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Editorial

Complexity of mental illness: A new research dimension

Human brain is characterized by its astonishing complexity. This complexity arises from the interaction of numerous neuronal circuits that operate over a wide range of temporal and spatial scales, enabling the brain to adapt to the constantly changing environment and to perform various amazing mental functions. By the late twentieth century, research on the human brain had become a fascinating interdisciplinary science that covers a broad range of fields of psychiatry, neurology, and neuroscience.

Concepts from mathematics, physics, and computer science are increasingly applied to the study of the brain and the dysfunctions associated with the mentally ill. In the past few decades, attempts to employ these non-medical disciplines to better the understanding of complex human behaviors have been conducted. Additionally, a new discipline called the complexity science is emerging (Ehlers, 1995). The cognitive disorganization of schizophrenia or the unstable mood fluctuations of bipolar disorder support the notion that analysis of nonlinear dynamics (or a broader term, complexity science) may increase insight into complex human behaviors (Freeman, 1992).

This editorial will therefore focus on the recent advances of applying complexity science to the understanding of the aging, sleep, and mental illness. The topics of this special section include (1) a general introduction to the understanding of mental illness under the context of complexity science (Yang and Tsai, 2013); (2) physiologic complexity and aging (Manor and Lipsitz, 2013); (3) complexity and sleep disorders (Bianchi and Thomas, 2013); (4) complexity and schizophrenia (Fernandez et al., 2013); and (5) complexity analysis of spontaneous brain activity in mental illness (Takahashi, 2013).

It has long been observed that physiologic output (e.g., heart rate) under healthy conditions typically exhibits multi-scale complexity, long-range correlation, and non-linearity (Lipsitz and Goldberger, 1992). Increased complexity in physiologic output has been observed to be correlated to healthy conditions whereas aging and pathological conditions often show a reduction in the complexity of physiologic output (Goldberger et al., 2002). In the review by Manor and Lipsitz (2013), they discussed several caveats that one must consider when examining the functional and rehabilitative implications of physiologic complexity, and importantly, the potential for interventions to restore the complex dynamics that characterize healthy physiological function.

Such concept of physiologic complexity can be also applied to the study of sleep disorders, particularly in terms of complex interactions of various physiologic components during sleep. Bianchi and Thomas (2013) systemically reviewed the recent advances in autonomic measurements that provide additional important insights of sleep stability, and to the extent of the spectrum of approaches that have been leveraged towards improved understanding of the complexity of sleep.

In recent years, the concept of complexity has been applied to the analysis of neurophysiological data, such as an electroencephalogram or magnetoencephalography. The review by Takahashi (2013) comprehensively examined the various complexity analyses of spontaneous brain activities, and their relations to brain dysfunctions of the broad spectrums of mental illness. Furthermore, with the primary focus on schizophrenia, Fernandez et al. (2013) systemically reviewed the advances in complexity estimators which have been broadly utilized in schizophrenia investigation. Such investigation gave rise to the important implications in pathophysiology of schizophrenia. Recently, complexity analysis of resting-state blood oxygen level dependent (BOLD) signals obtained from resting state functional magnetic resonance imaging has attracted considerable interests. A study of the Hurst exponent calculated from the resting-state BOLD signals obtained from autistic children showed a shift to randomness in brain regions related to social, motor organization, and connection hubs (Lai et al., 2011). We have recently applied the entropic complexity method to the analysis of BOLD signals in an aging cohort, and found that the complexity of BOLD signals in default mode brain network was correlated positively to the various domains of cognitive functions (Yang et al., 2012). These studies provide a novel complexity approach to study brain dysfunction associated with aging and mental illness using the most sophisticated neuroimaging tool.

In this context, the concept of complexity provides a useful and promising tool for clinical psychiatry that may benefit the evaluation of the disease process or treatment outcome. From a systemic perspective, complexity reflects a system's ability to adapt to the constantly changing environment. Such adaptation is often impaired in mentally ill patients, producing either ordered or random behavioral patterns. However, considering that the brain is the organ of mind, the adaptability of mental functions must result from the underlying neuronal plasticity, which can be plausibly measured by complexity analysis at the microscopic level. Therefore, we propose that mental illness is the loss of brain complexity, which can be studied and quantified using methods adapted from the complexity science. Complexity analysis may have the potential to provide a new research dimension to the understanding of the pathophysiology of mental illness.

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