A Bibliometric Analysis of Neurofeedback Studies in Cognitive Impairment: Current Trends and Future Directions in Malaysia

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2023 IEEE 2nd National Biomedical Engineering Conference (NBEC) | 979-8-3503-3854-6/23/$31.00 ©2023 IEEE | DOI: 10.1109/NBEC58134.2023.10352610

***Abstract*— Neurofeedback training (NFT) is a brain wave self-training method that has gained attention in recent years, especially as an alternative for neurorehabilitation specifically for people with cognitive impairment (CI). In this short bibliometric review analysis, we analyzed 143 peer-reviewed articles on NFT in cognitive impairment between 2001 and 2022 to track the research progress in this specific area. The Scopus database was searched using "neurofeedback in cognitive impairment" as the main theme for the bibliometric analysis. In this analysis, bibliometric data of co-occurrence, citations, author keywords, and publications were briefly discussed. Neuroimage was the most cited source, with 27% of the total citations. The United States was the major country contributor, with 27.83% of the pieces of literature, and it also became the major top co-authorship country with 28% of citations, making it the most active country in the study of neurofeedback in CI. Malaysia was listed as one of the top 20 countries in terms of top co-authorship and top 14 in terms of high citations. The theme of the top search keywords by authors was related to the NFT techniques, while the least searched theme was related to the synonyms of NFT. The present study integrated bibliometric data on the current status and future directions of NFT research in the context of CI. These findings could benefit researchers in planning future studies that could help in the realization of NFT as a potential clinical neurorehabilitation intervention in a wide range of clinical settings. In conclusion, our study offers a perspective of the progress of NFT research and identifies the most significant interests in this field.**

Keywords—neurofeedback, biofeedback, cognitive impairment, cognitive deficit, neurorehabilitation

I. INTRODUCTION

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) defines 6 different domains of neurocognitive functions that constitute the normal functioning of healthy individuals which are: perceptual-motor function, language, executive function, learning and memory, complex attention, and social cognition [1]. Any deficit in any of these domains may be categorized into cognitive impairments. Cognitive impairment (CI) or cognitive deficit is a term referring to the decline of performance in a certain set of cognitive skills, mainly memory, attention, problem-solving, reasoning, or orientation. Cognitive impairment is present in various disorders, including learning difficulties and behavioral disorders (autism, Attentional Deficit Hyperactivity Disorder (ADHD)) [2], [3], neurocognitive disorders (mild CI, delirium, dementia) [4] and psychiatric disorders (schizophrenia, bipolar disorder, etc) [5]. The type of treatment for CI will vary depending on the cause. Some impairments, such as those caused by neurocognitive disorders, cannot be reversed. However, the progression of CI can be slowed down by taking preliminary measures such as early diagnosis, taking prescribed medication, and pursuing alternative non-pharmacological neurorehabilitation. One alternative non-pharmacological neurorehabilitation that is safe for most individuals is neurofeedback.

Over the past decade, there has been a growing interest in the use of neurofeedback training (NFT) as an alternative Neurotherapy for CI. The NFT is a non-invasive technique that trains the patterns of brainwaves based on specific brainwave protocols. It is also known as EEG biofeedback. Traditional NFT techniques use electroencephalography (EEG) as a tool, but there are other advanced tools such as real-time functional magnetic resonance imaging (fMRI) and functional near-infrared spectroscopy (fNIRS) based NFT. EEG-based neurofeedback is commonly preferred in neurofeedback research because it is relatively inexpensive and non-invasive. This is why much-established research have only used EEG NFT in the studies. The NFT works by measuring the brainwaves of an individual and providing real-time feedback based on the brainwave activity to modulate the individual's brainwaves into the desired ones. Therefore, it is known as neurofeedback [6].

Brain waves are brain signals that originated due to the neuronal activity inside our brain, and it categorized into five main waves: delta, theta, alpha, beta, and gamma [7]. Each brain wave has a specific frequency and is associated with different mental states. For example, a beta wave is dominantly found in a state of giving attention or focused mental work [8], and alpha waves are found in a state of quiet wakefulness [9]. Utilizing the advantage of specific brainwaves linked to specific cognitive states, NFT is used to train abnormal brainwave patterns in certain CI-related disorders back to normalcy using operant conditioning principles. For example, increasing beta waves (13-20 Hz) and lowering theta band activity in ADHD children have shown promising results in controlling their level of restlessness and hyperactivity, which are associated with a lack of ability to pay attention [10]. Similar protocols were applied to a group of Alzheimer's Disease patients with symptoms of Dementia who had shown improvements in memory task that requires them to recall information and recognition [11].