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# Social cognition, neurocognition, symptomatology, functional competences and outcomes in people with schizophrenia – A network analysis perspective

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ABSTRACT

*Background:* Extensive difficulties in reaching functional milestones characterize schizophrenia and related psychotic disorders. These impairments are in part explained by lower social cognitive abilities, cognitive impairment, and current psychopathology. The present study aims to model dynamic associations among social cognition, neurocognition, psychopathology, social skills, functional capacity, and functional outcomes in schizophrenia using network analysis in order to identify those factors that are most central to functioning.
*Methods:* The sample consisted of 408 patients with schizophrenia spectrum disorders who were drawn from the SCOPE project. Participants completed a complex battery of state-of-the-art measures of social cognition, neurocognition, and functional outcomes. Gaussian Graphical Modeling was used for estimation of the network structure. Accuracy of the network was evaluated using the Bootstrap method.
*Results:* Data supported the importance of functional capacity and social skills, which are prerequisites to real - world outcomes. These variables were among the most central in the network. Social cognition was related to functional capacity, social skills, and real - world functioning. Negative symptoms were connected to functional capacity, social skills, and real - world functioning.
*Conclusions:* Predictors of functional outcomes are complexly associated with each other. Functional capacity, social - skills, working memory, negative symptoms, mentalizing, and emotion recognition were central nodes that support their importance as potential targets of personalized intervention.

## 1. Introduction

Schizophrenia, a disorder characterized by extensive heterogeneity in clinical manifestation (Tandon et al., 2009), often leads to functional disability, and a substantial portion of patients are unable to achieve complete symptom and functional recovery (Jääskeläinen et al., 2013). Untangling the interplay among factors contributing to functional disability in schizophrenia spectrum disorders requires considering many variables spanning from psychopathology, cognitive and social - cognitive deficits, and personal resources (Galderisi et al., 2018, 2020).

For example, negative symptoms have robust associations with lower levels of functioning across several domains, from interpersonal relationships to work-related skills (Bowie et al., 2010; Galderisi et al., 2013), and avolition - apathy is a stronger predictor of less favorable outcomes than diminished emotion expression (Strauss et al., 2013). Cognitive impairment is also prevalent among patients (Palmer et al., 1997; Reichenberg et al., 2009), and its severity is a well-known risk factor for difficulties in vocational functioning and other real-world

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outcomes (Green et al., 2000). Patients with better cognitive functioning show higher functional capacity which might be considered a prerequisite for successful execution of day - to - day tasks (Harvey and Strassnig, 2012). Finally, social cognition, predominantly theory of mind/mentalizing and emotion recognition, predict functional outcomes above and beyond the effect of neurocognition (Couture et al., 2006; Fett et al., 2011) and can be considered as mediators of the association between neurocognition and real - world functioning (Halverson et al., 2019).

In sum, each of the above-mentioned variables independently explains a substantial portion of the variability in functional outcomes. However, the majority of previous studies have not thoroughly analyzed the potential complex associations among these various predictors of functional outcomes. Only two studies have modeled associations among a substantial number of predictors using an advanced statistical method called network analysis. Data from both studies are from the Italian Network for Research on Psychoses study, a multicentric study on a large sample of patients with schizophrenia. Results from baseline and follow up assessment robustly highlighted the central role of functional capacity in the estimated networks (Galderisi et al, 2018, 2020). Functional capacity was linked to real - word functional outcomes, neurocognition, and social cognitive abilities. Among the most central nodes in the estimated networks was working memory impairment, which is considered a hallmark feature of schizophrenia (Silver et al., 2003). Contrary to previous findings, social cognition was not directly related to real - world functioning, which might be explained by shortcomings of the tasks used for measuring social cognition and omitting a task measuring social - skills (Hajdúk and Pinkham, 2018). Until now, these results have not been replicated on an independent sample in a different cultural context using a well-validated social cognitive battery.

The present study aims to model the dynamic associations among social cognition, neurocognition, psychopathology, and functional outcomes in schizophrenia using network analysis. Here, we adapt this approach to: (1) estimate the overall structure of relationships between social and neurocognition, functional capacity, and functional outcomes, (2) to estimate the relative importance of particular nodes (centrality), and (3) to provide the first conceptual replication and expansion of influential early studies in this area (Galderisi et al, 2018, 2020) using a sufficiently large sample from a different cultural context.

## 2. Methods

### 2.1. Sample

The final sample was drawn from the large - scale, multisite Social Cognition Psychometric Evaluation (SCOPE) project, which evaluated the psychometric properties of social - cognitive measures in patients with schizophrenia (Ludwig et al., 2017; Pinkham et al, 2016, 2018). We used data from all phases of the project (N = 408). General inclusion criteria were age 18–65 and diagnosis of schizophrenia spectrum disorder. Diagnosis was confirmed by Mini International Neuropsychiatric Interview (Sheehan et al., 1998) and Structured Clinical Interview for DSM -IV Disorders - Psychosis module (First et al., 2012). General exclusion criteria for all participants were the following: (1) presence or history of intellectual disability (ID) (defined as IQ < 70), (2) presence or history of medical or neurological disorders that may affect brain function (e.g. uncontrolled hypertension, history of seizures, head trauma with unconsciousness for more than 15 min), (3) visual or hearing limitation that would interfere with assessment, and (4) current substance use disorder, except for nicotine. Detailed information about recruitment of patients can be found in following publications (Ludwig et al., 2017; Pinkham et al, 2016, 2018).

The study was approved by the ethical review boards of University of Texas at Dallas, University of North Carolina, and University of Miami. All participants provided written informed consent prior to study participation.

### 2.2. Measures

#### 2.2.1. Social cognition

We administered a comprehensive battery of previously validated social - cognitive measures (i.e., Hinting Task (Corcoran et al., 1995), Reading the Mind in the Eyes Test (Baron-Cohen et al., 1997), The Awareness of Social Inference Test (McDonald et al., 2003), Penn Emotional Recognition Task (Kohler et al., 2003), and Bell - Lysaker Emotion Recognition Test (Bryson et al., 1997)). These five social - cognitive measures were administered across all phases of the SCOPE project and were recommended as measures showing promising psychometric properties (Pinkham et al, 2016, 2018). Only these measures were included in the analysis.

#### 2.2.2. Cognition, social skill and functional capacity, functional outcomes, and psychopathology

Neurocognition was measured with an abbreviated MCCB - MATRICS neuropsychological battery (Nuechterlein et al., 2008) that included Trail Making Test-Part A, BACS-Symbol Coding, Category Fluency-Animal Naming, Letter-Number Span, and the Hopkins Verbal Learning Test-Revised. The UCSD Performance - Based Measure UPSA-B (Mausbach et al., 2011) and Social Skills Performance - Based Assessment - SSPA (Patterson et al., 2001) constituted functional and social competence assessments, respectively. The Specific Levels of Functioning (SLOF (Schneider and Struening, 1983); was used for assessment of real-world functional outcomes. We used informant ratings (close caregivers, clinicians, research assistants) for SLOF; if missing (N = 3), we imputed available self - report data instead. Psychopathology was assessed with the Positive and Negative Syndrome Scale (Kay et al., 1987).

#### 2.2.3. Statistical analysis

A network approach in psychopathology research models symptoms as a dynamic network consisting of nodes, representing the symptoms themselves, and edges, which quantify the magnitude of mutual statistical relationships among nodes in the estimated network (Borsboom, 2017; Borsboom and Cramer, 2013). The current study used Regularized Gaussian Graphical Model (GGM) to estimate the overall structure (associations between nodes) of the network. Displayed edges are partial correlation coefficients after accounting for the effect of all other variables in the network. Thicker edges indicate stronger associations. The EBIC Lasso (Chen and Chen, 2008) procedure was used to control for spurious associations (regularization), and the process of network estimation followed state - of - the art recommendations for network construction (Epskamp et al., 2018). To evaluate accuracy of the estimated network we utilized the Bootstrap method on the 1000 samples. Centrality estimates are considered stable if they are strongly correlated ($r > 0.7$) when estimated from the subset of the sample. We utilized recommended cut – offs for Coefficient Stability (CS) coefficient (minimum $CS > 0.25$, optimal $CS > 0.5$).

Networks were estimated using R packages *qgraph* (Epskamp et al., 2012) and *bootnet* (Epskamp and Fried, 2017). In our network, we used blue lines to depict positive relationships and red lines for negative relationships. The Fruchterman - Reingold algorithm was used for displaying nodes and edges. We focused on three centrality estimates:

- Strength - magnitude of direct relationships with other nodes.
- Closeness - magnitude of indirect relationships with other nodes in the network.
- Betweenness - whether a node lies along the shortest path between other nodes in the network.

## 3. Results

### 3.1. Demographics and clinical variables

The final sample was diverse, spanning from the first episode to multiple - episodes, chronic patients. The mean age of patients was M = 40.80 (SD = 12.28). Approximately 67% of the sample were male. 49% of the sample were Caucasian and 44% were African American. Detailed information about demographic and clinical variables are available in Table 1.

### 3.2. Network estimation

Nodes within social cognition, neurocognition, and real - world functioning were strongly interconnected (see Fig. 1). Relationships within each mentioned domain were stronger than those between domains, which suggest independence of these broader constructs. Centrality estimates are shown in Fig. 2. The most central nodes (strength) in the network were working memory, mentalizing, and emotion recognition from facial expressions. Nodes with the highest level of closeness (small distance to other nodes) were functional capacity, working memory impairment, negative symptoms, and social - skills. The node with highest betweenness (connecting other symptoms) was negative symptoms, which showed strong associations to capacity measures and real – world functioning. Estimates of strength (CS = 0.596) and closeness (CS = 0.360) were sufficiently stable; betweenness estimates should be interpreted with caution (CS = 0.206) (Fig. 3).

Visual inspection of the estimated network indicates that neurocognition, particularly working memory, was most strongly related to functional capacity. Similarly, social cognition, especially mentalizing (Hinting Task and TASIT) and emotion recognition (ER-40) were also related to functional capacity. Mentalizing (Hinting task) was also strongly related to social competence/social skill. We did not find strong direct relationships between social cognition, neurocognition and real - world functioning, but both domains were connected to functional outcomes via functional and social - skills capacity measures.

**Table 1**
Demographic and clinical variables.

| | M/N | SD/ % | Min | Max |
|---|---|---|---|---|
| Age | 40.80 | 12.28 | 18 | 69 |
| **Gender** | | | | |
| Female | 136 | 33% | | |
| Male | 272 | 67% | | |
| **Race** | | | | |
| Caucasian | 200 | 49% | | |
| African American | 179 | 44% | | |
| American Indian/Alaskan Native | 3 | 1% | | |
| Asian | 10 | 2% | | |
| Native Hawaiian/Other Pacific Islander | 0 | 0% | | |
| Other | 16 | 4% | | |
| Years of education | 13.03 | 2.31 | 6 | 20 |
| **Diagnosis** | | | | |
| Schizophrenia | 200 | 49% | | |
| Schizoaffective disorder | 182 | 45% | | |
| First Episode | 26 | 6% | | |
| **Symptoms, cognition, social cognition, and functional outcomes** | | | | |
| PANSS - Positive | 16.28 | 5.34 | 7 | 34 |
| PANSS - Negative | 14.14 | 5.20 | 7 | 34 |
| PANSS - General | 31.90 | 7.90 | 16 | 52 |
| Trail Making Test | 40.35 | 18.05 | 14.90 | 157.47 |
| Symbol Coding | 42.79 | 11.60 | 11 | 86 |
| Hopkins Verbal Learning Test | 21.19 | 5.74 | 4 | 36 |
| Letter Number Sequencing | 12.11 | 4.27 | 1 | 24 |
| Animal Fluency | 19.54 | 5.81 | 2 | 41 |
| Bell - Lysaker Emotional Recognition Test | 13.78 | 4.04 | 2 | 21 |
| Penn Emotion Recognition Test ER-40 | 30.54 | 4.94 | 7 | 39 |
| Reading the Mind in the Eye | 21.06 | 5.50 | 6 | 34 |
| Hinting Task | 13.60 | 3.66 | 2 | 20 |
| The Awareness of Social Inferences Test | 45.16 | 7.81 | 16 | 63 |
| UCSD - Performance-Based Assessment - UPSA-B | 70.17 | 14.22 | 23.74 | 100 |
| Social Skills Performance Assessment - SSPA | 4.14 | 0.51 | 2.31 | 5.00 |
| SLOF - Interpersonal Relationships | 3.42 | 0.91 | 1.00 | 5.00 |
| SLOF - Social Acceptability | 4.42 | 0.55 | 2.00 | 5.00 |
| SLOF - Activities | 4.40 | 0.74 | 1.09 | 5.00 |
| SLOF - Work skills | 3.66 | 0.90 | 1.00 | 5.00 |

## 4. Discussion

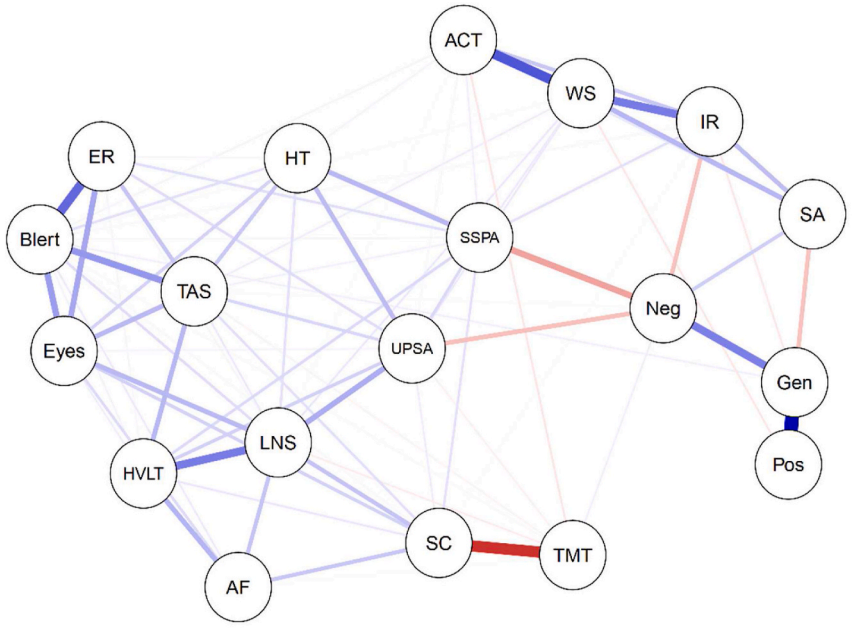
The aim of the present study was to model dynamic associations among social cognition, neurocognition, psychopathology, and functional outcomes in schizophrenia using network analysis. Overall, our results are consistent with much of the existing work on determinants of functional outcomes. First, these analyses support the notion that social cognition and neurocognition are related, but better understood as a separate construct (Mehta et al., 2013). Second, our results also confirm that both social and neurocognition are important contributors to functional abilities. Social cognition, namely mentalizing measured with the Hinting Task, was strongly associated with both social and non - social capacity measures, and neurocognition, particularly working memory, was related to functional capacity, which may reflect the importance of working memory for tasks like managing finances and appointments. These data therefore suggest more indirect (via capacity measures) relationships to real - world functioning. As both the SSPA and UPSA-B assess social and functional capacity under well-controlled laboratory conditions, it is understandable that traditional measures of social and neurocognition predict performance in these tasks, which then show strong relationships to functioning outside the laboratory.

In line with Galderisi et al.'s (2018, 2020) results, our data support the importance of functional capacity, and expanding on the previous work, highlight a critical role for objectively measured social skill in real-world functioning. Both functional capacity and social skill were among the most central in the network and are therefore likely to be prerequisites to real world outcomes that should be viewed as important treatment targets. Also consistent with Galderisi et al. negative symptoms were an important node in terms of having multiple connections with different constructs within the network including functional capacity, social skills, and real - world social functioning. These connections support the prominent role of negative symptoms in predicting functional outcomes (Fervaha et al., 2014; Strassnig et al., 2015). Positive symptoms, in contrast, showed a very low level of importance within the network and were related to functional outcomes indirectly, via general symptoms.

Our results should be interpreted with some caution. Betweenness estimates may be less accurate, and therefore a larger study might be useful to untangle this characteristic of nodes. Our study used only well - validated tasks, which were identified as strong predictors of functional outcomes. We were not able to measure or include other variables such as resilience (Galderisi et al., 2018), defeatist beliefs (Grant and Beck, 2009), or metacognition (Hasson-Ohayon et al., 2018), all of which might influence the structure of the estimated network.

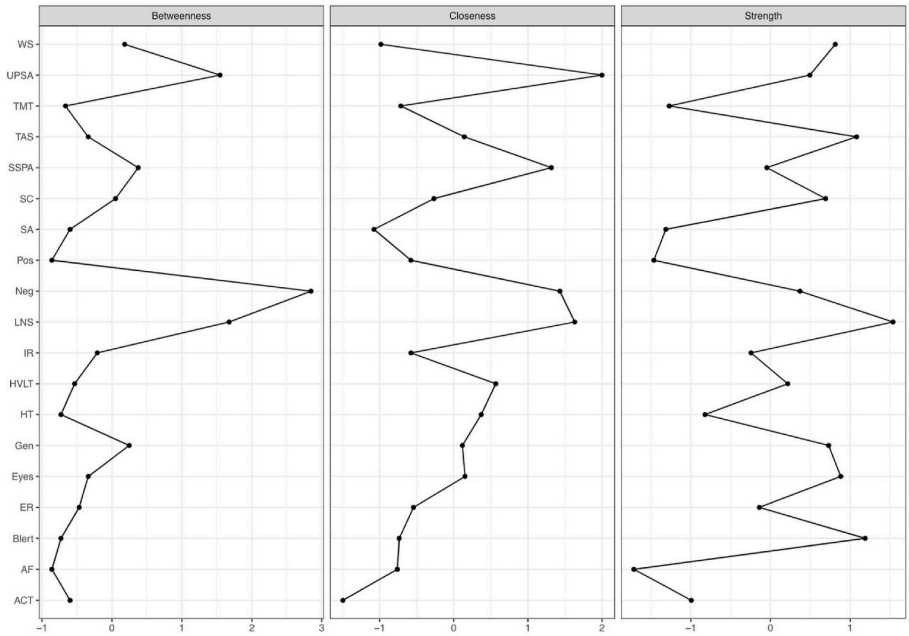
Network analysis is only one of the several potential analytical techniques for complex data as arising from the SCOPE project. Our primary reason for utilizing network analysis was the opportunity to directly compare results from the SCOPE data to the influential Italian studies that also used a network approach. Our goal was to test the structure of associations on the task (node) level. Therefore, in this case, adopting a data - driven approach might be more appropriate than testing a - priori hypothesis using structural equation modeling; however, theory-driven models should be tested in the future.

In sum, we provided the first successful conceptual replication of Galderisi et al.'s studies (2018, 2020). The pattern of results seems highly comparable even with data from a widely different culture. Despite this, future studies on large samples are still highly needed for




Footnote: BLERT – Bell - Lysaker Emotion Recognition Test, ER – PENN Emotion Recognition test ER – 40, Eyes – Reading the Mind in the Eye Test, TAS – The Awareness of Social Inferences Test, HT – Hinting Task, HVLT – Hopkins Verbal Learning Test, LNS – Letter Number Sequencing, AF – Animal Fluency, SC – Symbol coding, TMT – Trail Making Test, SSPA – Social Skills Performance Assessment, UPSA – UCSD Performance Based Assessment, NEG – PANSS Negative symptoms, GEN – PANSS General psychopathology, POS – PANSS Positive symptoms, WS – SLOF Work skills, ACT – SLOF Activities, IR – SLOF Interpersonal Relationships, SA – SLOF Social Appropriateness. Relationship between SC and TMT is negative. More symbols coded was associated with shorter time in TMT.

**Fig. 1.** Network plot.
Footnote: BLERT – Bell - Lysaker Emotion Recognition Test, ER – PENN Emotion Recognition test ER – 40, Eyes – Reading the Mind in the Eye Test, TAS – The Awareness of Social Inferences Test, HT – Hinting Task, HVLT – Hopkins Verbal Learning Test, LNS – Letter Number Sequencing, AF – Animal Fluency, SC – Symbol coding, TMT – Trail Making Test, SSPA – Social Skills Performance Assessment, UPSA – UCSD Performance Based Assessment, NEG – PANSS Negative symptoms, GEN – PANSS General psychopathology, POS – PANSS Positive symptoms, WS – SLOF Work skills, ACT – SLOF Activities, IR – SLOF Interpersonal Relationships, SA – SLOF Social Appropriateness. Relationship between SC and TMT is negative. More symbols coded was associated with shorter time in TMT.




Footnote: BLERT – Bell - Lysaker Emotion Recognition Test, ER – PENN Emotion Recognition test ER – 40, Eyes – Reading the Mind in the Eye Test, TAS – The Awareness of Social Inferences Test, HT – Hinting Task, HVLT – Hopkins Verbal Learning Test, LNS – Letter Number Sequencing, AF – Animal Fluency, SC – Symbol coding, TMT – Trail Making Test, SSPA – Social Skills Performance Assessment, UPSA – UCSD Performance Based Assessment, NEG – PANSS Negative symptoms, GEN – PANSS General psychopathology, POS – PANSS Positive symptoms, WS – SLOF Work skills, ACT – SLOF Activities, IR – SLOF Interpersonal Relationships, SA – SLOF Social Appropriateness. Relationships between SC and TMT is negative. More symbols coded was associated with a shorter time in TMT.

**Fig. 2.** Centrality estimates.
Footnote: BLERT – Bell - Lysaker Emotion Recognition Test, ER – PENN Emotion Recognition test ER – 40, Eyes – Reading the Mind in the Eye Test, TAS – The Awareness of Social Inferences Test, HT – Hinting Task, HVLT – Hopkins Verbal Learning Test, LNS – Letter Number Sequencing, AF – Animal Fluency, SC – Symbol coding, TMT – Trail Making Test, SSPA – Social Skills Performance Assessment, UPSA – UCSD Performance Based Assessment, NEG – PANSS Negative symptoms, GEN – PANSS General psychopathology, POS – PANSS Positive symptoms, WS – SLOF Work skills, ACT – SLOF Activities, IR – SLOF Interpersonal Relationships, SA – SLOF Social Appropriateness. Relationships between SC and TMT is negative. More symbols coded was associated with a shorter time in TMT.

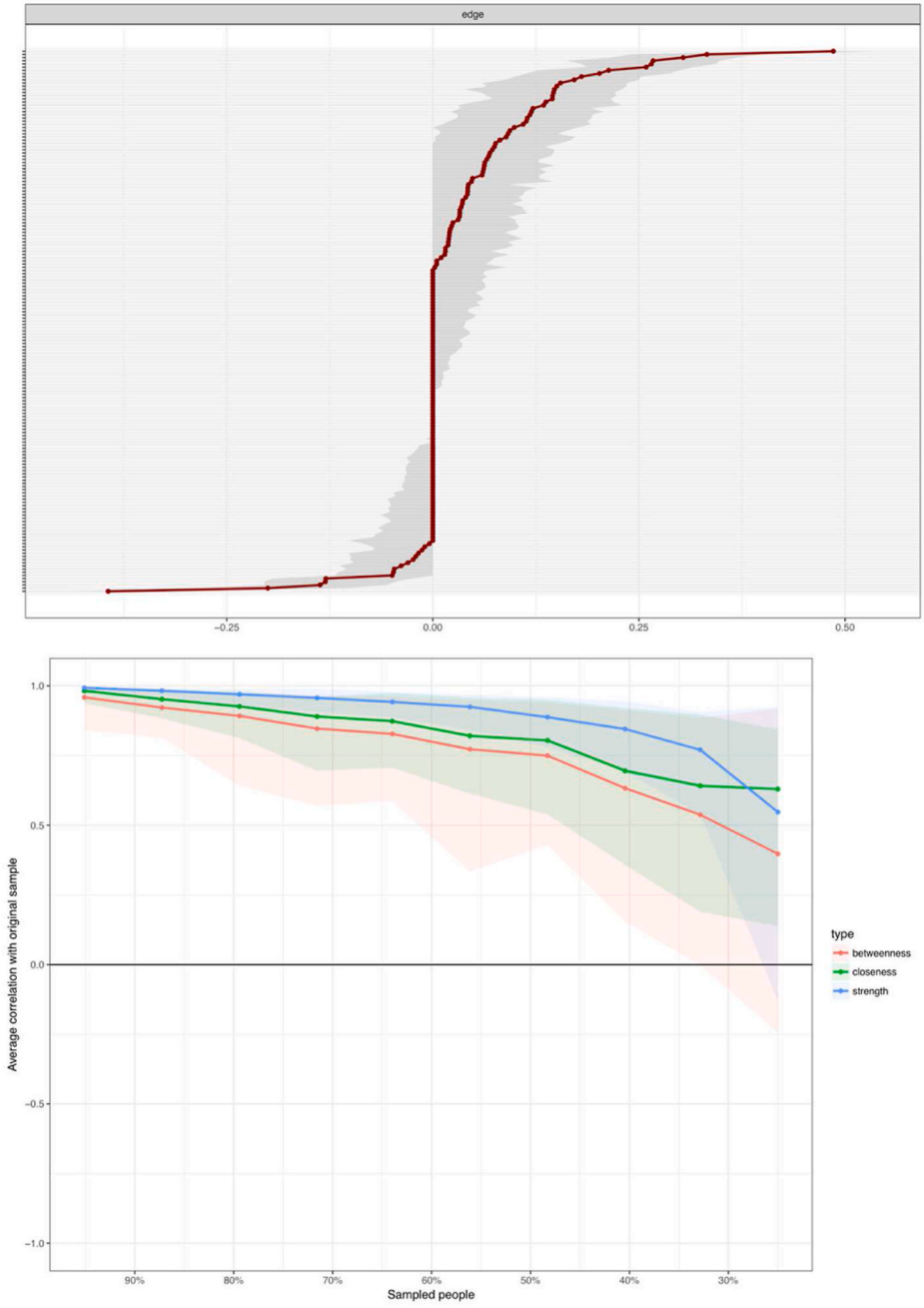



**Fig. 3.** Network stability.

evaluation of robustness of these findings. Moreover, our data also extend previous findings by highlighting the role of social cognition and neurocognition, which were more closely related to both social - skill and functional capacity, which were then the closest predictors of real - world functioning. Thus, a crucial finding from our study is that social skill capacity might be equally important as functional capacity, and both together bridge social and neurocognition to real - world functioning.

## Authors contribution

Dr. Hajdúk aided in study design and implementation, oversaw and completed all statistical analyses, wrote the first draft of the manuscript, and contributed substantially to all subsequent manuscript drafts. Drs. Harvey, Penn, and Pinkham obtained primary funding, aided in study design and original data collection, assisted with data interpretation, and substantially edited all drafts of the manuscript. All authors have approved the final manuscript.

## Declaration of competing interest

P.D.H. has received consulting fees or travel reimbursements from Acadia Pharma, Alkermes, Bio Excel, Boehringer Ingelheim, Intra Cellular Therapies, Minerva Pharma, Regeneron Pharma, and Sunovion Pharma. He receives royalties from the Brief Assessment of Cognition in Schizophrenia. He is chief scientific officer of i-Function, Inc. He had a research grant from Takeda and the Stanley Medical Research Foundation. M.H received honoraria for speaking at educational conference from Lundbeck.

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