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From Research to Rehabilitation: A Systematic Review of Brain-Computer Interface Feasibility and Functional Outcomes in Health

Patil, S; Shahi, S.

Corresponding author:
Sauvit Patil

sauvitpatil@gmail.com

Author Affiliation:
University of Mumbai.

ADMINISTRATIVE INFORMATION

Support - Decision Neuro Advantix, Gujarat, India.

Review Stage at time of this submission - Data extraction.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 27 June 2024 and was last updated on 27 June 2024.

INTRODUCTION

Review question / Objective Using the PICO framework, this systematic review aims to assess the utility and vigor of Brain-Computer Interface (BCI) interventions in individuals recuperating from neurological conditions such as a stroke, paralysis, and other related disorders. Following is the PICO framework for this systematic review:
1. Population (P): Individuals undergoing health recovery from neurological conditions such as stroke, paralysis or epilepsy.
2. Intervention (I): Application of BCI technology, either independently or combined with conventional therapies.
3. Comparison (C): Placebo, no treatment, or conventional therapies alone.
4. Outcomes (O): Primary outcomes encompass measures of functional recovery,
neurophysiological changes, and improvements in quality of life. Secondary outcomes show other outcomes that assist patients.
5. Study Types: Randomized controlled trials (RCTs), clinical trials (CTs), cohort studies, case-control studies, and observational studies will be considered.

Objectives
1. To assess the functionality and usability of BCI systems in individuals with neurological conditions.
2. To evaluate the impact of BCI interventions on tangible recovery and quality of life outcomes in patients with neurological disorders.

Rationale Since the discovery of EEG nearly a century ago, BCI technology has undergone substantial evolution. This review delves into the feasibility and complexities associated with BCI methodologies to advance treatment modalities. Recent scientific investigation has commenced into the invasive BCI. A profound understanding of it is therefore crucial to evaluate its potential in achieving precise neural control in neurological disorders. BCI shows immense promise, especially in neurological rehabilitation, providing

opportunities for tailored therapeutic interventions and potentially transforming patient outcomes.

Condition being studied This systematic review focuses on individuals recovering from mmultitude of neurological conditions such as stroke, paralysis, amyotrophic lateral sclerosis (ALS), spinal cord injury and epilepsy. These conditions often result in varying degrees of motor and cognitive impairments, significantly impacting daily life and independence.

METHODS

Search strategy A search strategy will be developed for each database, utilizing a combination of Medical Subject Headings (MeSH) terms and targeted keywords relevant to Brain-Computer Interface (BCI) interventions, augmented by Boolean operators.
An illustrative example of the search strategy for PubMed is as follows: (("Brain-Computer Interface" OR "BCI" OR "brain-computer interface" OR "neuroprosthetics") AND ("feasibility" OR "functional outcomes" OR "recovery")).

Participant or population Participants will encompass individuals undergoing rehabilitation from neurological conditions such as stroke, paralysis, ADHD, locked-in syndrome and related disorders.

Intervention Assessment of Brain-Computer Interface (BCI) technology, employed either independently or in conjunction with conventional rehabilitation therapies.

Comparator Placebo, no treatment, or conventional therapies administered alone.

Study designs to be included Inclusion of randomized controlled trials (RCTs), clinical trials (CTs), cohort studies, case-control studies, and observational studies.

Eligibility criteria
Inclusion criteria:
a. Studies conducted between 2013 and 2023.
b. Exclusively open-access studies.
c. Studies employing a rigorous scientific methodology focused on BCI
interventions in neurological rehabilitation.

Exclusion criteria:
a. Studies not published in English.
b. Studies lacking clear definitions or methodologies concerning BCI interventions.
c. Exclusion of conference presentations.

Information sources Primary sources will include PubMed, Web of Science, and the Cochrane Central Register of Controlled Trials (CENTRAL). Supplementary sources will encompass reference lists from included studies and pertinent grey literature, such as clinical trial registries.

Main outcome(s) The primary outcomes of interest in this systematic review include measures of functional recovery, neurophysiological changes, and improvements in quality of life among individuals using Brain-Computer Interface (BCI) technology. Secondary outcomes encompass additional benefits such as cognitive enhancement, communication augmentation, and sensory feedback restoration.

Quality assessment / Risk of bias analysis The risk of bias will be assessed using appropriate tools such as the Cochrane Risk of Bias tool for RCTs and possibly the Newcastle-Ottawa Scale for observational studies. One independent reviewer will evaluate bias risk, resolving discrepancies through consensus.

Strategy of data synthesis A comprehensive narrative synthesis will be performed for all studies that meet the inclusion criteria. If suitable, meta-analyses will be performed using a random-effects model. Heterogeneity will be evaluated utilizing the I2 statistic. Subgroup analyses will be conducted based on specific aspects of BCI interventions and outcomes in neurological rehabilitation.

Subgroup analysis
A. Type of Neurological Condition:
1. Stroke
2. Paralysis (e.g., spinal cord injury)
3. Traumatic brain injury (TBI)
4. Neurodegenerative diseases (e.g., Parkinson's disease, Alzheimer's disease)
5. Other neurological conditions (specify)

B. Type of Brain-Computer Interface (BCI) Technology:
1. Electroencephalography (EEG)-based BCI
2. Electrocorticography (ECoG)-based BCI
3. Functional near-infrared spectroscopy (fNIRS)-based BCI
4. Intracortical microelectrode-based BCI
5. Hybrid BCI systems (combining multiple modalities)

C. Type of Intervention:
1. BCI for motor rehabilitation
2. BCI for cognitive enhancement
3. BCI for communication augmentation
4. BCI for sensory feedback restoration

5. Other BCI applications

D. Stage of Intervention:
1. Acute phase rehabilitation
2. Chronic phase rehabilitation
3. Long-term maintenance and monitoring

E. Patient Demographics:
1. Age groups (e.g., pediatric, adult, elderly)
2. Disease severity (e.g., mild, moderate, severe).

Sensitivity analysis Forest plots will be used for sensitivity analysis. Various methods will be employed to enhance confidence in the review findings:
Inclusion Criteria: Excluding studies with high risk of bias, low quality, or outliers, comparing results with the overall analysis.
Study Designs: Including specific study types (e.g., only RCTs or observational studies) and comparing results.
Statistical Methods: Using different statistical models (e.g., fixed-effects vs. random-effects) to check the robustness of findings.

Language restriction The review will include studies published in English or fully translated in English.

Country(ies) involved India.

Keywords Brain-Computer Interface (BCI), Neurological conditions, Cognitive enhancement, Motor rehabilitation, Neurofeedback.

Dissemination plans The findings will be disseminated through multiple channels to maximize reach within the scientific community. Publication in a peer-reviewed journal is planned to ensure credibility of the review's conclusions.

Contributions of each author
Author 1 - Sauvit Patil.
Email: sauvitpatil@gmail.com
Author 2 - Siddharth Shahi.