Clinical, Military, Consumer and Educational Applications of Brain-Computer Interfaces

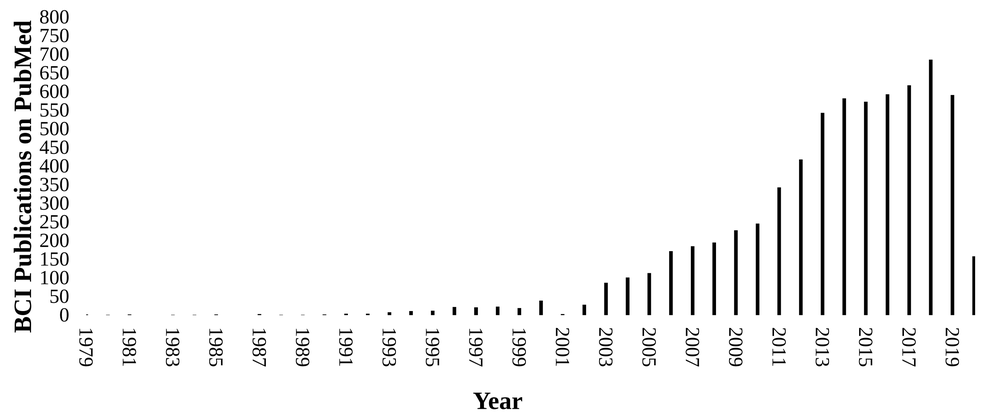
Lockman-Dufour, G[1,2]. Buchanan, D[1,2,3]., D'Angiulli, A[1,2]

[1]Department of Neuroscience, Carleton University, Ottawa, ON, Canada; [2]Neuroscience of Imagination Cognition Emotion Research Lab, Carleton University, Ottawa, ON, Canada; [3]Neuropsychiatric Lab, Children's Hospital of Eastern Ontario, University of Ottawa, Ottawa, ON, Canada.

What is a BCI?

Brain-Computer Interface (BCI): Electronic device capable of information storage & processing. It enables humans and computers to interact via brain signals.

Objective: Provide a review of BCI applications from four primary industries: healthcare and clinical, military, consumer and educational.



The ever-growing amount of papers published on BCIs warrants an investigation into its main topics.

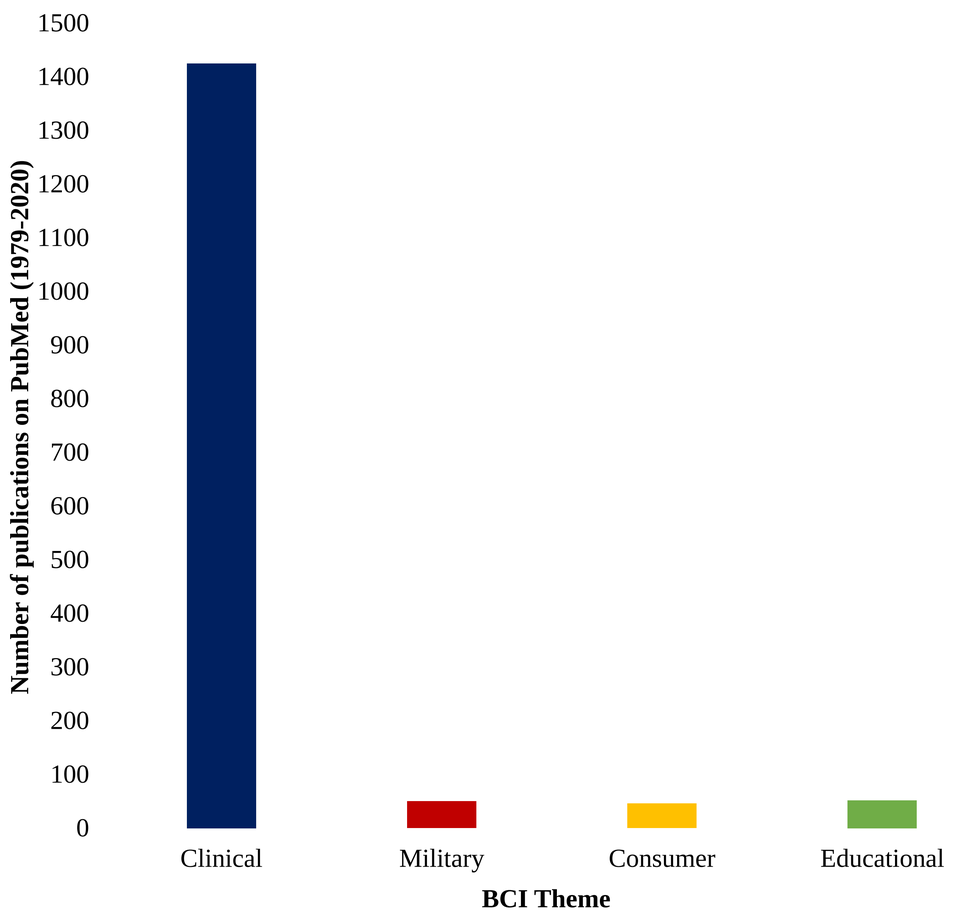
Industries were identified using Ryan and Bernard's (2003) methods for bibliometric analysis, choices supported by Hu *et al's* (2016) research. Education was added on the recommendation of friends and editors.

Clinical applications

Augmented/alternative communication
- Can be online (real-time) or offline (recorded)
- Useful for patients in locked-in or minimally conscious state and to narrow their diagnosis
- **EEG:** Letter recognition using ERPs or eye and muscle movement
- **fMRI:** Mostly yes/no answers, some multiple-choice questions using multi voxel analysis
- **Other neuroimaging techniques:** Often less practical, but can increase accuracy when used in conjunction with EEG/fMRI

Neurofeedback therapy
- Training people to regulate their brain activity
- Easily gamified and accessible to children
- Persistent brain reorganization after 20-40h

Neural prosthetics
- Typically more invasive, though EEG-based wheelchair control has been demonstrated



Military applications

Covert communication
- Speech synthesis by tracking lip and tongue movement with predictive algorithm

Subconscious threat detection
- Subconsciously perceived information might be filtered before reaching consciousness
- EEG-binoculars that can detect a user's P300s
- Identifying attention shifts when an operator monitors sonar images for underwater mines

Brain fingerprinting
- Highly accurate offline test to assess if someone is telling the truth
- Relies on P300 and late negative potential
- Requires some subject cooperation

Hands-free drone control
- Linked controls to EEG muscle movements (ex: blink, wink, raising an eyebrow or cheek)

Consumer applications

Video games
- BCI types vary but mostly rely on EEGs, with P300 and mental imagery detection
- **Active:** Imagined movements are picked up by the BCI and linked to their virtual action
- **Passive:** Gamified neurofeedback therapy
- **Reactive:** The user focuses on different on-screen stimuli, each linked to a virtual action

Sleep aids
- EEG-sensitive headphones detect sleep stage to select music and wake-up time accordingly

Guided meditation
- Neurofeedback therapy using an EEG headset with 7 sensors

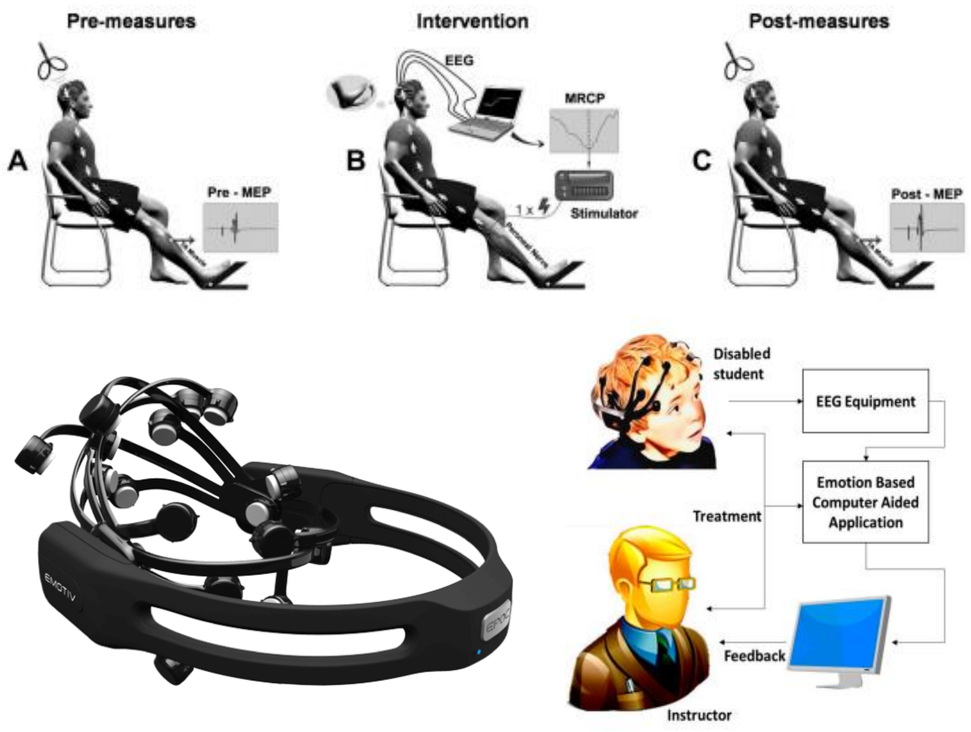


Figure 1. Computer-aided education system.

Educational applications

Workload personalization
- EEG can measure student attention, emotions and cognitive workload
- Can detect a participant's concentration and allow task completion only when focused

Neural plasticity
- Plasticity can be induced via neurofeedback to encourage motor recovery in stroke patients
- Possible applications to cognitive learning

General public awareness
- Using simple, bioelectrically-controlled devices to help the public understand concepts behind BCIs

Concluding remarks

Medical

Medical BCIs have some requirements (ex: certain levels of cognition, mobility, and general functionality) in order to successfully use them. Future research should focus on these limitations and aim to develop BCIs which remove as many user restrictions as possible.

Military

Military applications for BCIs will ideally lighten some human burdens of warfare. Due to the nature of the industry, the public will probably not be exposed to many of its applications. However, there are significant ethical concerns.

Consumer/educational

Consumer devices have made significant trade-offs by sacrificing neuroimaging quality for consumer friendliness. Nevertheless, consumer applications will likely grow, with possible uses including BCIs for people with learning disabilities and/or disorders.

NICER LAB Neuroscience of Imagination Cognition & Emotion Research

guillaumelockmandufo@cmail.carleton.ca

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