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The neural mechanisms behind mind wandering phenomenon: A brief review

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Abstract: *Mind wandering is the ability of an individual to spontaneously shift from one mental state to another in response to external stimuli. It is a crucial feature of human cognitive processes. To better understand the neurological mechanisms underlying mind wandering, researchers have recently integrated brain imaging methods with the phenomenon of mind wandering. This method offers a fresh perspective on the neurological underpinnings of mind wandering. This study presents a review of previous research on mind wandering from a neuromanagement viewpoint and explains popular methods to the field. The aim is to deepen understanding and provide innovative applications for organizational management, as well as new perspectives and approaches for exploring and solving cognitive, emotional, and decision-making problems in organizations.*

Keywords: *Mind wandering, EEG, Neural management science, Behavioral research*

1. Introduction

The knowledge of human brain activity is changing at a rate never seen before, owing to the advent of multidisciplinary study as well as the fast advancement of science and technology. Mind wandering, a concept that has received much attention in the field of psychology, refers to an individual's ability to shift from one mental state to another in response to external stimuli (Smallwood & Schooler,2006). This idea has a big impact on how we think about cognition, emotion, and behavior, which makes it important for cognitive neuroscience and psychology research. A basic feature of human mental activity, mind wandering is a crucial technique for adjusting to various contexts and circumstances.

The swift advancement of brain imaging technology, including the extensive application of electroencephalography (EEG), has resulted in an enhanced comprehension of the neurological processes behind mind wandering. We can see minute variations in brain activity thanks to electroencephalography (EEG), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), and other EEG methods, revealing the neural mechanisms behind mind wandering. The development of these techniques not only provides us with new tools to study mind wandering, but also offers new perspectives to understand the relationship between mind wandering and psychological processes such as cognitive functioning and emotion regulation.

This study aims to provide a thorough analysis of the notion of mind wandering, the use of EEG technology, and the latest developments in the fusion of mind wandering and brain imaging technology, and the prospects for developing neuromanagement. By exploring the neural basis of mind wandering, we can gain a better understanding of the human cognitive process. This may provide a solid scientific basis and practical guidance for managing people and organizations, as well as encourage further innovation and advancement in the field of organizational management[1-4].

2. Measurement of mind wandering

2.1. Questionnaire method

The questionnaire survey method is a frequently used approach to measure mind wandering. It collects individuals' subjective experiences and self-reports of mind state shifting by designing specific questionnaires or scales to reveal the characteristics, frequency, intensity, and related factors of mind wandering. The main features and applications of questionnaire survey method in mind wandering research include subjective experience acquisition, quantitative measurement, multidimensional

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assessment, individual difference analysis, and experimental control. Mrazek et al. (2013) created the classic wandering questionnaire (MWQ) to assess trait levels of mind wandering objectively and efficiently.

2.2. Verbal Reports

The verbal report method is a frequently used technique in mind wandering research. It involves individuals reporting whether they experience mind wandering or not, allowing for the measurement of its frequency. The method is divided into two categories, the experience sampling method (ESM) and the thought sampling method (TSM), depending on the application scenario. The Experience Sampling Method (ESM) involves collecting reports of mind wandering from random samples of individuals in their daily lives to obtain a natural and genuine mental state (Hasenkamp et al.,2012). In contrast, the Thought Sampling Method (TSM) requires subjects to report their mind wandering at a specific point in time during a particular experimental task, allowing the researcher to more accurately control the experimental conditions and obtain specific psychological data. Verbal reporting methods can be categorised as either probe-caught or self-caught, depending on the method of reporting.

2.3. Objective Indicator Support Method

The two methods mentioned above for evaluating subjects' states involve asking about their subjective feelings and lack objectivity. Therefore, behavioural measures are particularly important as a supplementary method. By asking objective questions to confirm the current state of the subject, such as their behavioural performance and verbal characteristics, more objective data can be obtained to support the evaluation. When objective measurements are combined with well-marked subjective self-evaluation, a full picture of the prevalence and traits of mind wandering from several angles may be obtained. This enhances the accuracy and credibility of the measurement of mind wandering. In recent years, the SART paradigm of sustained attention tasks has been a commonly used behavioural indicator(Li et al., 2023; McVay&Kane, 2012). The integration of both subjective and empirical data facilitates a deeper and more thorough comprehension of the nature and workings of the mind-wandering phenomena.

2.4. Physiological and Cognitive Neurological Approaches

Physiological and cognitive neurological approaches are used to study mind wandering through physiological indicators and neuroimaging techniques. These techniques can aid in the investigation of brain activity patterns, connections to cognitive performance, and neurological processes behind individual mind wandering. Typically, the study uses the following techniques: Real-time monitoring of the temporal and spatial aspects of mind-wandering activity is made possible by the electrical activity in the cerebral cortex being recorded by EEG (Bozhilova et al., 2021). fMRI techniques measure changes in blood oxygen levels in different regions of the brain, indirectly reflecting brain activity (Groot et al., 2021). MEG techniques can record changes in the brain's magnetic field, providing information on brain activity with high temporal resolution. Eye-tracking techniques involve recording an individual's eye movements and gaze points to reveal their attention allocation and information processing processes (Koessmeier & Büttner, 2022). These physiological and cognitive neurological methods can provide objective and intuitive neurological data to support the study of mind wandering, thus providing insights into the neural basis and cognitive mechanisms of mind state shifting. By combining these methods, researchers can gain a more comprehensive and accurate understanding of the neural processes involved in mind wandering. This offers crucial experimental resources and a theoretical framework for more psychology and neuroscience study.

3. A review of cognitive neural studies of mind wandering

As the study of human mental activities deepens, mind wandering has become a significant research topic in cognitive neuroscience. Mind wandering is the process of shifting an individual's attention and awareness from one mental object or task to another while performing a task or processing information. This concept has been developed through the cross-fertilization of cognitive psychology and neuroscience, as well as the continuous advancement of brain imaging technology. The study of mind wandering in cognitive neuroscience aims to explore its neural basis, brain mechanisms, and its relationship with cognitive processes such as cognitive control and attention allocation. This is a major step forward in our understanding of the composition and operations of human mental processes[5-9].

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3.1. ERP related to mind-wandering

Previous studies on the electrophysiological examinations of MW have focused on the Sustained Attention Response Task (SART) (Robertson et al., 1997). This task requires participants to perform a single manual response to frequently occurring non-targets (digits 1-9 excluding 3) while ceasing such responses to infrequently occurring targets (digit 3). To perform a manual response once, while stopping this response for infrequently occurring targets (excluding number 3). Numerous articles in the existing literature have documented ERP components during mind wandering. The most commonly studied perceptual level is the P1 component, while the most commonly studied cognitive level is the P3 component. Participants in a study by Baird et al. (2014) were asked to provide feedback on the values that were shown on the screen. When the number 3 occurred, they were told to respond to it; the other values didn't need to be responded to. The results of the study showed that a significant P1 component was observed during the task-focused state, which peaked significantly lower during mind wandering.

Focusing on anything else has been shown by Kam et al. (2011) to temporarily lower the degree of sensory-evoked brain activity across a range of sensory domains. This decrease may be linked to a reallocation of the brain's resources in processing external stimuli, resulting in reduced activation of brain regions. When people wander their thoughts, their attention is diverted from one thing or activity to another, and the brain modifies its resource allocation to meet the new demands of cognition. Therefore, the study of mind wandering focuses on the relationship between shifts in attention and task performance, as well as changes in the brain's patterns of neural activity and resource utilization.

3.2. Relevant effects of mind wandering on frequency bands

This section focuses on studies related to EEG spectroscopy in mind wandering. Studies that focus on certain frequency bands—theta, beta, and delta bands being the most popular—have been published in the literature to date.

Arnau et al. (2020) found that activity in the delta band significantly increases during mind wandering and is significant at all electrode sites. Baldwin et al. (2017) discovered that participants' alpha abilities were significantly enhanced prior to the presence of a report of wandering during a simulated driving and vigilance task. This study proposes that the brain proactively adapts its neural activity patterns to prepare for potential distractions or mind-wandering states when faced with tasks that require sustained attention. Previous research has identified spatially and temporally localised slow waves as a pattern of neural activity during the transition to sleep. The study demonstrated that the pattern of neural activity was linked to missed behavioural markers, as well as previously reported wandering and foggy-headedness. Specifically, the location of slow waves was found to differentiate between delayed and impulsive behaviour, as well as wandering and mind blanking[10-14].

These findings highlight the shared physiological origins of attention deficit in the presence of localised sleep-disordered activity in the waking brain (Andrillon et al., 2021).One research, during the SART task, demonstrated a link between mind wandering and less stimulated prefrontal activity in the wandering state relative to the task state, which defied the conclusions of most prior studies (Wamsley & Summer, 2020). Polychroni et al. (2022) found that alpha power significantly increased in participants experiencing conscious mind wandering, while delta and theta power increased during unconscious mind wandering.Similarly, Martel et al. (2019) reported that an increase in alpha energy was associated with conscious mind wandering, and a general reduction in responses evoked in off-task states[15-17].

4. Conclusion

This review's objective is to provide a broad overview of recent studies on mind-wandering measurements and electrophysiological indicators of brain processes. The findings show that during mind wandering, the strength of the low-frequency band increases, the amplitude of the ERP component drops, and conscious vs unconscious mind wandering causes distinct band activity. These findings offer significant new insights into the mental processes and brain systems that underlie mind wandering. Future research endeavors might investigate the correlation between mind wandering and the interconnectivity of the brain's neural networks, cerebral activity patterns across different regions, and cognitive functions. This would disclose the meaning and brain underpinnings of mind wandering.

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