Brief Communication

Yonsei Med J 2020 Aug;61(8):726-730
https://doi.org/10.3349/ymj.2020.61.8.726

Yonsei Medical Journal
YMJ
pISSN: 0513-5796 · eISSN: 1976-2437

Network Analysis of Language Disorganization in Patients with Schizophrenia

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Language disorganization, an objective component of formal thought process abnormality, has been regarded as a core symptom of schizophrenia from an evolutionary psychopathology perspective. However, to the best of our knowledge, the network structure of language disorganization has rarely been examined in patients with schizophrenia. Thus, our preliminary study aimed to evaluate the network structure using the Clinical Language Disorder Rating Scale (CLANG) in 167 inpatients with schizophrenia. All 17 of the CLANG items were considered to be ordered categorical variables ranging from 0 to 3. Our results indicated that disclosure failure, excess syntactic constraints, abnormal prosody, and aprosodic speech rank among the top five central domains within the network structure. We deemed that disclosure failure and prosody problems are the most important symptoms of language disorder in schizophrenia. Thus, reduced top-down processing of linguistic information may be a core neurobiological underpinning of language disorganization in schizophrenia. Further studies controlling for the potential effects of confounding factors (i.e., duration of illness) on network analyses of language disorder and formal thought disorder are warranted in patients with schizophrenia.

Key Words: Language disorganization, disclosure failure, network structure, schizophrenia

Language disorganization, which is an objective constituent of formal thought process abnormality, is considered to be a core symptom of schizophrenia.[1] Researchers have proposed that language disorganization may indicate greater severity and poor social functioning in patients with psychotic disorders.[2] According to the conceptualization of Crow,[3] there is a shared common neurobiological underpinning of both language and psychosis. Thus, the nuclear symptoms of schizophrenia can be conceptualized as extreme forms of language disorganization, denoted as disturbance of the "axis of indexicality."[4] Additionally, clinical language disorder has been continually defined as a diagnostic criterion for schizophrenia, although its expression has been changed from "incoherence" or "marked loosening of associations" to "disorganized speech" following increased empiricism in the consecutive Diagnostic and Statistical Manual of Mental Disorders (DSM) editions.[1] Network analysis has been used to provide a new perspective in psychopathology by considering "symptoms and associations among them" as the disease itself. On the contrary, traditional theory has regarded "symptoms" as "outcome factors of an underlying disease."[5] Since network analysis defines centrality as the overall inter-connec-

Received: May 18, 2020 **Revised:** June 16, 2020
Accepted: July 3, 2020
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•The authors have no potential conflicts of interest to disclose.

tion of symptoms, central symptoms can be characterized by greater influences on the network structure rather than peripheral symptoms.[6] To the best of our knowledge, the network structures of positive and negative symptoms, but not language, have been estimated in patients with schizophrenia. Thus, our preliminary study aimed to estimate the network structure of language disorganization in patients with schizophrenia.

As described elsewhere,[7] during a survey period from January to June 2014, a total of 167 inpatients with DSM-5 diagnosed schizophrenia[8] were recruited from Yong-In Mental Hospital and Chuncheon National Hospital in Korea. Inclusion criteria were age between 19 and 64 years, having greater than 2 weeks of psychiatric hospitalization, and attainment of over 6 years of education. Exclusion criteria were comorbid organic mental disorders, intellectual disability, alcohol or substance abuse, seizure disorders, neurological disorders, and severe physical disorders. DSM-5 was used in the evaluation of psychiatric disorders. Principally, the Thurstone Word Fluency Test was used to detect intellectual disability, given that it has been shown to be positively correlated with intelligence quotient and letter association condition.[9] The study protocol and case report form were approved by the Institutional Review Board of Yong-In Mental Hospital (receipt number: 2013-49). Language disorganization in the study participants was evaluated with the Clinical Language Disorder Rating Scale (CLANG),[10] which assessed language disorganization and observable expressions of formal thought disorder. CLANG includes a total of 17 items, which are rated on a Likert scale from 0 (normal) to 3 (severe) and has been translated and formally standardized in Korean.[7]

Using the R-package qgraph,[11] the network structure of the 17 CLANG items was estimated in the study participants. The nodes (symptoms) and edges (associations among the symptoms) both constituted the network structure. In addition, the false positive edges were controlled with the least absolute shrinkage and selection operator (LASSO);[12] therefore, very small edges were set exactly to zero. Moreover, using the GLASSO (or graphical LASSO) procedures,[13] the average edge was defined with the relationship level between two symptoms controlling for all other relationships within the network. Using the shrinkage parameter, extended Bayesian information criteria were minimized, and the underlying network structure was accurately recovered.[14,15] All CLANG items were regarded as ordered-categorical variables and ranged from 0 to 3. Using the modularity-based community-detection algorithm, node clusters were investigated. Using the spin-glass algorithm, we tested whether the number and weighted strength of edges within a cluster exceeded those within another cluster, in terms of communities within the network.[16,17] In terms of centrality indices, node strength centrality was defined as the sum of all associations of a given node with all other nodes, and closeness centrality was defined as a measure of how close a symptom was to all other symptoms. Finally, betweenness centrality was defined as the shortest length of a path connecting any two nodes. Thus, since node strength centrality was substantially correlated with closeness centrality and betweenness centrality, the most central symptoms were estimated within the network structures of the 17 CLANG items.

As described elsewhere,[7] the mean age and mean duration

Table 1. Percent Scores for the CLANG Items (n=167)

CLANG items	Abbreviation	%score			
		%0	%1	%2	%3
1. Excess phonetic association	PHO	92.2	5.4	2.4	0.0
2. Abnormal syntax	ASY	67.7	16.8	10.2	5.4
3. Excess syntactic constrains	ESY	74.9	20.4	3.0	1.8
4. Lack of semantic association	ASS	62.3	15.0	9.0	13.8
5. Referential failures	REF	92.8	4.2	1.2	1.8
6. Disclosure failure	DSC	46.1	21.0	20.4	12.6
7. Excess details	EDE	54.5	29.9	12.6	3.0
8. Lack of details	LDE	41.3	28.7	18.6	11.4
9. Aprosodic speech	APR	63.5	20.4	10.2	6.0
10. Abnormal prosody	ABP	88.6	7.2	2.4	1.8
11. Pragmatics disorder	PRA	71.9	14.4	10.2	3.6
12. Dysfluency	FLU	70.1	21.6	7.2	1.2
13. Dysarthria	ART	64.1	18.0	10.2	7.8
14. Poverty of speech	POV	51.5	23.4	10.8	14.4
15. Pressure of speech	PRS	74.3	17.4	6.6	1.8
16. Neologisms	NEL	92.2	4.2	2.4	1.2
17. Paraphasic error	PAR	85.0	6.6	5.4	3.0

ABP, abnormal prosody; APR, aprosodic speech; ART, dysarthria; ASS, lack of semantic association; ASY, abnormal syntax; CLANG, Clinical Language Disorder Rating Scale; DSC, disclosure failure; EDE, excess details; ESY, excess syntactic constrains; FLU, dysfluency; LDE, lack of detail; NEL, neologisms; PAR, paraphasic error; PHO, excess phonetic association; POV, poverty of speech; PRA, pragmatics disorder; PRS, pressure of speech; REF, referential failure.

of illness of the study participants were 46.5 (SD=11.2) years and 20.9 (SD=10.3) years, respectively (Supplementary Table 1, only online). More than half of the participants were men (51.5%), unmarried (79.1%), educated below a high school graduate level (73.0%), religiously-affiliated, and recruited from Yong-In Mental Hospital (86.8%). In addition, the mean chlorpromazine equivalent dose[18] of prescribed antipsychotics was 921.1 (SD=952.0) mg per day. The abbreviations and percentscores of the CLANG items are presented in Table 1.

Fig. 1A shows how a psychopathological network consisting of the CLANG items was constructed. In terms of the edge statistics, about 88% (n=120) of all possible 136 edges were estimated to be above zero. The estimated network revealed strong positive connections between pragmatic disorder and paraphasic error (0.806), aprosodic speech and abnormal prosody (0.679), lack of detail and poverty of speech (0.611), excess syntactic constraints and referential failures (0.598), excess phonetic association and neologisms (0.528), excess syntactic constraints and abnormal prosody (0.506), and referential failures and aprosodic speech (0.506). On the contrary, the network revealed strong negative connections between poverty of speech and pressure of speech (-0.552), poverty of speech and neologisms (-0.521), and referential failures and abnormal prosody (-0.514). Remarkably, pragmatics disorder, excess phonetic association, and dysfluency were largely isolated within the network. A community-detection method revealed an organization of roughly five clusters as follows: Cluster A included excess phonetic association, pragmatics disorder, neologisms, and paraphasic error. Cluster B included abnormal syntax, lack of semantic association, disclosure failure, excess details, and

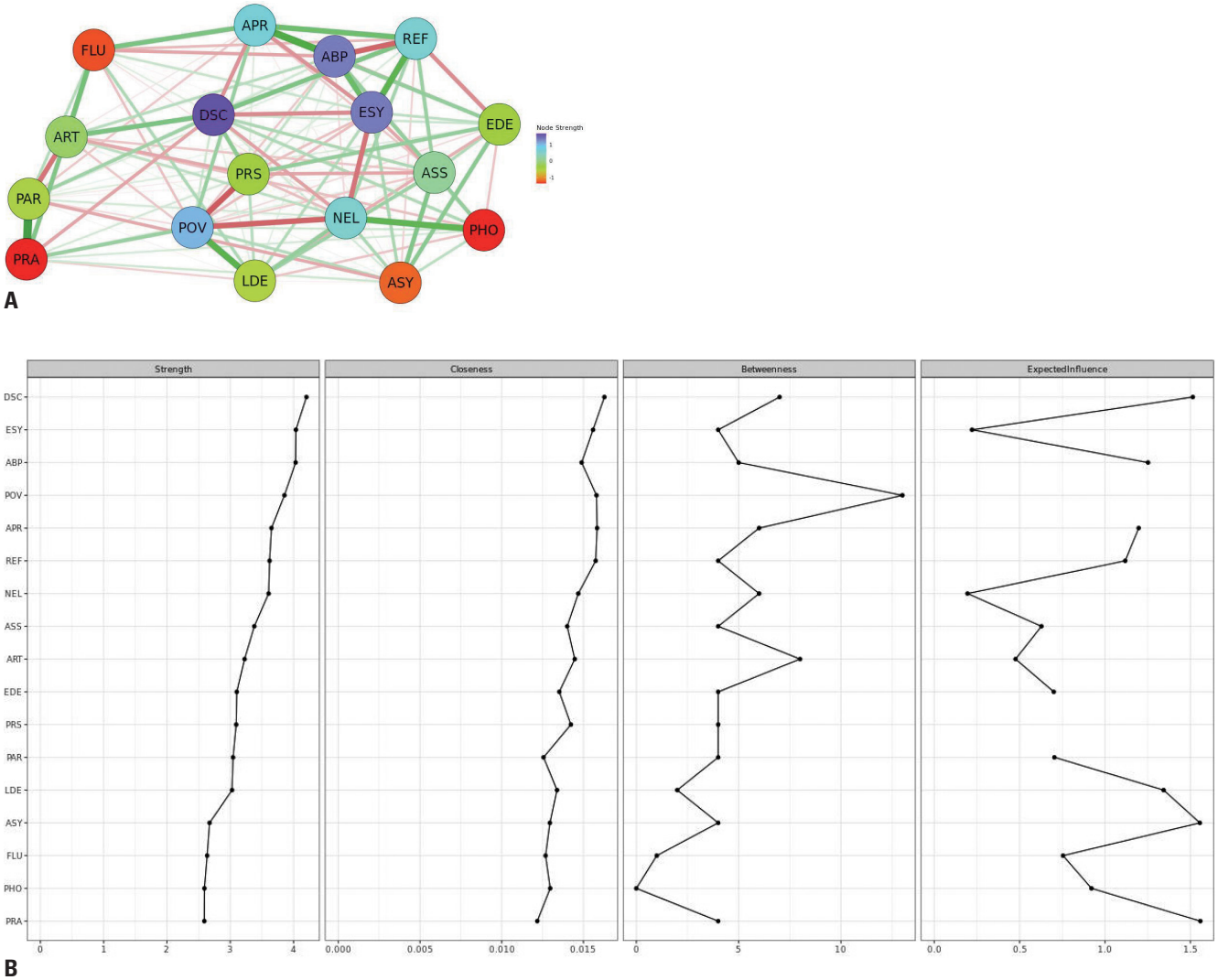

Fig. 1. Network analysis of the 17 Clinical Language Disorder Rating Scale (CLANG) items in patients with schizophrenia (n=167). (A) Network structure of the 17 CLANG items in patients with schizophrenia. Green lines represent positive associations, whereas red lines represent negative associations. Language disorganization was evaluated with CLANG. (B) Node strength centrality, closeness centrality, and betweenness centrality of the 17 CLANG items in patients with schizophrenia. ABP, abnormal prosody; APR, aprosodic speech; ART, dysarthria; ASS, lack of semantic association; ASY, abnormal syntax; DSC, disclosure failure; EDE, excess details; ESY, excess syntactic constrains; FLU, dysfluency; LDE, lack of detail; NEL, neologisms; PAR, paraphasic error; PHO, excess phonetic association; POV, poverty of speech; PRA, pragmatics disorder; PRS, pressure of speech; REF, referential failure.

https://doi.org/10.3349/ymj.2020.61.8.726

pressure of speech. Cluster C included excess syntactic constraints and referential failures. Cluster D included lack of details and poverty of speech. Finally, cluster E included aprosodic speech, abnormal prosody, dysfluency, and pressure of speech.

In terms of the node statistics, there were no abrupt changes with smooth declines in symptom importance as shown in Fig. 1B. Disclosure failure was most centrally situated within the network, followed by excess syntactic constraints and abnormal prosody; therefore, it also showed the highest symptom importance within the network. On the contrary, as pragmatics disorder was nearly unconnected, it represented the lowest node strength within the network, followed by excess phonetic association, and dysfluency.

In our findings, variability in node strength centrality for the 17 CLANG items was estimated. Disclosure failure, excess syntactic constraints, abnormal prosody, and aprosodic speech (mainly related to the disturbance of disclosure and prosody) ranked among the top five central symptoms (ranking 1, 2, 4, and 5 out of 17, respectively) within the network. In contrast, pragmatic disorder, excess phonetic association, and abnormal syntax (mainly related to the disturbance of association) were among the five most peripheral symptoms (ranking 17, 16, and 14 out of 17, respectively). Thus, as disclosure failure and dysprosody were situated relatively centrally and associative disturbance was situated relatively peripherally within the network, we speculated that self-monitoring problems may be the most influential constituent of language disorganization in schizophrenia. Most notably, disclosure failure was the most central domain within the estimated network of language disorganization in patients with schizophrenia. According to definitions in CLANG, disclosure failure (loss of schematic disorganization) involves a "lack of normal organization in which larger speech units progress from one context to the next in a gradual and prepared manner."[10] The immediate failure to construct coherence links contributes to building meaning across the sentences (discourse) in patients with schizophrenia.[19] Also, schizophrenia patients, rather than normal controls, have been characterized by less connection between ideas and clauses. Language disorder of schizophrenia can be closely related to a reduction in the top-down process of linguistic information.[20] Herein, our findings suggest that disclosure failure may be a relatively essential factor of language disorganization from a psychopathological network perspective. Furthermore, one study has shown that dysprosody is lateralized to nondominant hemispheres in epilepsy patients.[21] Thus, we suspect that language disorganization may be neurobiologically underpinned by dysfunction of the nondominant hemisphere. Remarkably, the five organized clusters of language disorganization are partly consistent with the five-factor solution, including pragmatics (i.e., paraphasic error, pragmatics disorder), disclosure (i.e., lack of semantic association, abnormal syntax, disclosure failure, lack of details, dysarthria), production (i.e., excessive details, poverty of speech, pressure of speech), prosody (i.e., aprosodic speech, abnormal prosody, dysfluency, excess syntactic constrains), and association (i.e., excess phonetic association, neologisms, referential failures), which has been previously extracted by a factor analysis of our data.[7] Thus, the organization of the five clusters may be supported.

Our study has several limitations. First, estimations of centrality may be biased due to restrictions in the range of CLANG items. In addition, the Pearson correlation coefficients (r) between the standard deviation and node strength centrality of the 17 items were negligible. Second, the study was conducted with a cross-sectional design, and thus, estimated unidirectional networks. As a result, our study could not assess differentiation between outdegree and indegree centrality. Third, since all recruited participants were schizophrenia patients hospitalized in Korean mental hospitals, our findings cannot be generalized to the entire population with schizophrenia. Fourth, since the mean duration of illness of the study participants was greater than 20 years, the chronic course of schizophrenia could affect the estimated network of language disorganization. It has been reported that the first, second, and third phases of the course of schizophrenia are characterized by thinking disorders, neologism and others, and schizophasia, respectively.[22] Thus, the possibility that language disorganization may be a chronic feature of schizophrenia rather than a core symptom of schizophrenia cannot be overlooked. However, as per our findings, disclosure failure has been the most central domain with the network of language disorganization, followed by excess syntactic constraints and abnormal prosody. Given that the symptoms of schizophasia have not been situated at a relatively central domain within the network, the chronic feature of schizophrenia may not significantly affect our findings. Despite these limitations, our study is the first to investigate the network structure of language disorganization from a new perspective of psychopathology. Altogether, we deemed that disclosure failure may be the most influential domain of language disorganization in patients with schizophrenia. Moreover, our results may provide future directions for additional studies controlling for the potential effects of confounding factors (i.e., duration of illness) on network analyses of language disorder and formal thought disorder in patients with schizophrenia.

ACKNOWLEDGEMENTS

This work was supported by the 2019 an Inje University Research Grant. We would like to thank Dr. Jinseob Kim for his valuable help with the network analysis.

AUTHOR CONTRIBUTIONS

Conceptualization: Seon-Cheol Park. Data curation: Seon-Cheol Park, Kang Uk Lee, and Joonho Choi. Formal analysis: Seon-Cheol Park. In-

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https://doi.org/10.3349/ymj.2020.61.8.726