Depth: higher and more predictable
- Less and shorter NPs
- More but shorter VPs

2. Semantic graph of discourse

Integration:
- Closeness centrality (CC)
- Global efficiency (GE)

Segregation:
- Clustering coefficient

Balance:
- Small-worldness coefficient (sigma)

Semantic similarity matrix → Dynamic threshold → Semantic graph

In FES:
- Node count as a covariate
- CC&GE: significantly higher centrality
- Clusters: insignificant more clusters
- Lower sigma: disrupted small-world structure

Correlation between brain gradient and language structure

	Nodes	Phrase_fraction	Depth	DepthMean	DepthApEn	NP_count	NP_nest	NP_length	VP_count	VP_nest	VP_length	FT_CC	FT_GE	FT_Clustering	FT_Sigma	ST_CC	ST_GE	ST_Clustering	ST_Sigma
VN_DMN	0.354	-0.523	0.055	0.081	-0.130	0.613	0.797	0.375	0.062	-0.152	0.210	1.600	1.746	0.622	-2.531*	2.393*	2.459*	3.690***	-1.976*
SMN_DMN	0.777	-0.345	0.780	0.892	0.561	1.038	1.252	1.240	0.577	0.776	1.521	0.563	0.650	-0.148	-1.573	1.838	1.994	2.837*	-0.881
VN_SMN	0.063	-0.095	0.036	0.046	-0.305	0.098	0.369	-0.036	-0.210	-0.820	0.203	0.111	0.040	-0.002	-0.471	0.032	0.087	0.613	0.437
SemN_G1	2.358*	1.933	2.296*	2.331*	0.451	1.523	0.350	0.046	2.235*	2.299*	1.809	-0.248	-0.210	-0.230	-0.214	0.799	0.782	0.723	-0.149

- The principal gradient of the whole cortex as indexed by VN-DMN dispersion and SMN-DMN dispersion is related to the topology of semantic graphs.
- The principal gradient of the semantic network is related to the structure of syntactic tree and properties of verb phrases.

Acknowledgement

We appreciate all the participants and their families for the time and effort to contribute to this study. Funded by the European Union (GA 101080251 - TRUSTING). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Agency. Neither the European Union nor the granting authority can be held responsible for them.

Affiliations and funding

Universitat Pompeu Fabra Barcelona · GRAC Grammar & Cognition Lab · ICREA · China Scholarship Council

Funded by the European Union · TRUSTING · DISCOURSE IN PSYCHOSIS