Network insights

DOI: 10.1002/brx2.53

COMMENTARY

Brain-X Open Access WILEY

Network insights: Transforming brain science and mental health through innovative analysis

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Funding information
Fundamental Research Funds for the Central Universities, Grant/Award Number: 22CX04014B; The 71st Batch of China Postdoctoral Science Foundation, Grant/Award Number: 2022M712151; Social Science Planning Research Project of Shandong Province

KEYWORDS
brain sciences, mental health, methodology, network analysis, network theory

Network analysis, an interdisciplinary method rooted in graph theory and complex systems, is a promising approach for advancing our understanding of the brain's complex architecture and its implications for behavior, cognition, and mental health. Network analysis transcends the traditional psychiatric diagnostic model, which oversimplifies mental disorders by treating them as distinct physical illnesses, often creating an "epistemic prison" that fails to account for the nuanced interplay between neurological, biological, psychosocial, and cultural influences shaped by patients' life experiences.[1] By mapping and examining the intricate network of neuronal connections and larger brain region interactions, network analysis offers deep insights into brain communication pathways, their role in cognitive function, and how their disruption may lead to neurological disorders. Despite the potential of this method, the application of network analysis in brain science is underutilized, highlighting the need for increased awareness and the development of network-based studies to fully realize its transformative potential for behavior and brain research. Therefore, we introduce an insightful behavioral exemplar to increase awareness of the potential application of network analysis in brain science.

In their landmark study, Hu et al. not only challenged the compartmentalization of psychiatric diagnoses but also provided a novel lens through which we can view mental disorders from a neurobiological perspective.[2] By employing network analysis, they illustrated that psychiatric symptoms occur in isolation but as a part of a complex network at the behavioral level, significantly resonating with a variety of human brain functions and structures. This approach underscores the centrality of the motivation and pleasure factor, which is potentially linked to the brain's reward system, and its significant impact on broader cognitive and social functioning across different psychiatric conditions. The study integrated the transdiagnostic model with sophisticated statistical methods, such as the least absolute shrinkage and selection operator, further elucidating ways to examine potential intricate brain–behavior relationships in the future.[3] Such neuroscientific insights pave the way for a more nuanced understanding of psychopathology; additionally, they can inform targeted interventions that can modulate specific neural circuits implicated in multiple psychiatric disorders.

Although network analysis was employed behaviorally in this study, it offers methodological breakthroughs for

prospective neurological studies, allowing for a unified representation of complex brain functions and statistically significant control over variables of interest. It illuminates how alterations in one node can reverberate throughout the entire network, providing a level of insight traditional models have failed to achieve.[4] This holistic approach enables a comprehensive examination of behaviors and their neurological underpinnings.

Hu et al.'s work transcended mental health to probe the intricacies of human behavior.[2] Their application of transdiagnostic and network theories revealed a sophisticated behavioral system in which individual actions are influenced by psychological factors and governed by an intricate network of neural regions. This method exemplifies the potential for cross-disciplinary analysis and forecasts a future in which network analysis could refine our understanding of behavior over time, surpassing the limitations of reaction time studies.

However, the self-reported cross-sectional data in Hu et al.'s study may not capture the full complexity of neural processes.[2] Longitudinal neuroimaging can address this limitation by providing dynamic, objective insights into brain function with similar network methods, which are pivotal to cognitive neuroscience.[5] The promise of this methodology extends to brain network analysis—potentially revolutionizing personalized cognitive interventions—and treatment strategies for cognitive dysfunctions.

Our discussion underscores the study's impact on brain–behavior dynamics, advocating for an integrative approach that merges cognitive neuroscience, psychiatry, and computational modeling to decode the multifaceted nature of psychiatric conditions and their cognitive aspects. Our commentary is presented through the following promising aspects in which network analysis may demonstrate potential regarding brain sciences:

1. *Diagnosing and understanding brain disorders*: Network analysis is crucial in identifying specific brain connectivity patterns associated with various neurological and psychiatric disorders. This can enhance the understanding and accurate diagnosis of conditions such as Alzheimer's disease, schizophrenia, autism, and depression.
2. *Personalized medicine for tailored treatments*: Introducing the time variable could allow the analysis of intra-individual brain networks. A thorough understanding of how intra-individual brain networks cause or contribute to certain behaviors could allow treatments to be customized for neurological and psychiatric disorders, leading to more effective therapies and improved patient outcomes.
3. *Advancements in brain–computer interfaces*: Network analysis in the context of brain–computer interfaces (BCIs) involves studying the complex connectivity and interactions between different regions of the brain. This can help elucidate how neural signals associated with specific thoughts or intentions are generated and interconnected. By analyzing network patterns, researchers can identify the most relevant signals for controlling BCIs, leading to more accurate and efficient systems. This is especially useful for BCIs aimed at aiding individuals with motor impairments or communication difficulties, as it can lead to the development of interfaces that are better tailored to the users' unique neural activity patterns. Therefore, network analysis can contribute to the enhancement of BCIs by improving precision, response time, and overall usability.
4. *Predictive analysis for early intervention*: The role of predictive analysis in early intervention is crucial, particularly because the inclusion of prognostic factors could enhance its utility. By anticipating not only the onset of neurological conditions but also their potential trajectory, the combination of network analysis and time-varying vector autoregressive models can inform more personalized and effective intervention strategies, potentially altering the course of these disorders before they fully manifest.

AUTHOR CONTRIBUTIONS

Peng Wang: Conceptualization; writing—original draft. **Lulu Cheng**: Writing, reviewing, and editing.

ACKNOWLEDGMENTS

This research was supported by the Taishan Scholars Project Special Fund, the Fundamental Research Funds for the Central Universities "The cognitive research of autistic children with language disorders" (grant number 22CX04014B), the 71st Batch of China Postdoctoral Science Foundation "A Study on metaphor and metonymy acquisition of Chinese autistic children" (grant number 2022M712151) and the Social Science Planning Research Project of Shandong Province: A Study on Family Language Planning for Children with Delayed Speaking in Shandong Province.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ETHICS STATEMENT

The ethics approval was not needed in this study.

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How to cite this article: Wang P, Cheng L. Network insights: transforming brain science and mental health through innovative analysis. *Brain-X*. 2024;2:e53. https://doi.org/10.1002/brx2.53