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Brain-computer interfaces in digital mindfulness training for metacognitive, emotional and attention regulation skills: a literature review

Interfaces cérebro-computador no treinamento de mindfulness digital para habilidades metacognitivas, emocionais e de regulação da atenção: uma revisão da literatura

Interfaces cerebro-computadora en el entrenamiento de atención plena digital para habilidades metacognitivas, emocionales y de regulación de la atención: una revisión de la literatura

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Eleni Mitsea
ORCID:https://orcid.org/0000-0003-4054-6318
N.C.S.R."Demokritos"IIT- Net Media Lab & Mind - Brain R&D, Athens, Greece
University of the Aegean, Information and Communication Systems Engineering Department, Greece
E-mail: e.mitsea@gmail.com
Athanasios Drigas
ORCID: https://orcid.org/0000-0001-5637-9601
N.C.S.R."Demokritos"IIT- Net Media Lab & Mind - Brain R&D, Athens, Greece
E-mail: dr@iit.demokritos.gr
Charalabos Skianis
ORCID: https://orcid.org/0000-0001-9178-4418
University of the Aegean, Information and Communication Systems Engineering Department, Greece
E-mail: cskianis@aegean.gr

Abstract
Brain–Computer Interfaces (BCIs) are specialized systems that allow users to control computer applications using their brain waves. With the arrival of consumer-grade electroencephalography (EEG) equipment, brain-controlled systems began to find fertile ground in mental training. One particular area that is gradually gaining attention is that of mindfulness training. In this paper, the results of a literature review of BCI-assisted mindfulness training using BCI's are presented. The specific aim is to review the effects of BCIs embedded in mindfulness interventions on training metacognitive, emotional, and attention regulation skills. Papers published the last 10 years were reviewed. The results showed that the use of BCIs provides subjects the unique opportunity to self-regulate mental and emotional functions using the feedback derived from their own brain activity. Subjects were found to raise better awareness about the ways non-conscious operations influence mental and emotional states. It was observed that subjects by learning to deal with the neurofeedback within immersive worlds or with the aid of mobile devices can better develop awareness and self-regulation skills including inhibition and flexibility. Learning environments have been undergoing rapid change driven by the evolution and availability of digital technologies. In that vein, BCIs combined with mobiles and immersive technologies could support mindfulness as an innovative practice for cognitive, emotional, and metacognitive development. This study aims to contribute to the debate about the use of BCI-assisted mindfulness practices as proactive methods and training strategies for various target groups such as students, teachers, and workers to achieve well-being and peak performance.
Keywords: Brain-computer interfaces; Consumer-grade EEG devices; Metacognition; Self-regulation skills; Attentional control; Emotional regulation.

Resumo
Interfaces cérebro-computador (BCIs) são sistemas especializados que permitem aos usuários controlar aplicativos de computador usando suas ondas cerebrais. Com a chegada do equipamento de eletroencefalografia (EEG) de consumo, os sistemas controlados pelo cérebro começaram a encontrar um terreno fértil nas intervenções de treinamento mental. Uma área específica que está gradualmente ganhando mais atenção é a do treinamento de atenção plena. Neste artigo, são apresentados os resultados de uma revisão da literatura do treinamento de mindfulness assistido por BCI usando dispositivos de nível de consumo. O objetivo específico é revisar os efeitos dos BCIs incorporados em intervenções de atenção plena no treinamento de habilidades metacognitivas, emocionais e de regulação da atenção. Foram revisados artigos publicados em um período de 10 anos. Os resultados mostraram que o uso de BCIs oferece aos sujeitos a oportunidade única de autorregular as funções mentais e emocionais usando o feedback derivado de sua própria atividade cerebral. Verificou-se que os sujeitos aumentavam a consciência sobre as maneiras pelas quais as operações não conscientes influenciam os estados mentais e emocionais. Observou-se que os sujeitos aprendendo a lidar com o neurofeedback em mundos imersivos ou com o auxílio de dispositivos móveis podem desenvolver melhor habilidades

de consciência e autorregulação, incluindo inibição e flexibilidade. Os ambientes de aprendizagem têm passado por rápidas mudanças impulsionadas pela evolução e disponibilidade das tecnologias digitais. Nesse sentido, os BCIs combinados com celulares e tecnologias imersivas podem apoiar a atenção plena como uma prática inovadora para o desenvolvimento cognitivo, emocional e metacognitivo. Este estudo visa contribuir para o debate sobre o uso de práticas de mindfulness assistidas por BCI como métodos proativos e estratégias de treinamento para vários grupos-alvo, como alunos, professores e trabalhadores, para alcançar bem-estar e desempenho máximo.
Palavras-chave: Interfaces cérebro-computador; Dispositivos de EEG de nível de consumo; Metacognição; Habilidades de auto-regulação; Controle atencional; Regulação emocional.

Resumen
Las interfaces cerebro-computadora (BCI) son sistemas especializados que permiten a los usuarios controlar aplicaciones informáticas utilizando sus ondas cerebrales. Con la llegada de los equipos de electroencefalografía (EEG) para consumidores, los sistemas controlados por el cerebro comenzaron a encontrar un terreno fértil en las intervenciones de entrenamiento mental. En este documento, se presentan los resultados de una revisión de la literatura sobre el entrenamiento de atención plena asistido por BCI utilizando dispositivos de grado de consumo. El objetivo específico es revisar los efectos de las BCI incluidas en las intervenciones de atención plena en el entrenamiento de habilidades metacognitivas, emocionales y de regulación de la atención. Se revisaron trabajos publicados en un período de 10 años. Los resultados mostraron que el uso de BCI brinda a los sujetos la oportunidad única de autorregular las funciones mentales y emocionales utilizando la retroalimentación derivada de su propia actividad cerebral. Se encontró que los sujetos aumentaron la conciencia sobre las formas en que las operaciones no conscientes influyen en los estados mentales y emocionales. Se observó que los sujetos, al aprender a lidiar con el neurofeedback dentro de mundos inmersivos o con la ayuda de dispositivos móviles, pueden desarrollar mejor la conciencia y las habilidades de autorregulación, incluidas la inhibición y la flexibilidad. Los entornos de aprendizaje han experimentado cambios rápidos impulsados por la evolución y disponibilidad de las tecnologías digitales. En ese sentido, las BCI combinadas con dispositivos móviles y tecnologías inmersivas podrían respaldar la atención plena como una práctica innovadora para el desarrollo cognitivo, emocional y metacognitivo. Este estudio tiene como objetivo contribuir al debate sobre el uso de las prácticas de atención plena asistidas por BCI como métodos proactivos y estrategias de capacitación para diversos grupos objetivo, como estudiantes, docentes y trabajadores, para lograr el bienestar y el máximo rendimiento.
Palavras-chave: Interfaces cerebro-computadora; Dispositivos de EEG de grado de consumidor; Metacognición; Habilidades de autorregulación; Control atencional; Regulación emocional.

1. Introduction

Mindfulness can be simply defined as the process of openly attending, with awareness, to one's present-moment experience (Creswell, 2017). Vago et al. (2012) described the concept as (a) a method for training a multidimensional skillset for the reduction of self-processing biases and as a continuous discriminative attentional meta-ability termed as "mindful awareness. Mindfulness is considered a set of techniques for mental training and rehabilitation. Through the practice of monitoring thoughts, sensations, and emotions that arise in real-time experience, mindfulness training aims at cultivating self-awareness, self-regulation, and a positive relationship between self and others (Vago et al., 2012; Tang et al, 2015).

Metacognition is a term introduced by Flavell to describe learners' awareness of their cognition and cognitive operation (Flavell, 1979). Metacognition comprises both the ability of awareness as well as the self-management of cognition (Fleur et al., 2021). Recent studies present data according to which metacognition has a strong link with affect and motivations. More specifically, metacognitive processes play a crucial role in the awareness and self-regulation of emotions (Pennequin et al., 2020). Metacognition also includes a set of meta-processes individuals can apply in monitoring and controlling actions and behavior (Rhodes, 2019).

Mindfulness-based interventions are well-recognized practices for improving physical and mental health (Dunning et al., 2019). A growing body of research has already revealed that mindfulness interventions have positive therapeutic effects in various conditions including those characterized by reduced self-control such as depression, anxiety, and mood problems (Hofmann et al., 2010; Creswell, 2017). Other studies have concluded that mindfulness training has a positive impact on attentional performance, substance abuse, chronic pain, and physical disorders (Chiesa et al., 2010). Prior research has already shown that mindfulness-based interventions can enhance metacognitive skills (Dunning et al., 2019). Dunning et al. (2019)

conducted a meta-analysis of mindfulness interventions with youth exclusively composed of randomized controlled trials. The results showed that, indeed, mindfulness interventions can enhance executive functions and other metacognitive aspects in children and adolescents. Other studies confirm that mindfulness practices induce functional and structural brain modifications in areas involved in self-referential processes, self-awareness, and self-regulation as well as in areas responsible for self-control procedures such as attention and executive functions (Boccia et al., 2015). Electroencephalographic (EEG) studies have revealed that significant alterations in brain activity occur influencing crucial areas for metacognition, self-awareness, and self-control abilities such as the prefrontal cortex and hippocampus (Chiesa et al., 2010).

Although everyone is capable of practicing mindfulness, formal mindfulness training can be quite effortful and challenging at first. In conventional mindfulness training interventions, it is quite challenging for novices to keep their attention and motivation active and monitor their progress (Creswell, 2017). Especially for children and adolescents, practicing mindfulness may be quite difficult because there are no overt signs of awareness that can be utilized for feedback by teachers (Vekety et al., 2022). Thus, it is quite difficult for the person to self-assess what is the impact of the practice on one's state of mind (Pawade, 2023). In that vein, in this study, we hypothesized that providing scaffolding through feedback on the electrical activity of the brain could facilitate the practice of mindfulness leading to subsequent improvements in the development of metacognitive skills.

Technological aids, interactive technologies digital games are increasingly being utilized to aid in the practice of mindfulness. Indeed, research reveals that digital mindfulness-based interventions offer significant advantages in various domains of human life and are considered a promising path for training in the coming years. A growing body of research refers to improvements in measures of attention, stress, depression, and anxiety (Mrazek et al., 2019; Economides et al., 2018).

Digital technologies have the potential to outperform conventional face-to-face formats in terms of accessibility, standardization, customization, and efficacy of mindfulness training. Smartphone apps, web-based platforms, biofeedback sensors, immersive technologies, and virtual coaches are considered new trends in supporting mindfulness training. Subjects can have unlimited access to high-quality training at the time of their choice. Digital training allows for the standardization of important parts of course content and presentation, guaranteeing that all users receive the same high-quality education. Digital training technologies standardize key elements of course content and presentation ensuring high-quality instruction. Digital training provides information that is customized to the strengths, weaknesses, interests, and values of individual users providing at the same time personalized feedback (Mrazek et al., 2019; Sliwinski et al., 2017).

In recent years, neurocognitive enhancement constitutes a field of growing interest. Neuroenhancement concerns the employment of different neuroscientific methods that increase individuals' cognitive performance operating on the brain and the nervous system (Fronda et al., 2018). Neurofeedback constitutes a technology that allows users to observe, reflect, and learn from their brain activity. Neurofeedback enables users to know what their brain waves are doing in real-time in the form of visual and/or auditory feedback. Electroencephalogram (EEG), for instance, is commonly used to analyze and evaluate patients' brain wave patterns. Non-invasively attaching electrodes to the scalp help doctors or researchers to observe much about the brain's operation. Neurofeedback gathers the information provided by an EEG and represents it to the user in a way that trains them self-direct their actions to achieve the optimal mental state (Schaefer, 2018). Smart headbands are devices that measure the users' brainwaves via electroencephalography sensors and provide collected data in smartphones or virtual worlds to help learners raise awareness of their mental and emotional state, the levels of their attention and anxiety, and generally the readiness of being effectively engaged in learning procedures (Richer et al., 2018; Papanastasiou et al., 2020).

With the rapid development of immersive technologies, virtual reality is gaining ground as a tool for improving personal well-being, for example via platforms for mindfulness-based meditation practice. Immersive virtual reality-enhanced mindfulness may be notably useful for a wide range of healthcare therapies where traditional mindfulness is now beneficial.

(Arpaia et al., 2021). According to the Arpaia et al. (2021) virtual reality exhibits potential favorable features to support mindfulness practice, especially in the case of immersive and multisensory virtual reality with the use of bio/neurofeedback sensors which can allow a real-time adaptive experience.

The same applies to mobile technologies. Brain-computer interfaces for smartphones and other mobile devices seem to be promising technologies for low-cost interventions which can take the form of personal training (Dobosz et al., 2015).

Searching the international literature, it was observed that there is less evidence regarding the positive effects of EEG feedback on improving mindfulness practices' effectiveness (Vekety, 2022). In addition, fewer studies examine the impact of BCI-assisted mindfulness practices on metacognitive skills training including self- and emotional awareness, self- and emotional regulation, and on higher cognitive abilities such as attentional control.

The objective of this study is to review the existing literature regarding the effectiveness of brain-computer interfacing in assisting mindfulness interventions. More specifically, we examined brain-computer interfaces as assistants of digital mindfulness interventions for training metacognitive skills. In the umbrella of metacognitive skills, we included attentional regulation skills and self-control abilities including emotional and inhibition control. Most importantly, with the term metacognition, we mean all those abilities that provide a subject with a better awareness of mental and emotional states. This review is one of the few that emphasize the role of brain-sensing devices as interfaces that provide positive feedback and scaffold in supporting practitioners to develop better awareness and control over mental, emotional, and behavioral operations.

2. Methodology

The methodology for the current review was based on the guidelines for narrative reviews (Snyder, 2019; Pereira et al., 2018). A narrative review is a good method of synthesizing research findings to provide evidence on a meta-level and to identify areas in which more research is needed, which is a critical component of creating theoretical frameworks and creating conceptual models (Snyder, 2019). Brain-computer interfaces in digital mindfulness training is a new and constantly evolving field, but its role in supporting the development of metacognitive skills has not been extensively investigated, and not enough adequate data sets are available to draw definitive conclusions. The narrative review was chosen as the research aim was the identification, presentation, understanding, and discussion of the main points in the current literature in this area.

2.1 Search Strategy

A literature search was undertaken using PubMed, Google Scholar, and ScienceDirect databases and references of retrieved articles. The search included papers published in English up to November 2010. The literature search was conducted in the databases using a combination of the keywords “mindfulness, meditation”, terms referring to “brain-computer interfaces, neurofeedback”, and terms referring to “metacognitive skills, self-regulation, emotional regulation, attentional control, self-awareness”. The combination of the above keywords was applied to each database from 2010 up until January 2023. Table 1 provides an overview of the research strategy applied in database research.

Table 1 - The search terms used and the total number of publications from each database.

Searching string and main searching terms
"Brain-Computer Interfaces" OR "BCI" OR "neurofeedback" OR "Brain sensing devices"
AND
"Virtual Reality" OR "Mobiles" OR "Smartphones" OR i-pads
"Mindfulness" OR "Meditation" OR "Contemplative"
AND
"Metacognitive Skills" OR "Self-regulation" OR "Emotion Regulation" OR "Self-awareness" OR "Emotional awareness" OR "introspection skills" OR "inhibition control" OR "attention regulation"

Source: Authors.

2.2 Selection of Relevant Publications

By applying the inclusion and exclusion criteria, papers that fulfilled the inclusion criteria were selected for further investigation and content assessments. The predefined literature inclusion and exclusion criteria to achieve this systematic review work are described in Table 2. This study mainly focused on experimental research (i.e. randomized controlled trials) that combined mindfulness training with BCI systems as neurofeedback interfacing not only as measuring devices of brain activity. On the other hand, gray literature, extended abstracts, presentations review articles, and non-English language publications were mostly excluded. All the studies included in the review provide data on the research design, the participants, the type of BCI device, the context of the intervention, the duration, the mindfulness training, the types of measurements, and the outcomes.

Table 2 - Selection of literature using inclusion and exclusion criteria.

Criteria	Decision
The publication is an experimental study	Inclusion
The publication is in English	
The intervention combined mindfulness with BCI	Inclusion
Studies that employ an EEG device as a neurofeedback interfacing	Inclusion
Studies examined BCI-assisted mindfulness' impact on metacognitive	Inclusion
skills	Inclusion
Book chapters, posters, and review articles were excluded from the current review	Exclusion
Studies that apply neurofeedback training without mindfulness	Exclusion
Studies that employ an EEG only as an instrument for measuring changes in brain waves	Exclusion

Source: Authors.

2.3 Data Extraction

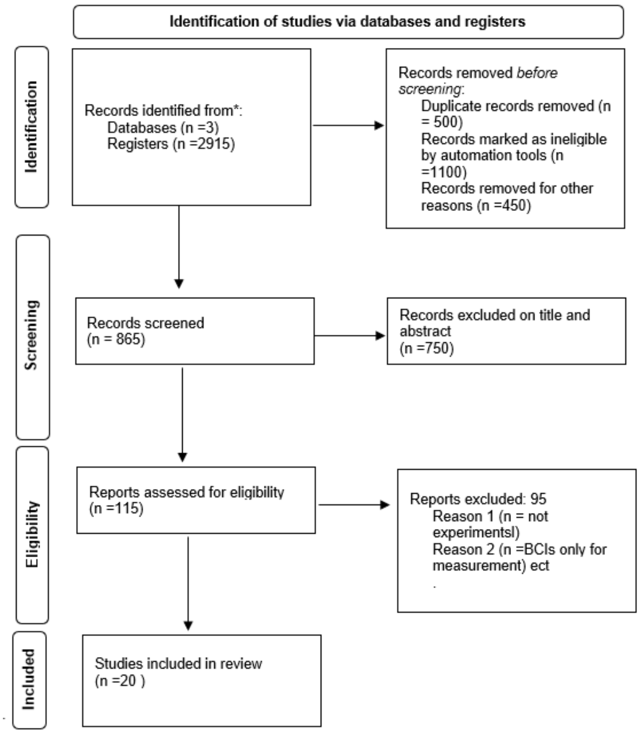
After the initial screening of the titles and abstracts and references to other relevant studies, the studies were evaluated according to the inclusion criteria. In the cases where inclusion in the review was not clear, the first author reviewed the study independently.

2.4 Search Results

The general screening processes and the flow of selecting relevant literature were presented in Figure 1 according to Page et al. (2020). This initial search revealed 2915 studies, of which 500 were common and were removed. The titles and abstracts of the remaining studies were screened for inclusion in the review, by the two authors. This process led to 115 studies for full-text screening.

The 115 initial studies were reviewed, taking into account the inclusion and exclusion criteria. After the full-text screening, 95 studies that did not meet the inclusion criteria, were removed. The 20 remaining studies were included in the final analysis. Figure 1 depicts the process and the results of the research strategy.

Figure 1 - Prisma Flowchart depicting the literature research and selection of studies for review (Page et al., 2020).



Source: Authors.

3. Theoretical Background

3.1 Brain waves: types and the relation with consciousness and emotional states

The brain consists of two kinds of cells, namely the neurons and the neuroglia. Neuroglia assists neurons in keeping them in balance and supplying them with nutrients and oxygen. Neurons are in charge of transmitting information via chemical and electrical impulses. The steady flow of electricity in the brain, induced by the synaptic excitation of the dendrites in the neurons, creates electrical signals that travel from the encephalic mass to the scalp. Thus, brainwaves are representations of electrical activity emerging from the brain measured in a unit of frequency called Hertz (Hz) (Figure 2) (Schaefer, 2018).

Brain waves include a set of signals that can be divided into five bands, i.e., delta, theta, alpha, beta, and gamma waves, classified according to their frequency. There are various frequencies at which the brain may pulse, and each frequency level corresponds to a distinct state of consciousness as well as an emotional state (Teplan, 2002).

Gamma Waves: Gamma rhythms are closely associated with large brain network activity which is responsible for the proper functioning of higher mental abilities such as attention, working memory, and perception (Das, 2018; Jensen et al., 2007). Studies have shown that people with learning difficulties and cognitive impairments exhibit lower gamma brain activity (Martinez et al., 2020). Recent research has revealed that gamma waves can increase through the practice of contemplating techniques (Braboszcz et al., 2017; Lutz et al., 2004).

Beta Waves: When the brain is awakened and actively engaged in mental processes, beta waves are produced. Beta waves have a modest amplitude and are the quickest of the four types of brain waves. Beta brainwaves occur when we are aware, attentive, and involved in problem-solving, judgment, decision-making, and concentrated mental work. Having the correct quantity of beta waves enables us to focus and quickly perform learning tasks. However, excessive beta may cause us to experience excessive tension and/or anxiety. Irregular beta activity patterns are often detected when subjects are inattentive (Das, 2018; Chiesa et al., 2018).

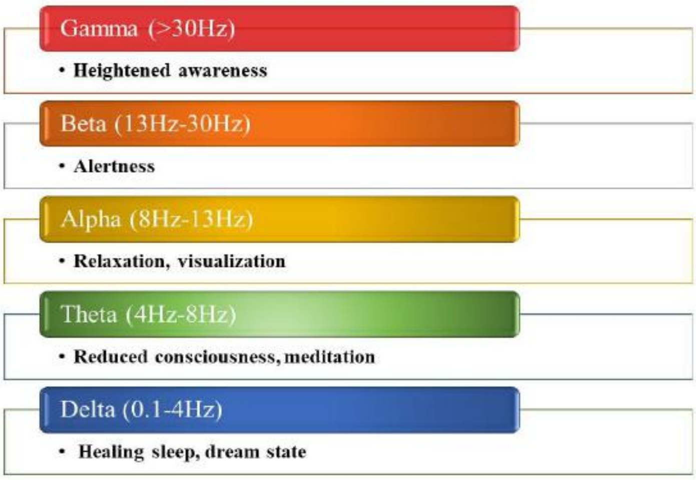
Alpha Waves are the frequency that ranges between beta and theta. These brain waves are associated with better regulation of feeling and deep relaxation. Every time the eyes close and the body relaxes, alpha waves increase. Every time intense mental efforts are made, alpha waves decrease (Nicolas-Alonso et al., 2012). Alpha oscillations are involved in inhibitory control operations which regulate a variety of cognitive operations such as attention and memory (Knyazev, 2007). They also enhance mental coordination, relaxation, attentiveness, mind/body synergy, and learning. Individuals with abnormal delta activity may have learning impairments or difficulty in maintaining conscious awareness (Das, 2018; Knyazev, 2007).

Theta Waves are most frequent during sleep, although they are also prominent during deep meditation (Lomas et al., 2015). They are considered the portal to learning and memory and especially implicit learning (Loonis et al., 2017). In this state of theta brain waves, the senses are pulled away from the outside world and turn inward on information coming from the inside. Theta waves are associated with emotional processes and emotional regulation (Knyazev, 2007). Theta offers the advantage of improving our intuition, creativity, and making us feel more natural (Wokke et al., 2018).

Delta Waves are slow waves at high amplitude (Amzica, 1998). They arise in deep meditation and dreamless sleep. In this state, healing mechanisms and regeneration take place. For instance, delta waves are associated with the increase of growth hormones (Das, 2018; Gronfier et al., 1996; Amzica, 1998). Delta oscillations depend on the activity of motivational systems (Knyazev, 2007).

The frontal theta/beta ratio has been recognized as an electrophysiological biomarker of executive control, particularly attentional control among healthy participants (Angelidis et al., 2018). It is not accidental that people with attentional disorders exhibit abnormalities in the frontal theta-beta ratio (Arns et al., 2013).

Figure 2 - Brain wave characteristics. Delta, theta, alpha, beta, and gamma EEG bands.



Source: Authors.

Effects of mindfulness practices on brain activity

Recent studies reveal that contemplative practices have an immediate and visible impact on practitioners' brainwaves providing new knowledge about the impact of mind-training practices on brain activity (Braboszcz et al., 2017; Lutz et al., 2004). Mindfulness interventions have also been shown to induce changes in EEG, magnetic resonance imaging, and functional magnetic resonance imaging (fMRI) activity. A substantial amount of research has been accumulated in the exploration of psychophysiological indicators of meditation. Nevertheless, not all meditation techniques are equal. The strategies utilized to evoke certain moods varied between practices, resulting in diverse psychophysiological fingerprints (Ford et al., 2016; Lomas et al., 2015).

Cahn et al. (2006) reviewed the literature regarding neuroelectric and imaging studies of meditation and found an overall slowing after meditation, with theta and alpha activation related to mastery of practice. Lomas et al. (2015) conducted a systematic review of a total of 56 papers which consisted of 1715 subjects to identify the most common brain waves in mindfulness training. The systematic review showed that mindfulness was most linked with enhanced alpha and theta power as compared to an eyes-closed resting state. These results reveal that mindfulness training elevated the brain waves that signify a state of relaxed awareness.

Jung et al. (2021) examined the effects of a mindfulness-based education program on mindfulness, brain waves, and the autonomic nervous system in university students. After six sessions of mindfulness-based interventions, measures of brain waves indicated an increase in the alpha and theta waves and a decrease in the beta waves. The findings indicated that mindfulness induces a state of mind that is responsible for attentional awareness, relaxation, and positive emotions.

Lee et al. (2018) conducted a systematic review of the neural oscillations on four common meditation practices including focused attention, open-monitoring, transcendental meditation, and loving-kindness. Their study revealed that during active meditation, distinct changes occur in the electrographic activity, both regionally and globally. In addition, differences in EEG profiles were observed depending on practitioners' experience and the practice's duration. For instance, one study with intermediate practitioners (mean experience 4 years) had increased low-frequency oscillations (theta and alpha) in the right superior frontal, right inferior frontal, and right anterior temporal lobes, whereas, advanced (mean experience 30 years) practitioners had increased high-frequency oscillations (beta and gamma) in the same regions (Thomas et al., 2014).

Travis et al. (2010) conducted electrophysiology experiments during mindfulness practices. It was found that practices such as transcendental meditation can promote greater stimulation in alpha waves in the prefrontal and temporal areas, which are responsible for abilities such as concentration and decision-making.

Aftanas et al. (2001) observed that in meditative states, in which focused internalized attention gives rise to an emotionally positive "blissful" experience, an increased anterior frontal and midline theta synchronization, as well as enhanced theta long-distant connectivity between prefrontal and posterior association cortex with distinct "center of gravity" in the left prefrontal region, occurs. It was also revealed that theta and alpha oscillating network activity were also associated with states of internalized attention and positive emotional experience.

During a contemplative and guided mind-wandering block, Braboszcz et al. (2018) compared practitioners of three different meditation traditions (Vipassana, Himalayan Yoga, and Isha Shoonya) to a control group. It was revealed that meditation could enhance gamma wave production. These results alter previous knowledge while meditation was formerly thought to consist mostly of passive relaxation states, current EEG data indicate that it is also related to active states involving cognitive reorganization and learning (Fell et al., 2010).

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The metacognitive components of mindfulness

Self-observation skills: Mindfulness grounds attention and awareness in one's present moment experience. The present-moment experience that one attends to can take many forms, including one's body sensations, emotional reactions, mental images, mental talk, and perceptual experiences. This is a self-monitoring feature of mindfulness (Creswell, 2017).

Acceptance: mindfulness trains the ability to be open, attending to experiences with curiosity, detached, and nonreactive orientation. Acceptance of negative emotions implies a better perception and management of self (Creswell, 2017).

Attentional regulation skills: awareness towards inner and outer experiences and acting with awareness, all of which require attentional control (Sliwinski et al., 2017).

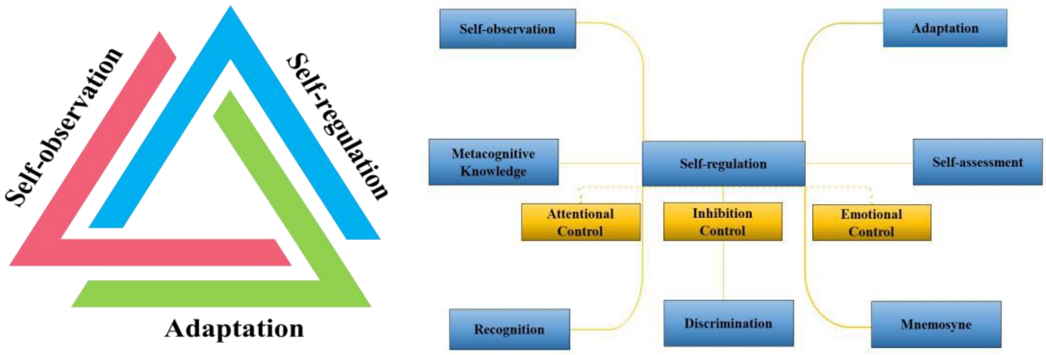
Self-regulation skills: Mindful self-regulation means that each time the observation procedure detects distractions, the subject employs self-regulation strategies to restore disturbances and re-establish relaxation (Drigas et al., 2020).

Emotional regulation skills: Mindfulness requires the ability to shift focus and modify emotional activity, for example, to inhibit negative self-talk and perceive stimuli more neutrally and with equanimity. Emotion management is exhibited by the process of mental recording and labeling of the emotional events, as well as the attitude of equanimity that facilitates the extinction and reconsolidation of dysfunctional memories (Vago et al., 2012).

Recognition skills refer to the realization that ideas, beliefs, and memories do not have universal truth, but are fully subjective and may not always match reality. It is the meta-ability of insightful understanding, which derives from the realization that experience is under the influence of subjective evaluation (Drigas et al., 2020; Sliwinski et al., 2017).

Discrimination skills: The meta-ability of filtering, making wise judgments, discerning between thoughts and emotions, and deliberately choosing those that assure physiological and psychological well-being (Drigas et al, 2020) (Figure 3).

Figure 3 - The triangle of metacognition (left) and the pillars of metacognition in mindfulness (Drigas et al., 2020)



Source: Authors.

BCIs in assistance of mindfulness practices

With recent technological advancements, portable and low-cost EEG measuring wearables are produced (Pawade, 2023). BCI devices have many features which may benefit mindfulness practices.

BCIs can satisfy the need for personalized intervention and training according to the users' needs and abilities. BCI, for instance, can evaluate users' strengths and weaknesses through the identification of their neurophysiological type, providing them with the appropriate feedback which in turn helps them to gain better awareness of their mental and emotional state. BCI devices record brain activity providing users with information that would otherwise not have been accessed. The feedback received in various forms has the potential to be an important element in metacognitive skills training. Therefore, BCI devices have a significant potential to be effectively engaged in intervention methods that intend to raise users' self-awareness and develop metacognitive skills (Fingelkurts et al., 2015).

Brain-computer interfaces within virtual environments can help subjects to achieve higher levels of concentration while entertaining the user. BCIs can non-invasively monitor and record the electrical activity of the brain incorporating the data into the VR experience. By sensing brain waves using a series of EEG sensors, the level of activity can be fed back to the user via 3D content in the virtual environment (Amores et al., 2016; Mitsea et al., 2022).

4. Results and Discussion

Vekety et al. (2022) investigated the effectiveness of mindfulness training supported by EEG feedback on executive functions, attention regulation skills and attention-related brain activity correlates among thirty-one healthy elementary school children aged between 9 and 10 years old. Students were randomly assigned to either an eight-session mindfulness-based stress reduction protocol with EEG feedback (Muse^{TM} headband supported by a smartphone application) or a passive control group. Results showed that the BCI-mindfulness group showed positive changes in inhibition skills and attention regulation abilities. Significant positive outcomes were also detected in children's brain activity (alpha-theta waves) indicating increased calm/focused brain states and improved ability to redirect attention when it wandered. It was concluded that BCI-supported mindfulness practice embedded in everyday practice in schools could help students to independently train their self-regulation skills and learn how to voluntarily manage their attentional powers to be independent and self-regulated learners.

Hawley et al. (2021) conducted a randomized controlled trial to examine the potential benefits of using a consumer-grade EEG-based biofeedback device on the regulation of obsessive behaviors and mind-wandering. Seventy-one subjects diagnosed with Obsessive Compulsive Disorder (OCD) were divided into two groups, the experimental (n=36) and the waitlist control group (n=35). The experimental group followed a meditation intervention involving the daily use of a Muse^{TM} device. After training, participants completed self-report measures of mindfulness and OCD symptoms. At weeks 1, 4, and 8, participants completed a five-minute "open monitoring" training while EEG data were recorded, and then they completed self-report measures of mindfulness and OCD symptoms. Results showed that participants in the BCI group (in comparison to the control group) were more able to self-regulate obsessions and mind-wandering.

Crivelli et al. (2018) investigated the effectiveness of four-week BCI mindfulness training on cognitive control performance and neural efficiency. Forty participants were randomly assigned to either an experimental group or an active control group. The experimental group underwent intensive focused attention training using a noninvasive wearable EEG device supported by a smartphone application. The control group followed breathing exercises accompanied by listening to natural sounds. Electrophysiological markers showed that the experimental group, in comparison with the control group, showed significantly better markers of attention orientation and executive control, suggesting improved focus and attention regulation skills. The authors concluded that the feedback received by the BCI device helped subjects to be aware and better self-regulate their cognitive performance.

Acabchuk et al. (2021) explored the effectiveness of mindfulness intervention supported by a consumer-grade EEG (Muse headband) device on self-management of anxiety symptoms. Fifty-three subjects aged between 18 to 36 years old were randomly assigned to either the Muse meditation intervention (n = 26) or the apps-only meditation intervention (n = 27). Both groups showed significantly reduced distress and increased mindfulness scores following the intervention.

Martinez et al. (2018) conducted a quasi-experimental pilot study to explore whether BCI-assisted mindfulness training could help middle grades students to regulate inappropriate behaviors. Ten students were randomly assigned to the BCI-assisted mindfulness group and ten were assigned to the control group (n=10). Participants in the experimental group received a three minutes mindfulness training with a commercial noninvasive EEG device once per week for in total of 20 sessions. Data analysis revealed that participants in the BCI mindfulness group could better perform self-regulated behaviors compared to the control group.

Balconi et al. (2018) examined the effectiveness of BCI mindfulness training intervention on participants' ability to control anxiety and mood states. Fifty-five participants were randomly divided into an experimental and an active control group. Both groups underwent training constituted by brief daily activities based on mindfulness practices. The experimental group practiced focused attention training with the support of wearable brain-sensing devices and a smartphone app to provide real-time feedback based on EEG markers. Results showed that perceived stress, anxiety, and mental fatigue were better managed. Practitioners empowered attentional skills and emotion regulation abilities. It was also revealed that the subject could transfer self-regulation abilities to both stressful and non-stressful situations. They were also more able to accept negative emotions, adopt a positive attitude, and a detached observational stance in stressful situations.

Hunkin et al. (2021) conducted a crossover trial aimed to evaluate the effects of auditory EEG neurofeedback on state mindfulness during focused attention meditation. Sixty-eight adults aged between 18 and 60 years completed a task-based measure of state mindfulness while meditating with and without auditory feedback from a consumer-grade EEG headband. Device-measured mind wandering was lower when feedback was present. EEG neurofeedback appeared to increase the state of awareness in adults during a brief BCI-assisted meditation as well as perceived control over feedback.

Antle et al. (2018) explored the effectiveness of a mindfulness-oriented, neurofeedback-based, brain-computer system to help teach children living in poverty to self-regulate anxiety and attention. Twenty-one children aged between 5 and 11 took part in the study. The results indicated that a 6-week BCI-mindfulness intervention that trained Alpha/Theta and beta bands was viable and effective for self-regulation of both anxiety and attention and helped children to transfer self-regulation skills into everyday behaviors.

Bhayee et al. (2016) conducted a randomized, active control trial to examine the effectiveness of a six-week BCI-assisted mindfulness training system on attentional and affective self-management. The experimental group, which consisted of 13 healthy adults followed a 10 min of daily home-based BCI mindfulness practice, while the active control group (n=13) followed a cognitively-demanding training condition (solving online math problems). Training effectiveness was assessed on target measures of attention, mood, body awareness, and stress. During the intervention, the EEG device collected data and transmitted the information to the application to provide real-time auditory feedback, such as beach waves and wind sounds that grew louder and more intense if increased mind-wandering was identified. Results revealed that the intervention group improved inhibition control skills and attentional regulation. In addition, they had better self-awareness and a positive mood.

Balconi et al. (2019) compared the efficacy of mindfulness training on attentional skills and behavioral regulation with or without the use of a neurofeedback device. Fifty participants were randomly divided into an experimental and an active control group. Both groups underwent mindfulness training but with the difference that the experimental group practiced with the support of a wearable brain-sensing device (Lowdown Focus glasses), while the control group practiced breathing awareness without BCI support. A multi-measure assessment (self-report, neuropsychological, psychophysiological and behavioral level) administered before and after the interventions revealed that the BCI-assisted mindfulness training group displayed a physiological, behavioral, and neuropsychological increased efficiency related to attention and behavioral regulation skills.

Crivelli et al. (2019a) evaluated the effectiveness of a two-weeks mindfulness-based training assisted by brain-sensing wearable technology on a subjective level and physiological markers of stress, anxiety and mood profiles, cognitive abilities, and markers of neurocognitive efficiency. Sixteen professionals with top management duties took part in the study. The BCI device and the app informed the participants on the focused vs distracted/agitated status of their minds and brains, thus allowing them to develop a deeper awareness of their bodily arousal and greater stress-coping resources. The findings revealed that participants in the BCI group showed lower stress, anger, and mental fatigue. In addition, it was observed better information-processing efficacy. The authors concluded that BCI-assisted mindfulness training improves cognitive and affective regulation skills.

Schuurmans et al. (2020) conducted a randomized controlled trial to examine the effectiveness of a 6 weeks Muse assisted mindfulness training in reducing posttraumatic stress and normalizing neurobiological stress systemsEighty adolescents aged 10 to 18 years, with clinical levels of posttraumatic symptoms were randomized to receive either the Muse therapy sessions and treatment as usual (intervention) or treatment as usual alone (control). In the experimental group, a game-based meditation app was played on an iPad with an electroencephalography (EEG)–based headband that utilized real-time neurofeedback. For instance, when the participant's mind was calm, the environment showed calm and settled winds, but these winds picked up and blew when the participant's mind became more anxious. This study is expected to enhance the ability to self-regulate anxiety symptoms.

Crivelli et al. (2019) aimed at investigating the potential of a 2 weeks mindfulness–neurofeedback training protocol for improving attention control, self-awareness, and psychological well-being. Fifty participants were divided into groups undergoing experimental and active control training programs. The experimental group engaged in breathing-awareness practices supported by wearable neurofeedback, while the active control engaged only in breathing practices. Before and after training, standardized neuropsychological and electrophysiological assessments followed. After fourteen sessions, it was observed for both groups a significant reduction of response times and false alarms at computerized cognitive tasks, as well as a consistent improvement of the N2 event-related potential—a marker of attention regulation processes. It was also found an improved ability for anxiety self-regulation, and better acceptance of emotions. The authors hypothesized that both programs gave to participants the opportunity to strengthen their self-awareness skills.

Millstine et al. (2019) investigated the effectiveness of a portable, wearable, electroencephalographic device for guided meditation practices by breast cancer patients. Thirty participants aged between 20 to 75 years were randomly assigned to perform guided meditation with the device (intervention group) or receive CD-based stress-reduction education (control group). The participants in the Muse intervention group received a Muse headband, instructions for use, and guidance for installing the Muse app on their smartphone or tablet. Surveys were used to identify the extent to which intervention affected stress, quality of life, and fatigue. The results showed that both reduced mental fatigue and improved self-management of anxiety.

Richter et al. (2019) investigated the efficacy of a technology-supported mindfulness meditation practice for regulating obsessive and compulsive symptoms using a consumer-grade EEG-based biofeedback device during guided meditation. Fifty-five participants were randomized to an 8-week BCI-assisted intervention (n=27) or a waitlist group (n=28). The results showed that, after the intervention, participants were better able to inhibit and control obsessions and compulsiveness.

Rolbiecki et al. (2022) conducted a feasibility pilot study to investigate the effectiveness of a nature-based virtual reality combined with neurofeedback for helping patients with cancer to better regulate mood and anxiety. Fifteen participants with cancer aged between 36 to 70 years old engaged in a 22-minute training wearing a virtual reality headset with Brainlink headband measuring brain activity. The experience consisted of several guided meditations that took place in nature-based scenes including calming music and soft noises found in nature. Results indicated that BCI virtual reality mindfulness helped subjects to better regulate anxiety and mood.

Tarrant et al. (2022) compared a virtual reality plus neurofeedback mindfulness training intervention with a standard guided audio-only meditation in improving emotional regulation skills. One hundred participants were divided into the experimental and the control group. The VR experience was "relaxation beach" from the Healium platform viewed through an Oculus Go VR headset. The BrainLink Lite EEG headband was utilized in conjunction with the VR environment and guided meditation instructions. EEG data were transferred to the Healium platform via Bluetooth, allowing users to control aspects of the VR experience. The results showed that both groups could better regulate negative moods and emotions such as anger, depression, and tension. However, the experimental group could better control mood, as subjects were more able to offset the negative emotions with positive ones.

Viczko et al. (2021) conducted a randomized between-group design to compare the effectiveness of augmented reality mindfulness training with or without the assistance of neurofeedback integrated into the virtual experience. Forty-one adults subjects with a moderate-to-severe range of depression and/or anxiety symptoms were randomly assigned to either an augmented reality mindfulness training assisted by frontal gamma asymmetry neurofeedback integrated (n=22, mean age 34.8) or an augmented reality mindfulness without neurofeedback (n=19, mean age 35.4). It was found that subjects in both groups could better manage negative moods. However, the levels of engagement were higher for the neurofeedback group. The authors concluded that the addition of a neurofeedback input in augmented reality mindfulness training enhances the positive effects on self-regulation of mood and emotion. In addition, it motivated more effort for training.

Kosunen et al. (2016) examined the effectiveness of a neuroadaptive virtual reality meditation system that combined virtual reality with neurofeedback in a sample of 43 students aged between 20 and 48 years old. Using a head-mounted display, users could levitate in a virtual world by doing meditation exercises (focused attention and body scan). The system also measured users' brain activity in real-time via EEG and calculated estimates for the level of concentration and relaxation. The results showed that the BCI mindfulness system elicited better attentional control and stress regulation ability. Virtual Reality technology elicited more positive outcomes compared to the same intervention displayed on a normal screen.

Järvelä et al. (2021) evaluated an intervention that combined respiration, brainwave–based neurofeedback, and visualizations to support meditation and virtual reality. The intervention aimed to enhance interoception and the deep empathetic processes involved in compassion meditation with real-time visualizations. The interventions were manipulated across eight separate conditions (dyadic or solo meditation; brainwave, breathing, both or no biofeedback) in an experiment with 39 dyads (n=78), observing the effect of conditions on self-reported experience and physiological synchrony. A summary of BCI-assisted mindfulness training intervention is presented in Table 3.

Table 3 - Summary of BCI-assisted mindfulness training interventions.

Study	Sample: number (n), mean age (M)	Mindfulness Training	BCI system	Complementary technology	Duration	Type of measurement	Research Design	Main Results
Vekety et al., 2022	n=31 M = 9.92	Mindfulness-based stress reduction	Muse™ headband	Smartphone	8 sessions	Neurocognitive tests, EEG assessment	Randomized controlled trial	Improved executive functions (inhibition, reaction speed, accuracy)
Hawley et al., 2021	n=71 M=26	Open monitoring	Muse™ headband	Smartphone	8 weeks	EEG assessment, mindfulness, and obsessive-compulsive scale –	Randomized controlled trial	Less mind-wandering, reactivity, distressing, and

						self-reports		obsessions
Crivelli et al., 2018	n=40 M=23.47	Focused attention	Muse™ headband	Smartphone	4 weeks	Cognitive assessment, EEG Assessment	Randomized controlled trial	Better behavior control skills, attention regulation, and inhibition skills
Acabchuk et al., 2021	n=53 M= 20.52	Self-guided meditation	Muse™ headband	Mobile device	4 weeks	EEG Measurements, Depression, Anxiety, Stress Scale, Mindfulness Questionnaire	Randomized controlled trial	Improved self-regulation
Martinez et al., 2018	n=20	Focused attention	Muse™ headband	iPad tablet	20 sessions	EEG assessment	Quasi-experimental pilot study	Improved self-regulated behaviors
Balconi et al. 2018	n=55 M = 23.212	Focused attention	Muse™ headband, lowdown focus glasses	smartphone	4 weeks	Psychometric and psychophysiological measurements	Randomized controlled trial	Better sense of control, adaptive detached observational stance, emotional control
Hunkin et al., 2021	n=68 M=22.66	Breath-focused meditation	Muse™ headband	iPad tablet	2 weeks	EEG assessment	Crossover trial	Increased awareness, a better sense of self-control
Antle et al., 2018	n=21	Mindfulness Stress Reduction	NeuroSky headset	Smartphone	6-weeks	Behavioral assessment	Randomized waitlist control design	Improved self-regulation skills
Bhayee et al., 2016	n=26 M=33.3	Breath-focused meditation	Muse™ headband	Mobile app	6 weeks	EEG assessment, attention and affective measures	Randomized, active control trial	Better attention control, inhibition, and positive mood
Balconi et al., 2019	n=50, *M*= 24.20	Breathing awareness	Lowdown Focus glasses	Mobile app	21 days	behavioral, psychometric, neuropsychological, and psychophysiological measures	Randomized control trial	Enhanced attention regulation skills
Crivelli et al., 2019a	n=16 M=44.38	Vipaśyanā meditation	Lowdown Focus brain-sensing eyeglasses, V-Amp system,	Smartphone app	2 weeks	EEG, stress, anxiety and mood assessment	Longitudinal control trial	Improved cognitive and affective regulation
Schuurmans et al. 2020	n=80	Deep-breathing techniques	Muse™ headband	iPad	6 weeks	Questionnaires, neurobiological Reactivity to Acute Stress	Randomized control trial	Better self-regulation of anxiety symptoms
Crivelli et al., 2019	n=50, M=22.94	Focused attention, breathing awareness	Muse™ headband	Smartphone app	2 weeks	neuropsychological and electrophysiological assessment	Three-branch pre–post experiment study	Improved attentional regulation skills
Millstine et al., 2019	n=30 20 to 75 years	Meditation instructions	Muse™ headband	Smartphone or tablet	2 weeks	Quality of life, stress and fatigue scales	Randomized controlled trial	Better self-management of emotional fatigue
Richter et al., 2019	N=55	Guided Meditation	Muse™ headband	Smartphone or tablet	8-week	obsessive compulsive scales. EEG assessment	Randomized controlled trial	Better self-management of obsessions and compulsiveness
Rolbiecki et al., 2022	n=15 M=52.4	Guided meditation	Healium™	VR (Oculus Go virtual reality headset)	12 30´ sessions	EEG assessment Edmonton symptom assessment	Exploratory, single-group, mixed-methods feasibility	Better self-regulation of anxiety and mood

							trial	
Tarrant et al., 2022	n=100 M=42.1	Guided meditation	BrainLink Lite EEG headband	Healium Oculus Go Virtual Reality headset	single 50-min visit	Mood scale	Randomized control trial	Better emotional control
Kosunen et al., 2016	n=43, M=28.7	Focused attention, body scan	QuickAmp	Oculus Rift DK2 head-mounted display	Single session	Meditation Depth Questionnaire, Sense of Presence Inventory	Exploratory study	Better anxiety self-management
Viczko et al., 2021	n=41 M=35.4	Guided meditation	Muse headband	Augmented Reality Phone App	Single session	Mood scale, EEG data collection,	Randomized between-group design	Improved self-regulation of mood and emotion
Järvelä et al., 2021	n=78	compassion meditation	QuickAmp	Virtual Reality		EEG assessment. Affect scales, self-reports	Experimental study	Better emotional awareness

Source: Authors.

4. Final Considerations

BCI-assisted mindfulness training has the potential to raise practitioners' motivation for continuous practice and employment of self-regulation strategies during and after the intervention. It is of great importance that practitioners who received this type of intervention tend to transfer self-regulation skills in real situations.

The findings of this review revealed that mindfulness training supplemented by EEG feedback can appropriately direct subjects to voluntarily increase alpha waves and, as a result, improve executive operations and particularly those mental operations which have a self-regulatory role such as attention and inhibition control (Richter et al., 2022; Bhayee et al., 2016). Studies showed that BCI-assisted mindfulness can train students to voluntarily regulate attention and in turn develop self-regulated behaviors. This finding may be promising for supporting self-regulated learning and applying academic achievement strategies in the coming years (Vekety et al., 2022).

The interventions presented revealed that BCI-assisted mindfulness can train subjects to be aware of how attention works, and voluntarily regulate attentional processes (Bhayee et al. 2016; Hunkin et al., 2021; Hawley et al., 2021; Vekety et al., 2022). It is equally important to outline that the benefits of attentional regulation skills were significant for groups that utilized feedback by BCI devices compared to conventional mindfulness interventions.

BCI along with attentional awareness has a positive impact on the affective processes. People who learn to deal with the feedback derived from brain activity can not only improve attention but also use attention as a means to regulate emotions and behaviors. In several studies, it was found that participants in this type of intervention increased positive mood, acceptance of negative emotions and in general could perceive events with resilience (Balconi et al, 2018; Crivelli et al., 2019)

Other findings showed that the use of neurofeedback, can reduce cognitive effort and mental fatigue, factors that have a significant impact on human's capacity to voluntarily apply self-control strategies (Millstine et al., 2019). In addition, subjects tended to have an increased sense of agency, which in turn implies a better ability to control volitional actions (Jeannerod, 2003; Rolbiecki et al., 2022; Tarrant et al., 2022).

The positive outcomes of BCI-assisted digital mindfulness training may be due to the engaging experiences that brain-computer interfaces can offer especially when these systems are embedded within virtual worlds that immerse subjects in spectacular environments. According to Amores et al. (2016), using virtual reality and real-time brain activity sensing devices can enable subjects to voluntarily use their attention as means to make changes in a 3D environment and develop superpowers such as levitation and telekinesis (Amores et al., 2016).

Awareness practices supported by neurofeedback provided practitioners with access to the source of information which derives from unconscious processes and helped them via various forms of feedback to train self-regulation mechanisms.

Thus, the integration of neurofeedback devices in mindfulness training could actively foster implicit mechanisms of self-regulation and make subjects experience it as not so effortful and invasive (Crivelli et al., 2019).

Mindfulness practices aim to increase internal and external awareness. To that end, it is required awareness not only of mental processes but also of bodily functions (Vago et al., 2012). BCIs can facilitate practicer's awareness about the mental as well as the bodily functions and gradually raise practicers awareness about the relation between mind and body interrelationship.

Nowadays, it is recognized that students should train their brains to be more receptive and adaptive to not only new information but also new ways of reframing what they already know. Systematic training in mindfulness training supported by digital technologies supported by the brain-computer interface can raise students' self-awareness and understanding of the ways their mental state influences their perceptions and their ability to see things in a new way (Schaefer, 2018).

Nowadays, personalized training is considered a significant trend in education, vocational training even in rehabilitation treatments (Fingelkurts et al., 2015).

It is worth noting, that most studies utilized similar low-cost consumer-grade EEG devices. This is one limitation of our study. On the one hand, we can draw safer conclusions about the devices in question. On the other hand, future research should further investigate the effectiveness of additional BCI systems and consumer-grade EEG devices on cognitive and behavioral control interventions.

BCI-assisted digital mindfulness training was found that it has significant benefits for the development of metacognitive skills which are required for the self-management of cognition, emotion, and behavior. However, these interventions face various challenges. BCI-assisted interventions should be appropriately designed based on the target group's characteristics. For instance, if the target group has a clinical diagnosis of Attention Deficit/Hyperactivity Disorder, learning objectives might align with the need of cultivating a growth mindset about attention. In addition, a mindfulness program should be appropriately designed with clear objectives about the facet of mindfulness which should be trained. Personalization of the mindfulness program content can accelerate individuals' engagement and improve positive outcomes by aligning a user's experience with their previous knowledge, interests, and goals. The BCI-assisted mindfulness training combined with immersive technologies or mobile applications could be designed to raise users' motivation and engagement (Mrazek et al., 2019).

Learning environments have been undergoing rapid change in the last decade driven by the evolution and availability of digital technologies (Vekety et al., 2022). In that vein, BCIs combined with mobiles and immersive technologies could support mindfulness as an innovative practice for relaxation, and cognitive and metacognitive development. BCI-assisted mindfulness training with the use of mobiles and immersive technologies could be used for training students' metacognitive, emotional, and attention regulation skills both within the educational context and/or at home. Especially for students with learning difficulties, attentional disorder, mood, and behavioral problems could be a beneficial method to reduce anxiety, inattentiveness, and impulsivity which lead to academic underachievement. In school, settings, the inclusion of gamified elements may enhance motivation, and make training even more effortless (Choo et al., 2014). In workplaces, BCI-assisted mindfulness could help workers to better deal with stressful situations and improve decision-making and problem-solving abilities.

BCI-assisted mindfulness training has the potential to train metacognitive skills such as self- and emotional regulation, introspection, attentional regulation, and inhibition control which are well-recognized factors of academic achievement, peak performance, and mental and emotional well-being. These abilities can be trained in a way that transcends the traditional ways of teaching metacognitive skills.

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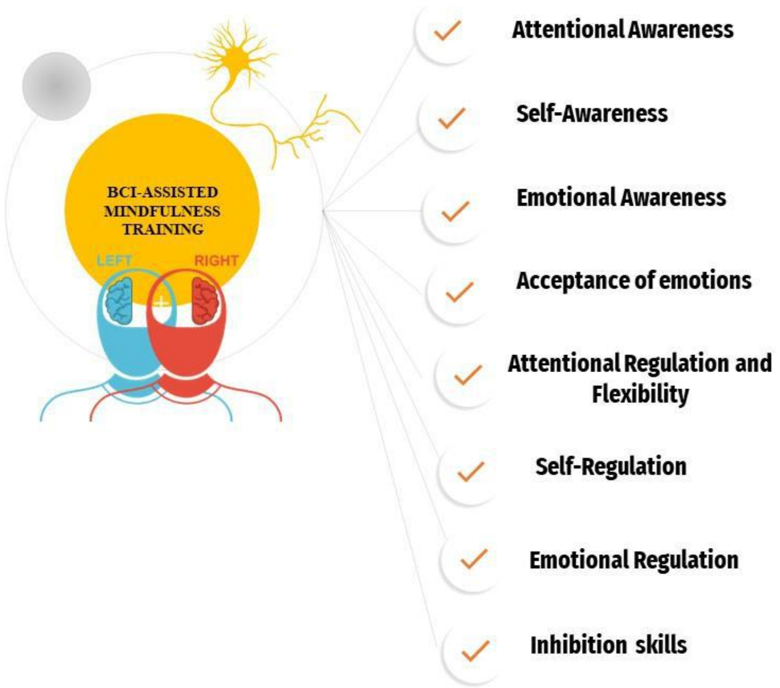
BCI-assisted mindfulness training can help subjects to be independent and self-regulated. BCI-assisted mindfulness training can help users to raise consciousness about their ability to voluntarily utilize attention as a tool of self- and emotional regulation. This is a conclusion of great importance considering the power of attention on human cognition. Figure 4 presents the main areas of metacognitive development after BCI-assisted mindfulness training.

Figure 4 - BCI-assisted digital mindfulness positive impact on metacognitive abilities.



Source: Authors.

As shown in Figure 4, BCIs providing users with real-time feedback derived from their own brain activity can facilitate subjects' metacognitive training, since they have better awareness about their mental and emotional operations as well as better flexibility to apply self-regulation strategies each time they observe disturbances caused by negative thoughts, anxiety, and mental fatigue. In recent decades, significant social changes have been observed, which are related to the role of A.I. and technology in people's daily lives. The most important of them concern communication, diffusion and management of information, and the ability to assimilate and utilize the produced new knowledge. We have to underline that the role of Digital Technologies in education domain as well as in all the aspects of everyday life, are very productive and successful, facilitate and improve the assessment, the intervention, decision making, the educational procedures and all the scientific and productive procedures via Mobiles (Stathopoulou et al., 2018, 2019, 2020; Kokkalia et al., 2016; Drigas et al., 2015; Vlachou et al.,2017; Papoutsi et al., 2018; Karabatzaki et al., 2018), various ICTs applications (Drigas et. al, 2004, 2005, 2006, 2009, 2011, 2013, 2014, 2015, 2016, 2017, 2019; Pappas et al., 2018, 2019; Papanastasiou et al., 2018, 2020; Alexopoulou et al., 2019, Kontostavlou et al., 2019; Charami et al., 2014, Bakola et al., 2019, Kontostavlou et al., 2019, Alexopoulou et al., 2019), via AI Robotics & STEM (Drigas et. al, 2004, 2005, 2009, 2014; Vrettaros et al., 2009; Anagnostopoulou et al., 2020; Lytra et al., 2021, Pappas et al., 2016, Mitsea et al., 2019. 2020, 2021, 2022, Chaidi et al., 2020), and games (Chaidi et al., 2022; Kokkalia et al., 2017; Drigas & Mitsea, 2021). Digital Technologies provide the tools for access, analysis and transfer of information and its management and utilization of new knowledge. Information and Communication Technologies (ICT), unprecedented technological capabilities of man, have a catalytic effect, create a new social reality and shape the Information Society (Pappas & Drigas, 2015, 2016; Drigas & Koukiannakis, 2004, 2006, 2009; Drigas and Kontopoulou, 2016; Theodorou & Drigas, 2017; Drigas & Kostas, 2014, Bakola et al., 2019, 2022; Drigas & Politi-Georgousi, 2019, Karyotaki et al., 2022). Moreover, games and gamification techniques and practices within general and special education improve the educational procedures and environment, making them more friendly and enjoyable (Drigas et al., 2014, 2015; Papanastasiou et al., 2017; Kokkalia et al., 2016, 2017; Doulou et al., 2022, Chaidi et al., 2022).

Concluding, it's necessary to refer that the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation accelerates and improves more over the educational, productive, and decision-making practices and results (Drigas & Papoutsi, 2020; Drigas & Mitsea 2020, 2021, 2022; Kokkalia et al., 2019; Pappas & Drigas, 2019; Papoutsi & Drigas, 2016; Karyotaki & Drigas, 2015, 2016; Papoutsi et al., 2019, 2021; Chaidi et al., 2020, Drigas & Karyotaki, 2019; Mitsea et al., 2020, 2021,2022; Angelopoulou & Drigas, 2021; Tourimpampa et al., 2018; Kapsi et al., 2020; Drigas et al., 2021, 2022; Galitskaya & Drigas, 2021). Finally, Driga et al., 2019; Stavridou et al., 2021 and Zavitzanou et al., 2021 suggest that various environmental and dietary factors can act as inhibitors or facilitators of the improvement of mental abilities and strengths.

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