Local Oscillatory Brain Dynamics

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A number of studies have focused on brain dynamics underlying mind wandering (MW) states in healthy people. However, there is limited understanding of how the oscillatory dynamics accompanying MW states and task-focused states are characterized in clinical populations.

Keywords: schizophrenia ; Q-EEG ; mind wandering ; cognitive functioning

1. Introduction

In recent years, there has been a growing interest in the study of mind wandering (MW) within the field of cognitive and clinical neuroscience. MW can be understood as a cognitive state originating from transitions between externally guided and self-generated thoughts. During MW, perceptual decoupling occurs so that sensory processing of an immediate task is reduced and attention is directed towards thoughts, images or internal memories [1]. MW has been associated with the activity of the default mode network (DMN), a cortical network located along the midline of the prefrontal cortex, the rostral anterior cingulate cortex, the posterior cingulate cortex and the precuneus [2][3]. However, some authors argue that DMN activation alone is insufficient to capture the neural base of the MW [4]. Other brain regions outside the DMN also show associations with various content and forms of MW.

Functional connectivity studies have gained increasing interest in this area of research. It is known that the local synchrony pattern varies remarkably across the cortex [5]. A number of studies have focused on brain dynamics underlying mind wandering (MW) states in healthy people. However, there is limited understanding of how the oscillatory dynamics accompanying MW states and task-focused states are characterized in clinical populations. From a clinical point of view, the dysfunctional properties associated with MW are closely related to neuropsychiatric disorders [6][7]. Recent research [8][9] has reported that patients with schizophrenia exhibited states of MW more frequently than healthy controls. This greater frequency of MW has been explained by a frequent disconnection of attention from external events accompanied by an excessive focus on the inner world [9][10][11][12]. Dysfunctional properties associated with MW in schizophrenia may be mediated by deficits at the neural level. For example, there is evidence describing aberrant dysfunctional connectivity patterns and hyperactivity both in the DMN, as well as between this network and other neural networks [13]. The dysfunctional brain dynamics in schizophrenia could be responsible for diverting attention resources when patients try to perceive, think or act in the external world [14][15], leading to an increase in MW episodes. Hence, schizophrenia can be characterized by alterations in brain connectivity during states of rest and during cognitive tasks [16][17][18]. Some recent research has used local synchrony to explore local brain activity in schizophrenia [13][19][20][21]. Local alterations in synchrony suggest a disrupted balance in the local functionality of the entire brain network and are characterized by alterations in the power, or amplitude, of local oscillations within a brain region [22] that may be present in the first psychotic episode [23]. The severity of these deficits correlates with the severity of the symptoms [24], which suggests that abnormal brain dynamics at the neural level may be related to the cognitive and behavioral deficits associated with schizophrenia. These findings, combined with previous results [8], confirm differences in EEG modulation between patients with schizophrenia and healthy controls and lead us to the subject of the present work. Our research allowed us to extend these results by exploring the neural correlates in local EEG synchrony that accompany MW and attention to an external task in schizophrenia. Specifically, we intended to characterize the differences between both states according to the power in each frequency band and cortical location. The approach we presented measured the oscillatory power in different frequency bands evoked by a specific task, in which MW episodes were recorded while participants (schizophrenia patients and healthy controls) watched short video clips. Based on previous data, we expected to find differences in the oscillatory dynamics that accompany the fluctuations between MW and external attention in different cortical regions.

2. Current Analysis

In this study, we explored EEG local synchrony of MW associated with schizophrenia, under the premise that changes in attention that arise during MW are associated with a different pattern of brain activity. Specifically, we studied the changes in the spectral power of the different frequency bands (delta, theta, alpha, beta and gamma) in different scalp regions (frontal, central, posterior and temporal) during periods of MW and task-focused attention in the context of an undemanding task. To this end, we measured the power of EEG oscillations in different frequency bands, recorded while participants watched short video clips. In the group of participants diagnosed with schizophrenia, the power in MW states was significantly lower than during task-focused states, mainly in the frontal and posterior regions. These findings supported the role of specific cortical regions in fluctuation between internally generated thoughts and external task-related thoughts in patients and controls. hese cortical activation changes could be responsible for the greater susceptibility to MW associated with schizophrenia [8][9]. In patients, the differences between the two states were mainly located in the frontal and temporal regions, which are closely related to cognitive and clinical symptoms, especially with the deficient mechanisms of attentional control responsible for inhibiting interference (external or internal) with the task. These findings corroborated current theoretical frameworks that emphasize the role of the temporal and frontal areas in supporting self-generated thoughts (MW) in clinical populations [21][25][26]. Furthermore, according to Thézé et al. [27], abnormal brain activation in these regions in patients may suggest greater cortical processing to connect to the task. However, in the group of healthy controls, the differences in power between the task-focused and MW states occurred exclusively in the posterior region. It should be considered that the oscillatory activity of the EEG is not necessarily a uniform phenomenon; that is, it can be associated with different cognitive processes, which can explain the variation between different topographic regions of the cortex as well as the differences between groups. Furthermore, the power of the frequency bands during MW and during episodes of task-focused attention correlated with cognitive variables such as processing speed and working memory. These findings on dynamic changes of local synchronization in different frequency bands and areas of the cortex can improve our understanding of mental disorders, such as schizophrenia.

This study provided new insights into neural markers of MW and task-focused states in patients with schizophrenia. We found that MW was associated with a decrease in the oscillatory power of the delta, theta, alpha and beta bands, and these findings help to clarify the differences in MW between people with schizophrenia and healthy people, as well as which cortical regions intervene during dynamic changes between the two states. Future research should continue the study of oscillatory activity during MW in schizophrenia and related mental disorders.

References

1. Smallwood, J.; Fishman, D.J.; Schooler, J.W. Counting the cost of an absent mind: Mind wandering as an underrecognized influence on educational performance. Psychon. Bull. Rev. 2007, 14, 230–236.
2. Buckner, R.L.; Andrews-Hanna, J.R.; Schacter, D.L. The brain's default network: Anatomy, function, and relevance to disease. Ann. N. Y. Acad. Sci. 2008, 1124, 1–38.
3. Spreng, R.N.; Mar, R.A.; Kim, A.S.N. The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: A quantitative meta-analysis. J. Cogn. Neurosci. 2009, 21, 489–510.
4. Fox, K.C.; Spreng, R.N.; Ellamil, M.; Andrews-Hanna, J.R.; Christoff, K. Corrigendum to The wandering brain: Meta-analysis of functional neuroimaging studies of mind-wandering and related spontaneous thought processes. NeuroImage 2015, 111, 611–621.
5. Zang, Y.; Jiang, T.; Lu, Y.; He, Y.; Tian, L. Regional homogeneity approach to fMRI data analysis. NeuroImage 2004, 22, 394–400.
6. Smallwood, J.; Andrews-Hanna, J. Not all minds that wander are lost: The importance of a balanced perspective on the mind-wandering state. Front. Psychol. 2013, 4, 1–6.
7. Whitfield-Gabrieli, S.; Ford, J.M. Default Mode Network Activity and Connectivity in Psychopathology. Annu. Rev. Clin. Psychol. 2012, 8, 49–76.
8. Iglesias-Parro, S.; Soriano, M.F.; Prieto, M.; Rodríguez, I.; Aznarte, J.I.; Ibáñez-Molina, A.J. Introspective and Neurophysiological Measures of Mind Wandering in Schizophrenia. Sci. Rep. 2020, 10, 1–12.
9. Shin, D.D.; Lee, T.Y.; Jung, W.H.; Kim, S.N.; Jang, J.H.; Kwon, J.S. Away from home: The brain of the wandering mind as a model for schizophrenia. Schizophr. Res. 2015, 165, 83–89.

10. Barch, D.M.; Carter, C.S.; Dakin, S.; Gold, J.; Luck, S.J.; MacDonald, A.; Ragland, J.D.; Silverstein, S.; Strauss, M.E. The Clinical Translation of a Measure of Gain Control: The Contrast-Contrast Effect Task. Schizophr. Bull. 2011, 38, 135–143.
11. Humpston, C.S. Perplexity and meaning: Toward a phenomenological ‘core’ of psychotic experiences. Schizophr. Bull. 2014, 40, 240–243.
12. Phillips, R.C.; Salo, T.; Carter, C.S. Distinct neural correlates for attention lapses in patients with schizophrenia and healthy participants. Front. Hum. Neurosci. 2015, 9, 502.
13. Wang, H.; Zeng, L.-L.; Chen, Y.; Yin, H.; Tan, Q.; Hu, D. Evidence of a dissociation pattern in default mode subnetwork functional connectivity in schizophrenia. Sci. Rep. 2015, 5, 14655.
14. Buckner, R.L. The brain’s default network: Origins and implications for the study of psychosis. Dialogues Clin. Neurosci. 2013, 15, 351–358.
15. Whitfield-Gabrieli, S.; Thermenos, H.W.; Milanovic, S.; Tsuang, M.T.; Faraone, S.V.; McCarley, R.; Shenton, M.E.; Green, A.I.; Nieto-Castanon, A.; LaViolette, P.; et al. Hyperactivity and hyperconnectivity of the default network in schizophrenia and in first-degree relatives of persons with schizophrenia. Proc. Natl. Acad. Sci. USA 2009, 106, 1279–1284.
16. Adams, R.A.; Bush, D.; Zheng, F.; Meyer, S.S.; Kaplan, R.; Orfanos, S.; Marques, T.R.; Howes, O.D.; Burgess, N. Impaired theta phase coupling underlies frontotemporal dysconnectivity in schizophrenia. Brain 2020, 143, 1261–1277.
17. Kim, J.S.; Shin, K.S.; Jung, W.H.; Kim, S.N.; Kwon, J.S.; Chung, C.K. Power spectral aspects of the default mode network in schizophrenia: An MEG study. BMC Neurosci. 2014, 15, 104.
18. Schulz, S.; Cladera, B.L.; Giraldo, B.; Bolz, M.; Bar, K.; Voss, A. Neuronal desynchronization as marker of an impaired brain network. In Proceedings of the 2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Jeju, Korea, 11–15 July 2017; pp. 2251–2254.
19. Chen, J.; Xu, Y.; Zhang, K.; Liu, Z.; Xu, C.; Shen, Y.; Xu, Q. Comparative study of regional homogeneity in schizophrenia and major depressive disorder. Am. J. Med Genet. Part B Neuropsychiatr. Genet. 2013, 162, 36–43.
20. Wei, Y.; Chang, M.; Womer, F.Y.; Zhou, Q.; Yin, Z.; Wei, S.; Zhou, Y.; Jiang, X.; Yao, X.; Duan, J.; et al. Local functional connectivity alterations in schizophrenia, bipolar disorder, and major depressive disorder. J. Affect. Disord. 2018, 236, 266–273.
21. Xu, Y.; Zhuo, C.; Qin, W.; Zhu, J.; Yu, C. Altered Spontaneous Brain Activity in Schizophrenia: A Meta-Analysis and a Large-Sample Study. BioMed Res. Int. 2015, 2015, 1–11.
22. Spellman, T.J.; A Gordon, J. Synchrony in schizophrenia: A window into circuit-level pathophysiology. Curr. Opin. Neurobiol. 2015, 30, 17–23.
23. Spencer, K.M.; Salisbury, D.F.; Shenton, M.E.; McCarley, R.W. Gamma-Band Auditory Steady-State Responses Are Impaired in First Episode Psychosis. Biol. Psychiatry 2008, 64, 369–375.
24. Spencer, K.M.; Niznikiewicz, M.A.; Nestor, P.G.; Shenton, M.E.; McCarley, R.W. Left auditory cortex gamma synchronization and auditory hallucination symptoms in schizophrenia. BMC Neurosci. 2009, 10, 85.
25. Maillet, D.; Rajah, M.N. Association between prefrontal activity and volume change in prefrontal and medial temporal lobes in aging and dementia: A review. Ageing Res. Rev. 2013, 12, 479–489.
26. O’Callaghan, C.; Shine, J.M.; Hodges, J.R.; Andrews-Hanna, J.R.; Irish, M. Hippocampal atrophy and intrinsic brain network dysfunction relate to alterations in mind wandering in neurodegeneration. Proc. Natl. Acad. Sci. USA 2019, 116, 3316–3321.
27. Thézé, R. Neural correlates of reality filtering in schizophrenia spectrum disorder. Schizophr. Res. 2019, 204, 214–221.