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The role of metacognition in healthcare: Shaping the future with artificial intelligence

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Abstract
Metacognition, the cognitive process of reflecting on one's own thoughts, is regarded as a vital function for human development across various domains. Nonetheless, the empirical evidence supporting this assertion remains insufficient, which has led to a burgeoning interest within the scientific community during recent decades in exploring the relationship between metacognition and cognitive processes. The current study investigates the role of metacognition in mental health, with particular emphasis on how metacognitive training is integrated into psychotherapeutic practices. Furthermore, the potential of advanced technologies, such as artificial intelligence, to enhance cognitive and metacognitive skills is documented, accompanied by recommendations for future research directions.

Keywords: Metacognition, mathematical cognition, artificial intelligence, metacognitive training, mental health, psychotherapy

Introduction
Recent theoretical perspectives posit that the primary social function of metacognition is to communicate an individual's insecurities to others, thereby facilitating cooperative coordination. A study assessed children's competence in solitary contexts, primarily based on the assumption that metacognition is most effective for introspection and decision-making at an individual level [1]. The findings challenge traditional views on the long-term development of metacognition and support the theory that it primarily constitutes a social-cognitive ability. A deficiency in self-awareness regarding one's own limitations may originate from impaired metacognition. Research demonstrates that patients exhibiting metacognitive impairments across various neurological and psychiatric conditions—such as traumatic brain injury, dementia, and schizophrenia—may still recognize such difficulties in others and themselves when provided with third-party perspectives [2]. Exploring the relationship between perspective acceptance and metacognition could be beneficial in improving the quality of life for individuals with dementia, considering that metacognitive deficits are a prominent feature of the disorder, especially in Alzheimer's disease. Given that the default mode network is disrupted during the early stages of Alzheimer's disease and is involved in self-referential versus other-referential processing, it is plausible that this network explains how perspective acceptance influences awareness deficits in Alzheimer's disease [2]. Moreover, individuals who have experienced traumatic brain injuries frequently exhibit deficiencies in metacognitive functions and tend to make decisions at a slower rate in comparison to their neurotypical peers. Investigations conducted to clarify the differences in neural substrates underlying metacognitive abilities post-trauma have demonstrated that prefrontal gray matter volume and internetwork connectivity serve distinct roles in metacognitive processes following injury [3]. In the context of obsessive-compulsive disorder, spontaneous activity within the left, middle temporal gyrus has been associated with levels of insight [4].
Metacognition is a cognitive function localized in specific brain areas. In a study involving metacognition tasks related to mathematical problems, parts of the prefrontal cortex (such as the left/right middle frontal gyri and the left inferior frontal gyrus), the right insula, the left/right cingulate gyri, as well as the right insula were observed to be active during the metacognition task [5]. In a similar study involving metacognitive assessments of cognitive effort, increases in task difficulty during mathematical operations were found to activate the

frontal lobe, the parietal lobule, the precuneus, the cingulate gyrus, and the insular cortex [6]. The role of the insular cortex in human cognition is vital and multidimensional. Apart from metacognition and self-awareness, the insula is involved in various other cognitive functions, including sensory perception, and it seems to play a role in depression [7]. In Figure 1 the higher cognitive function of metacognition is depicted.

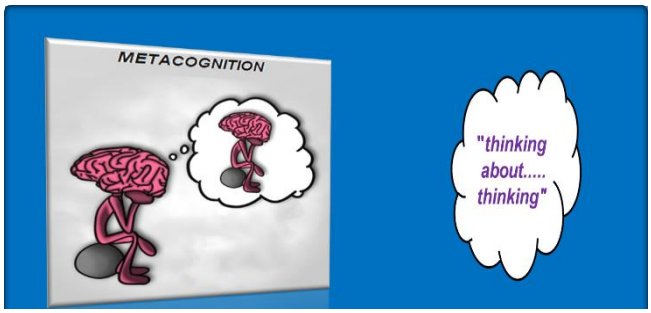

Fig 1: Metacognition, the process of thinking about thinking, is used to assess and monitor one's own plans and performance.

Reflecting on our own thoughts can amplify or redirect our cognition; therefore, it is a vital factor in understanding human behavior [8]. Many individuals suffering from mental illness experience impaired metacognition, which results in a lack of awareness of their own emotions, an inability to perceive their thoughts as subjective, and a failure to employ metacognitive knowledge about themselves to resolve issues within difficult psychological circumstances [9]. It has been suggested that deficits in metacognition may also contribute to personality disorders and decrease the efficacy of treatment [10]. Moreover, effective treatment requires that psychotherapists specifically address deficiencies in metacognitive abilities associated with the patient's condition [11].

The present study examines the role of metacognition within the field of mental health, with particular emphasis on the integration of metacognitive training in psychotherapy. Additionally, it delineates how advanced technologies, including artificial intelligence, can serve to improve cognitive and metacognitive abilities, and provides suggestions for future research avenues.

Clinical psychology: Metacognitive training as a form of psychotherapy

Metacognitive therapy consists of a sequence of steps grounded in metacognitive perceptions of anxiety, demonstrating effectiveness in the treatment of anxiety and depression [12]. A theoretical model of metacognition within clinical psychology has been introduced, wherein patients experiencing excessive anger observe, label, and set goals regarding the desired transformation of their emotions, subsequently working to implement these changes [13]. In a study involving 112 patients who articulated their beliefs about paranoid thoughts, findings suggested that metacognition could serve as a valuable tool to cultivate positive beliefs about paranoia, thereby alleviating persecutory delusions in individuals with schizophrenia [14]. Monitoring beliefs pertaining to thought processes has been shown to be particularly advantageous for disorders characterized by recurrent patterns of unwanted thoughts, such as obsessive-compulsive disorder [15].

Metacognitive models of therapy focus on the process of thinking, whereas traditional therapies emphasize the content of thoughts [16]. Exposure therapy and cognitive restructuring are therapeutic methods utilized for the treatment of anxiety that involve modifications in the metacognitive states of patients [12]. The cognitive function of metacognition serves as the primary focus of three therapeutic approaches: Metacognitive Therapy, Metacognitive Reflection and Insight Therapy, and Metacognitive Training [17]. Metacognitive Training has demonstrated greater efficacy than cognitive remediation in patients diagnosed with schizophrenia and has shown superiority over standard treatment in patients with obsessive-compulsive disorder [18]. Furthermore, Metacognitive Therapy has been found to be more effective than cognitive-behavioural treatments in patients suffering from anxiety [18].

Cognition and Artificial Intelligence Machines

The rate at which artificial intelligence machines are integrating into our daily lives is increasing exponentially. Cognitive machines equipped with autonomous capabilities will soon become part of our households [19]. The process of identifying and selecting the appropriate tool for assembly, constitutes a complex movement—an intricate combination of cognitive processing and action execution—and the successful implementation of such acts by a robot remains a significant challenge in the field of cognitive robotics [20]. Language represents another complex aspect of cognition, which has been extensively studied with the aim of incorporating it into artificial intelligence systems to translate sound into actionable output [21]. Numerous approaches focusing on self-examination are aimed at designing artificial intelligence systems capable of outperforming humans [22]. Although cognitive performance can be predicted with high accuracy, machine learning predictive models have yet to fully elucidate the underlying mechanisms of cognition [23]. Second-order computation offers significant potential to unify various forms of self-assessment and functions as an invaluable tool for exploring metacognition [24]. A computational rationality framework, tailored to compare diverse models of metacognition, appears promising in diminishing the experimental efforts necessary to identify the most suitable model [25]. Moreover, within the educational sector, educators have recognized that artificial intelligence can facilitate personalized mathematics instruction, support mathematics learning beyond formal educational settings, and augment students' motivation towards mathematics [26]. Furthermore, concept algebra can be employed to capitalize on cognitive knowledge and promote advancements in cognitive machine learning [27].

Conclusion

The increasing importance of advanced technologies in our daily lives is becoming more apparent with each passing day. Currently, such technologies are mainly incorporated within the industrial sector; however, it is inevitable that, in the future, advanced technologies will be utilized across all aspects of modern society. This study outlines the role of metacognition in mental health and investigates how artificial intelligence can assist in enhancing cognitive and metacognitive skills, thereby fostering mental well-being. Artificial intelligence exerts a significant and far-reaching

influence by improving the delivery of mental health services. As artificial intelligence continues to advance, its potential to transform mental healthcare becomes more evident, offering renewed hope and opportunities for both patients and practitioners [28]. The necessity to incorporate advanced technologies into the domain of cognitive sciences is unequivocal. Nonetheless, a discrepancy persists between these technologies and cognitive sciences, chiefly because machine learning is primarily focused on predictive accuracy, whereas cognitive sciences aim to elucidate the mechanisms of the mind. This disparity may potentially be addressed through enhanced interdisciplinary dialogue [29]. A recent review article endeavors to bridge this divide, highlighting the importance of additional empirical research [30]. Consequently, scholars from both fields should collaborate within a framework of mutual understanding. Researchers in mental health are encouraged to direct their future investigations towards advanced technologies to harness their potential benefits. Conversely, researchers involved in advanced technologies should consider the societal implications of their work, particularly when directed towards mental health, as mental well-being remains a paramount concern in contemporary societies.

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