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# The Puzzle of Functional Recovery in Schizophrenia-Spectrum Disorders—Replicating a Network Analysis Study

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***Background and hypothesis:*** **Recovery from psychosis is a complex phenomenon determined by an array of variables mutually impacting each other in a manner that is not fully understood. The aim of this study is to perform an approximated replication of a previous network analysis study investigating how different clinical aspects—covering psychopathology, cognition, personal resources, functional capacity, and real-life functioning—are interrelated in the context of schizophrenia-spectrum disorders.** ***Study design:*** **A sample of 843 subjects from a multisite cohort study, with the diagnosis of a schizophrenia-spectrum disorder, was used to estimate a network comprising 27 variables. The connectivity and relative importance of the variables was examined through network analysis. We used a quantitative and qualitative approach to infer replication quality.** ***Study results:*** **Functional capacity and real-life functioning were central and bridged different domains of the network, in line with the replicated study. Neurocognition, interpersonal relationships, and avolition were also key elements of the network, in close relation to aspects of functioning. Despite significant methodological differences, the current study could substantially replicate previous findings.** ***Conclusions:*** **Results solidify the network analysis approach in the context of mental disorders and further inform future studies about key variables in the context of recovery from psychotic disorders.**

*Key words:* psychosis/functional capacity/functioning/resilience/cognition/psychopathology

## Introduction

Schizophrenia-spectrum disorders are an important cause of disability worldwide.[1] The difficulties in addressing the consequences of these disorders might be related to the complexity of different factors at play.

Beyond psychopathology, an array of variables seems crucial to address during the recovery process.[2] Neurocognitive deficits in psychotic disorders have been pointed over several years as another fundamental dimension impacting on the success of rehabilitation outcomes and also as a target for interventions.[3] On a different angle, social and contextual factors such as stigma and social support have been shown to influence treatment outcomes.[4] Personal factors such as resilience have more recently been gathering attention in the context of schizophrenia-spectrum disorders and seem a promising point for future research.[5] Moreover, these factors mutually impact each other creating a web of relationships, the understanding of which could help design better treatments. However, most clinical studies are not designed to grasp this complexity and more sophisticated methodologies still have limitations such as the assumption of a-priori hypotheses or the exclusion of circular relationships between variables (e.g. directed acyclic graphs). Network analysis emerged in psychometric research as a tool that overcomes these limitations, while also being suited to accommodate the analysis of numerous variables simultaneously.[6,7] The use of network analysis in psychiatry can go beyond the study of psychopathology symptoms and deal with different interacting domains.[8]

An example of the usefulness of this approach is presented by Galderisi et al.[9] in the context of community-dwelling patients with schizophrenia. In their work, the authors included a set of variables cutting across different domains (i.e. psychopathology, neurocognition, functional capacity, personal resources, and real-life functioning). This way, they intended to gain insight into the complex associations between these domains, ultimately trying to clarify pathways in order to design integrated treatment plans. The main findings were that the capacity to perform everyday specific tasks in optimal conditions (i.e. functional capacity) and real-life functioning (a combination of interpersonal, work, and everyday life skills) showed a high connectivity within the network, whereas variables such as positive symptoms were deemed as more marginal. These results underscored the importance of approaches that are recovery-oriented and personalized. However, replication of these findings is needed in light of the exploratory nature of network models and the importance of taking the "replication crisis" in psychology and psychiatry seriously.[10,11]

The main goal of the current study was to evaluate an approximated replication of the study by Galderisi et al.[9] in a sample of patients with schizophrenia-spectrum disorders. By doing so, we hoped to simultaneously replicate important findings concerning factors contributing to real-life functioning while also extending the literature on network replicability to the context of schizophrenia-spectrum disorders. We also aimed to test the generalizability of Galderisi et al.'s[9] study to a broader clinical population (full schizophrenia-spectrum), hence expanding its original value.

## Methods

### *Sample Characteristics*

An already existing dataset from the Genetic Risk and Outcome of Psychosis (GROUP) study was used.[12] The GROUP research program is a longitudinal study coordinated by a group of researchers from four Dutch university psychiatric centers: UMC Amsterdam, UMC Groningen, UMC Utrecht, and Maastricht UMC. The aim of the research program was to elucidate etiological and pathogenetic factors influencing the onset and course of psychotic disorders.

The original dataset contains information on 1120 patients with a psychotic disorder, 1057 siblings, 919 parents, and 590 healthy controls (collected between 2004–2007). In the current analysis, only the patient data of the first follow-up assessment was used, 3 years after baseline ($n = 843$). This assessment wave was chosen as it was more comprehensive, hence allowing for a better approximation to Galderisi et al.'s[9]study. The participants were patients screened from the caseload of clinicians and included inpatients and outpatients presenting consecutively at the aforementioned centers and participating mental health organizations. Inclusion criteria were: 1) diagnosis of a nonaffective psychotic disorder according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition criteria;[13] 2) age range of 16–50 years at baseline; 3) good command of the Dutch language; and 4) able and willing to give written informed consent. The study protocol was approved centrally by the Ethical Review Board of the University Medical Centre Utrecht and also locally by all the participating institutes.

### *Materials*

We used the variables available in the GROUP study to select the best possible match for each of the 27 variables in the study by Galderisi et al.[9] As in that study, we divided these variables into 6 domains. The selected instruments are listed in table 1. Despite the effort to make each variable correspond as close as possible to the original construct, in a few cases the selected instrument had to be a less consistent match (e.g. facial recognition was used as a proxy for emotional evaluation; for a detailed comparison between study variables, see supplementary table S1).

### *Data Analyses*

Similar to Galderisi et al.,[9] a network model was constructed to model the relationship between the variables. All analyses were performed using the programming language *R*.[31] Network models consist of *nodes*, which represent variables (e.g. working memory, avolition) and *edges*, which indicate a statistical relationship between them.[32] In addition, edges can further give information about the strength of the relationship (thicker edges represent a stronger relationship) and also whether the association is negative (red edges) or positive (blue edges).

We modeled an adaptive least absolute shrinkage and selection operator (LASSO)[33] network using the *R* package *qgraph*.[34] Compared to correlation and partial correlation networks, a LASSO network can be more easily interpretable as it assigns penalties to shrink weak partial correlations to 0, thus creating a more parsimonious graph. To control the sparsity, LASSO uses a tuning parameter, the Extended Bayesian Information Criterion (EBIC), which is by default implemented in the *qgraph* package.[35] We used this network estimation technique to keep the methods aligned as much as possible with the study by Galderisi et al.[9] Spearman partial correlations were used to account for non-normality of the variables. The network layout was based on the Fruchterman-Reingold algorithm,[36] which places nodes with strong associations in the center of the network, and the proximity of the nodes is weighed based on the strength of the interaction. In line with Galderisi et al.'s[9] analysis, only edges of 0.05 or above were depicted. Pairwise estimation of missing data was used.

**Table 1.** Domains and Variables Used by Galderisi et al.[9] and the Correspondence to the Instruments Used in the Current Study

| Domains and Variables (as used in Galderisi et al[9]) | Corresponding Instruments and Measures (as used in the current study) |
|---|---|
| **Psychopathology** | |
| *Positive symptom factor* | PANSS—positive symptom factor |
| *Expressive deficit* | PANSS—Sum of items: blunted affect, poor rapport, lack of spontaneity and flow of conversation |
| *Avolition* | PANSS—Sum of items: emotional withdrawal, passive/ apathetic social withdrawal, disturbance of volition |
| *Depression* | CDSS—Total score |
| *Disorganization* | PANSS—conceptual disorganization item |
| **Neurocognition** | |
| *Verbal learning* | AVLT—Verbal learning score |
| *Problem solving* | RST—Conflict cost index |
| *Visuospatial learning* | WAIS-III—Block design |
| *Attention* | CPT—Accuracy score |
| *Processing speed* | WAIS-III—Digit symbol substitution test |
| *Working memory* | WAIS-III—Arithmetic |
| **Social cognition** | |
| *Emotional intelligence* | EMT—First order emotion score |
| *Facial emotion recognition* | DFAR—Total score |
| *Emotion evaluation* | BFRT—Total score |
| *Social inference minimal* | EMT—First order belief |
| *Social inference extended* | EMT—Second order belief |
| **Real-life functioning** | |
| *Interpersonal relationships* | SFS—Sum score of subscales: interaction and pro-social activities |
| *Everyday life skills* | SFS—Sum score of subscales: independence performance, competence, recreation |
| *Work skills* | SFS—Occupation/ employment subscale |
| **Resilience** | |
| *Perception of self* | BCSS—Positive self subscale |
| *Perception of future* | RAS—Confidence and hope subscale |
| *Social competence* | UCL—Seeking social support subscale |
| *Family cohesion* | Living situation—Living alone versus with family/partner |
| **Other variables** | |
| *Functional capacity* | CAN—functional disability (reversed score) |
| *Service engagement* | BIS—Total score |
| *Incentives* | CSQ—Total score |
| *Internalized stigma* | DCS—Total score (reversed score) |

*Note*: PANSS, Positive and Negative Syndrome Scale[14]; CDSS, Calgary Depression Rating Scale for Schizophrenia[15]; AVLT, Auditory Verbal Learning Test[16]; RST, Response Shifting Task, a modified version of the Competing Programs Task[17]; WAIS, Wechsler Adult Intelligence Scale[18]; CPT, Continuous Performance Test[19]; EMT, Emotional Mentalizing Task[20]; DFAR, Degraded Facial Affect Recognition Task[21]; BFRT, Benton Facial Recognition Test[22]; SFS, Social Functioning Scale[23]; BCSS, Brief Core Schema Scales[24]; RAS, Recovery Assessment Scale[25]; UCL, Utrecht Coping List[26]; CAN, Camberwell Assessment of Need[27]; BIS, Birchwood Insight Scale[28]; CSQ, Client Satisfaction Questionnaire[29]; DCS, Devaluation of Consumers Scale[30]

To account for the importance of individual nodes, centrality measures were computed: node strength, closeness, and betweenness.[32,37] Node strength is the sum of the weighted edges of a node, thus translating its local interconnectedness in the network. Closeness investigates how strongly a node is indirectly connected to other nodes by taking the inverse of the sum of all shortest paths between one node and all other nodes in the network. Betweenness is the measure of how many shortest paths between two nodes go through the node at hand, such that higher betweenness facilitates links in the network. Centrality measures help indicating which nodes might be more relevant in the network. The interpretation of specific centrality measures—i.e. betweenness and closeness—is not entirely clear when applying network analysis in mental disorders.[38] They were nonetheless included in our analysis to ensure a closer resemblance to Galderisi et al.'s[9]study and also because we considered them to have interest for the assessment of replicability.

The robustness of the network was computed as suggested by Epskamp et al.,[32] using the *bootnet R* package. We investigated the accuracy of edge-weights, followed by the stability of centrality indices and the bootstrapped difference tests between edge weights and centrality indices.

Finally, the extent to which the findings replicate Galderisi et al.'s[9] results was explored using different strategies, based on recommendations from the literature.[39] First, we calculated the correlation of edge weights and centrality measures between the two networks. These measures gave a broader overview of the networks' structural similarity. Secondly, we compared the five nodes with highest centrality scores between the two networks. This way, we gained further insight into the similarities and differences regarding the most important (i.e. central) nodes. Thirdly, we compared the two networks regarding the connections between domains, therefore aiming to identify the most important bridging nodes and compare them between the two networks. Bridge nodes are of particular interest due to their hypothesized role in cohering the overall network structure, hence, becoming natural targets for interventions.[40] The authors from Galderisi et al.'s[9]study provided us with the correlation matrix used as input for the network analysis, this way enabling the strategies outlined above.

## Results

### *Patient Characteristics*

Data were available of 843 patients, who were included in the analysis. Descriptive statistics can be found in table 2. The average percentage of missing observations per participant was 18.0% (SD: 21.7; see supplementary figure S1 for more details on missing data).

### *Network Analysis*

The adaptive LASSO network (figure 1) shows that nodes belonging to the same domain tended to be located proximal to each other and separated from other domains. Moreover, the domains also tended to share several edges between each other, highlighting their interconnected nature.

Descriptive statistics of the variables used as input for the network analysis can be found in supplementary table S2.

*Correlation of Edge Weights and Centralities.* To investigate how well the current study's network replicated Galderisi et al.'s,[9] we correlated all edge weights between them and obtained the correlation of $r = 0.64$, which indicates a moderate to strong relationship. The correlations between the centrality measures were lower: $r = 0.44$ for strength and betweenness centrality, and $r = 0.55$ for closeness (see supplementary figures S2–S5).

*Comparing Centrality Indices.* Figure 2 displays the centrality indices for every node in the current study's network. Furthermore, table 3 shows the five nodes with the highest centrality in each centrality domain for both networks. For the strength measure, the nodes "working memory" and "avolition" ranked high in both networks. For closeness and betweenness, three nodes replicated: "everyday life skills", "functional capacity", and "interpersonal relationships".

*Bridging Nodes.* Functional capacity took up the most central role of bridging nodes from the psychopathologic, neurocognitive, resilience, real-life functioning, and "other" domains together, thereby replicating one of the most important findings of Galderisi et al.'s[9] study to a great extent. Another central node was the neurocognitive item "processing speed" which bridged neurocognition and to a lesser extent social cognition items to the rest of the network. In the Galderisi et al.'s[9] study, working memory instead of processing speed took a more central role within cognition and also as a bridge to other domains (namely, functional capacity). Emotion recognition was another important bridge from cognitive variables to functioning variables in their study. The three real-life functioning variables acted as a bridge between all psychopathologic variables, resilience items, and variables from the "other" domain. This was also overall true for Galderisi et al.,[9] where everyday life skills, in particular, took on a very important bridging role. The psychopathology domain shared connections mostly with functional capacity and real-life functioning items. While "depression" connected the psychopathologic domain to resilience items, "avolition" connected it to real-life functioning items. In Galderisi et al.'s[9]study, the psychopathology domain was less pivotal between domains. However, disorganization and avolition played more relevant bridging roles with the first being connected to functional capacity and the latter closer to resilience items, while both being connected to real-life functioning items.

*Robustness Analysis.* Bootstrapped confidence intervals were calculated for each edge weight, in this way

**Table 2.** Demographic and Clinical Characteristics of the Study Sample

| Characteristic | Participants included in the analyses ($n = 843$) |
|---|---|
| Age, mean (SD) | 30.6 (7.2) |
| Male sex, No. (%) | 643 (76 %) |
| Married/living together, No. (%) | 116 (13 %) |
| Duration of illness, mean (SD), y | 8.45 (4.43) |
| Education | |
| No education/Primary school, No. (%) | 65 (7 %) |
| High school/Secondary school, No. (%) | 434 (51 %) |
| University/Vocational education, No. (%) | 343 (40 %) |
| Diagnosis | |
| Schizophrenia, No. (%) | 533 (63.2 %) |
| Schizoaffective disorder, No. (%) | 90 (10.7%) |
| Psychosis not otherwise specified, No. (%) | 88 (10.4 %) |
| Schizophreniform, No. (%) | 47 (5.6 %) |
| "Other", No. (%) | 85 (10.1 %) |
| Using antipsychotic medication1, No. (%) | 574 (93.8%) |

*Note:*
[1]For 232 subjects (28%) this was not recorded.

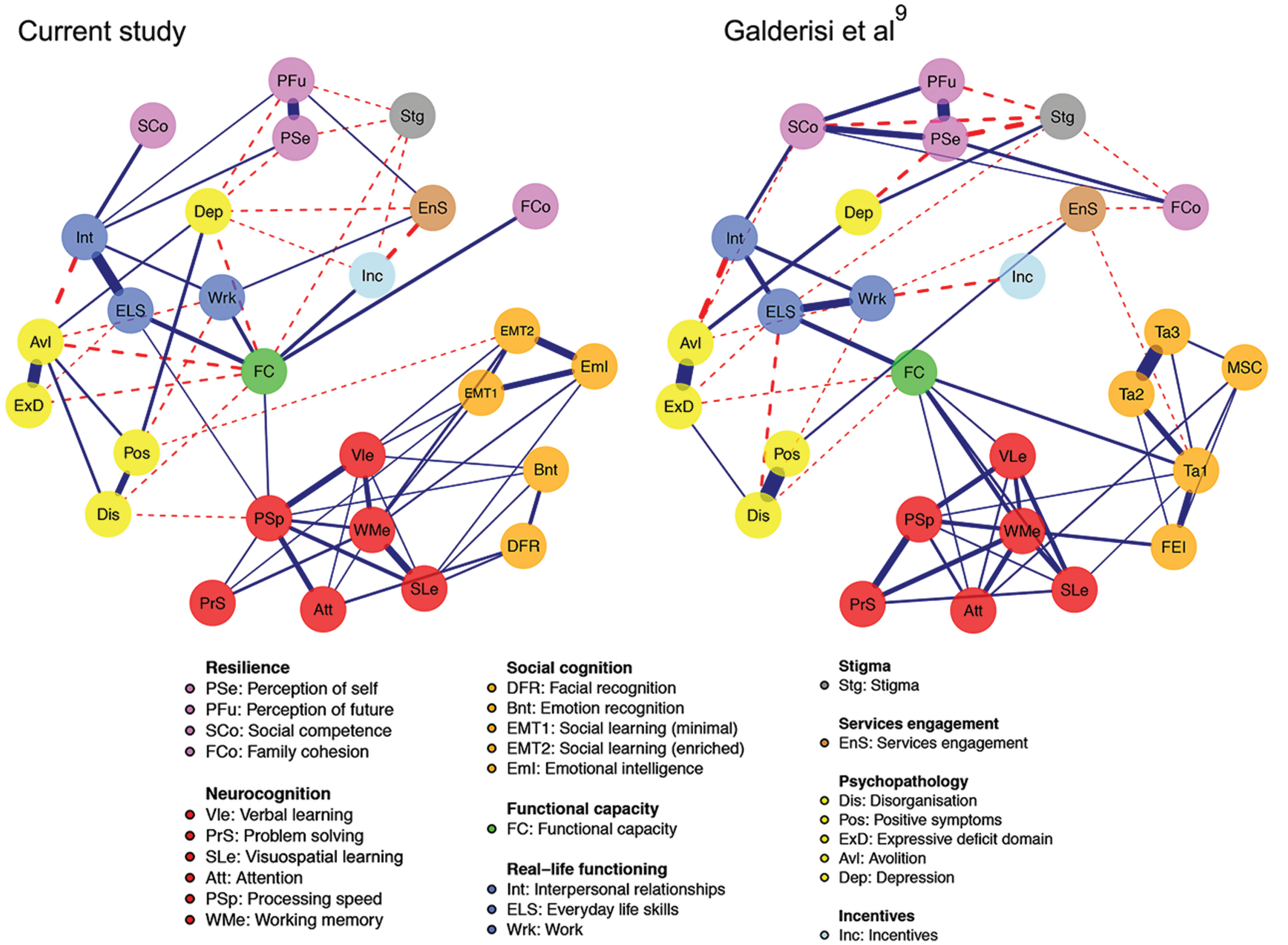


**Fig. 1.** Side by side comparison of the two networks using an averaged layout: current study's (left) and Galderisi et al.'s[9] study (right). Social cognition nodes in "Galderisi et al." are identified in a different manner due to the use of different instruments: FEI, Facial Emotion Identification Test (FEIT); MSC, MSCEIT managing emotion; Ta1, TASIT-1, emotion evaluation; Ta2, TASIT-2, social inference minimal; Ta3, TASIT-3, social inference–enriched. Solid edges represent positive associations and dashed edges represent negative associations.

estimating their accuracy. The results showed that the confidence intervals were generally narrow, suggesting that the stability of the edge weights estimates was likely good (supplementary figure S6).

The stability of centrality indices was evaluated with a case-dropping bootstrap procedure.[32] The correlation-stability coefficients were considered good for strength centrality (CS-coefficient = 0.60), acceptable for betweenness centrality (CS-coefficient = 0.28), and unstable for closeness centrality (CS-coefficient = 0.21; see supplementary figure S7). Despite betweenness and closeness warranting caution, we still considered all the centrality indices for discussion. Further bootstrapped difference tests can be found as supplementary figures S8–S11.

## Discussion

In the current study, we estimated a network model integrating multiple clinical domains relevant to schizophrenia-spectrum disorders, covering a wide range of variables, from personal to contextual factors, aiming to replicate findings reported by Galderisi et al.[9] In the current network, nodes representing different aspects of functioning showed vast interrelations with other domains, hence assuming a very central position. Functional capacity was of particular importance, bridging core neurocognition, avolition, and more general functioning outcomes. Findings affirm functional capacity as a very relevant clinical outcome while also confirming the need to concomitantly consider negative symptoms in the prediction of real-world functioning.[41,42]

Replication parameters comparing the current network to the study by Galderisi et al.[9] were overall considered good. This is also in line with previous studies which have investigated replication quality of the network approach, specifically in the context of major depression, generalized anxiety, posttraumatic stress disorder, and internalizing symptoms.[39,43–45]

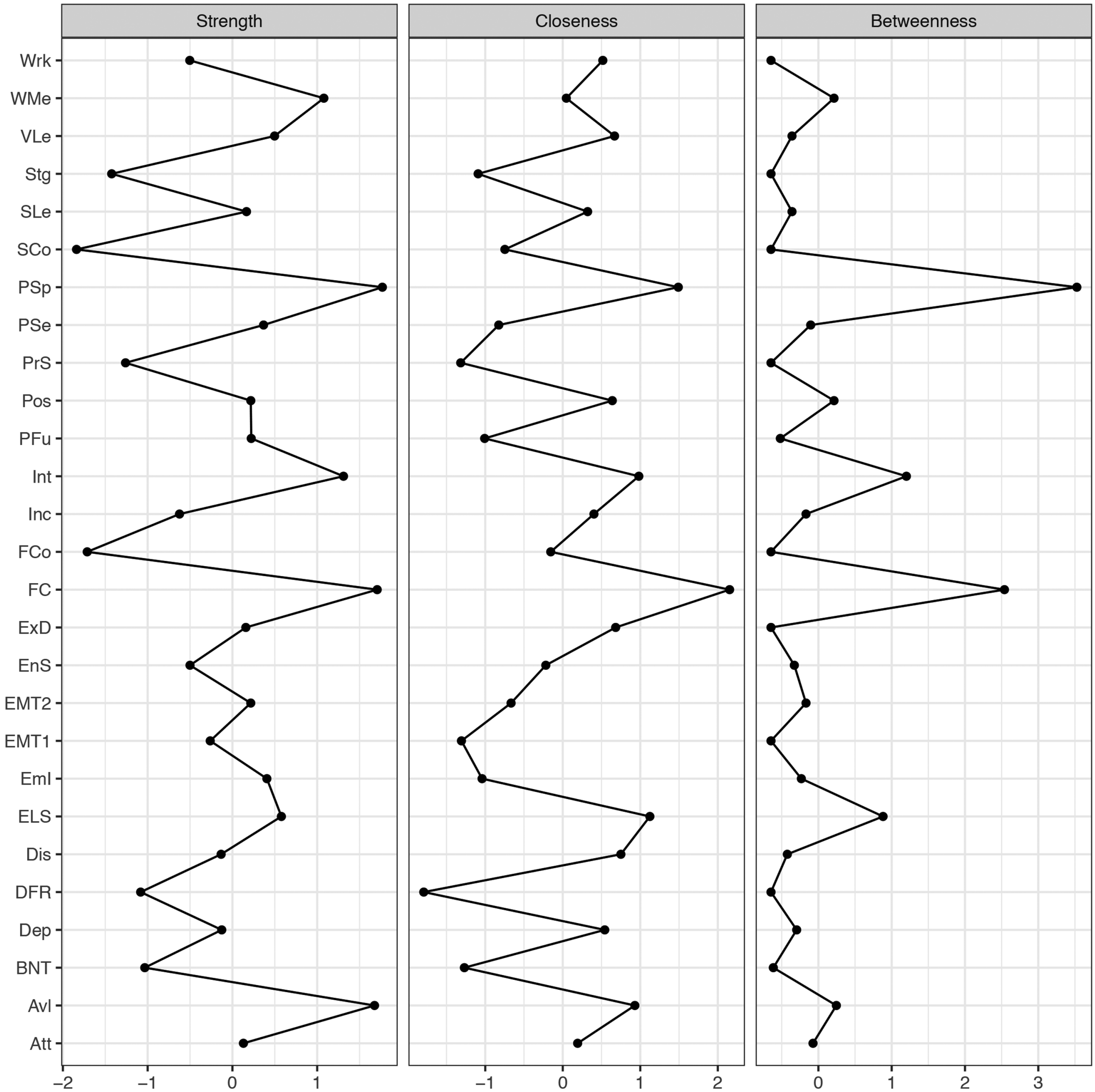


**Fig. 2.** Centrality measures. Att, attention; Avl, avolition; Bnt, Benton facial recognition test; DFR, Degraded Facial Affect Recognition task; Dep, depression; Dis, disorganization; ELS, everyday life skills; EmI, emotional intelligence; EMT1, EMT 1st order belief; EMT2, EMT 2nd order belief; EnS, service engagement; ExD, expressive deficit; FC, functional capacity; FCo, family cohesion; Inc, incentives; Int, interpersonal relationships; Pfu, perception of future; Pos, positive symptoms; PrS, problem solving; PSe, perception of self; PSp, processing speed; SCo, social competence; SLe, visuospatial learning; Stg, stigma; VLe, verbal learning; WMe, working memory; and Wrk, work skills.

*Similarities to the Study of Galderisi et al.*

The domains were generally spatially contiguous and interconnected, supporting the notion that they are robust and independent constructs, similarly to Galderisi et al.[9] The correlation between edge weights and centralities was considered strong or moderate, respectively. The most central items replicated well, particularly for closeness and betweenness centralities. The magnitude of edge-weight correlation was comparable to the findings of a previous study in PTSD where the analyzed networks relied on the same instrument.[43]

Both the importance of and the interactions between functional capacity and the real-life functioning domain were well replicated. The real-life functioning nodes (everyday life skills, work skills, interpersonal relationships)

**Table 3.** Comparison between the most central nodes in each network (per centrality index)

| Centrality measure | Galderisi et al.'s[9] network | GROUP network |
|---|---|---|
| Strength | 1. Working memory<br>2. Perception of self<br>3. Everyday life skills<br>4. Avolition<br>5. Disorganization | 1. Processing speed<br>2. Functional capacity<br>3. Avolition<br>4. Interpersonal relationships<br>5. Working memory |
| Closeness | 1. Everyday life skills<br>2. Functional capacity<br>3. Interpersonal relationships<br>4. Work skills<br>5. Working memory | 1. Functional capacity<br>2. Processing speed<br>3. Everyday life skills<br>4. Interpersonal relationships<br>5. Avolition |
| Betweenness | 1. Everyday life skills<br>2. Functional capacity<br>3. Interpersonal relationships<br>4. Emotion recognition<br>5. Working memory | 1. Processing speed<br>2. Functional capacity<br>3. Interpersonal relationships<br>4. Everyday life skills<br>5. Avolition |

created a "triangle" further connected to functional capacity (through work and everyday life skills). These four nodes were among the most connected in both networks and with highest centralities. They bridged the social cognitive and neurocognitive nodes with the resilience and psychopathology domains, as well as the "other" variables. These findings indicate that functional recovery is related to multiple dimensions. This seems to corroborate previous literature supporting integrated approaches for psychosis.[46,47] One way, then, to take these results (as also pointed out by Galderisi et al.[9]) would be to acknowledge that (i) outcomes close to real-life functioning such as functional capacity should be more often measured and directly addressed by therapeutic interventions, and (ii) at the individual level, different paths might lead to functional recovery, hence personalized interventions are warranted.

Interpersonal relationships, a real-life functioning variable, was again among the few variables connecting resilience items with the rest of the network. It was associated with the social competence, everyday life skills, functional capacity, and avolition nodes in both networks. Its high centrality values were to a great extent due to bridging functional capacity, resilience, psychopathology items, and three real-life functioning items. The link between interpersonal relationships, everyday life skills, and the standard of living in patients with schizophrenia has long been studied and explored with therapeutic purposes.[48] Indeed, meta-analytic research showed that social skills training is capable of increasing social performance, as well as decreasing patients' negative symptoms.[49]

The depression node was negatively connected to resilience items "perception of self" and "perception of future". In the network of Galderisi et al.,[9] depression was only associated with "perception of self" but the edge was very strong between "perception of self" and "perception of future" in both networks. Looking at the GROUP network, the resilience items "perception of self" and "perception of future" were not directly related to positive or negative symptoms, only through the depression node. This concurs with literature showing that affective symptoms (i.e. depression and anxiety), are more substantially associated with personal recovery than positive or negative symptoms.[50] Avolition was the psychopathology node with higher relevance, showing important connections to functional capacity and real-life functioning nodes, the latter also shared by Galderisi et al.'s[9] estimated network. This seems aligned with other network studies in schizophrenia and first-episode psychosis[51,52] and also non-network literature.[53] Overall, this points to the crucial role avolition plays within negative symptoms with regard to functional recovery and also within a broader set of clinical symptoms.[54]

### *Differences to the Study of Galderisi et al.*

Regarding neurocognitive variables, processing speed and working memory behaved differently in the two networks, the first being more central than the latter in the current study and the opposite pattern being found in Galderisi et al.'s[9] study. We believe this might be explained by the use of different underlying instruments between the studies. In particular, in the current study, working memory assessment was approached only through its verbal component, rendering a less central node when compared to Galderisi et al.'s[9] study (which also included a spatial span task). With a less central working memory node, this pivotal role was instead assumed by processing speed in the current study.

Despite the common role functional capacity played in both networks in connecting the neurocognition and social cognition domains to the rest of the nodes, some differences should be mentioned. In the current study's network, functional capacity was more closely related with psychopathologic, rather than neurocognitive items – it was associated with four out of five psychopathology nodes and only one neurocognitive node. Conversely, in Galderisi et al.[9] it was linked with four out of six neurocognitive nodes and only one psychopathology node. This was possibly due to the nature of the instruments used – an external evaluation of functioning in the current study vs. an active performance task in Galderisi et al.,[9] the latter being typically more related to neurocognitive outcomes. Support for the close association of functional capacity and neurocognition comes from previous studies, which recommend functional capacity as an additional measure in neurocognitive tests.[55,56] Those studies—similarly to Galderisi et al.[9]—conceptualized functional capacity using the UCSD Performance-based Skills Assessment (UPSA).[57] The UPSA batteries consist of performance-based assessments where subjects need to demonstrate their ability, for instance, to use public transport or buy groceries, rather than relying on a questionnaire, which was the case in the current study. However, considering this difference, it is notable how similar the functional capacity node behaved in both studies.

Positive symptoms played a relatively more important role in the current study's network when compared to Galderisi et al.'s[9] study, especially due to more connections within psychopathology. This translates previous evidence from the literature[58] concerning the close relationship between positive and affective symptoms in the wider spectrum of psychosis.

### *Limitations*

Several limitations of our study should be considered. First, there were significant differences between the participants and the instruments used in the two studies. While Galderisi et al.'s[9] sample consisted only of patients diagnosed with schizophrenia, subjects in the current sample were diagnosed with nonaffective psychotic disorders, with significantly less severe symptoms. Even though this is a limitation in the context of the replication reliability, it nevertheless contributes to expand the scope of Galderisi et al.'s[9] study. Divergences in instrument's choice were also clear, particularly for some items. While a few nodes were represented by identical or very similar instruments (e.g. disorganization, depression, positive symptoms, and attention), others differed in important ways (e.g. service engagement, work skills, functional capacity). In the current study, avolition was calculated including the item "disturbance of volition" from the PANSS. This item was not included in Galderisi et al.'s[9] avolition construct, in congruence with a recent guidance paper considering it to be closer to cognition/disorganization rather than negative symptoms.[59] This might explain connectivity differences between the studies regarding the avolition node. Nonetheless, for the vast majority of nodes, key constructs were comparable granting an acceptable resemblance between studies.

Second, on a technical note, two aspects should be mentioned: although the size of our sample ($n$ = 843) was similar to Galderisi et al.'s[9] study ($n$ = 740), the latter dataset was complete while in the current study there was a considerable amount of missing data. It was not possible to remove the missing data because there would have been too few remaining cases. The existence of missing data also prevented the use of a nonparanormal transformation with the aim of relaxing the normality assumption (as used in Galderisi et al.[9]). Another technical limitation relies on the use of the LASSO network estimation technique, which assumes that the variables are continuous. In fact, the variable "Family cohesion" was dichotomous in the current study. We still opted to use this method in order to keep a closer resemblance to Galderisi et al.'s[9] study. Of note, the use of Spearman correlations was shown to also work well in the case of network estimation with ordered non-normal data.[60]

Third, similarly to Galderisi et al.,[9] the cross-sectional nature of the current study prevents reaching conclusions with regards to causality and the direction of effects.

### *Conclusion*

In the current study, we showed, through a network approach, that various personal and contextual factors mutually impact each other and are associated with real-life functioning in schizophrenia-spectrum disorders.

To a large extent, we could replicate the findings of a similar study by Galderisi et al.,[9] even in light of important differences in instruments and methodology. Furthermore, a follow-up study from the same authors on the same cohort greatly overlapped with baseline findings.[61] This points to the robustness of the common findings and their relevance to the recovery of patients with psychotic disorders. The comparable findings between the studies point to the importance of neurocognition, social skills, and avolition for functional recovery in schizophrenia-spectrum disorders. Interventions targeting neurocognition, on one side, while simultaneously aiming at improving social skills and avolition are thought to be the most promising to stimulate functional recovery. Further intervention studies using longitudinal designs and network analysis are needed to shed light onto causal pathways hence clarifying the most promising approaches to recovery.

## Supplementary Material

Supplementary material is available at *Schizophrenia Bulletin* online.

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