A new decade for social changes
Mindfulness Strategies for Metacognitive Skills Training in Special Education: The Role of Virtual Reality

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Abstract. The purpose of the current review study is to provide representative evidence regarding the effectiveness of mindfulness training strategies on the development of metacognitive skills for people with special education needs. In addition, we explore the role of virtual reality in the efficacy of mindfulness interventions among people with learning disabilities, neurodevelopmental disorders, intellectual disabilities, and behavioral disorders. In addition, we present innovative mindfulness training strategies, appropriate for metacognitive skills training in special education. Finally, we seek the features that possibly make virtual reality a fertile ground for the implementation of mindfulness training. The results showed that mindfulness training improves the metacognitive skills needed for the inclusion of people with disabilities. Virtual reality constitutes an effective assistive technology that can facilitate mindfulness training in various contexts, accelerating positive outcomes in mental and physical health, academic performance, and well-being.

Keywords. Mindfulness strategies, special education, attentional control, emotional regulation, self-control, self-observation, self-awareness, inhibition control, executive functions, virtual reality, neuro-linguistic programming, positive psychology

1. Introduction

Learning Disabilities

Learning disabilities refer to a set of neurodevelopmental disorders with a biological origin that causes cognitive and behavioral abnormalities (American Psychiatric Association, 2013). Learning disorders includes a wide range of disorders including 1) physical disabilities, 2) sensory impairments, 3) moderate /severe cognitive disabilities, 4) autism, 5) learning disabilities, 6) attention deficit, 7) behavioral disorders, 8) Giftedness (Muktamath, Hegde & Chand, 2021; Sisk, 2021).

Researchers have already observed cognitive impairments in domains such as attention, perception, and memory (Malekpour et al., 2013). In addition, behavioral problems, mood disorders, and heavy anxiety are characterized as common signs. However, the most important deficits concern metacognition, which is responsible for self-control and most important awareness abilities (Drigas & Mitsea, 2020-2022, Mitsea, Drigas & Skianis, 2022).
**Metacognition**

Flavell who introduced the term and led the studies regarding metacognition defined metacognition as the learners’ awareness of their cognition and cognitive processes (Flavell, 1979). Metacognition comprises both the ability to be aware of one’s cognitive processes and to manage them effectively (Fleur et al., 2021).

According to Nelson and Narens (1994) two fundamental components are required: metacognitive monitoring and meta-control. Meta-control includes a set of top-down self-regulatory mechanisms responsible for the smooth operation of cognitive functions such as recognition and discrimination of objects, decision-making, semantic encoding, and spatial representation.

Metacognition also includes a set of meta-processes individuals can apply in monitoring ongoing cognition to effectively control their behavior (Rhodes, 2019). According to Brown (1978) metacognition requires also appropriate evaluation and organization of the thinking processes that people employ to plan their actions and behaviors, make decisions, and solve problems of daily life. Metacognition enables people to create meta-presentations of their internal mental states and monitor and regulate them aiming to achieve effective daily behavioral functioning (Nelson & Leonesio, 1988).

Drigas and Mitsea (2020, 2021) define metacognition as the set of regulatory meta-abilities and meta-skills that are consciously applied aiming at the smooth operation of the cognitive & psychophysiological mechanism as a means of achieving functional capability, self-efficacy, independent living & life satisfaction. Metacognition involves consciousness-raising skills and strategies including individuals’ ability to observe, regulate and adapt their internal cognitive processes, recognize the difference between functional and dysfunctional states of mind and consciously choose those states that awaken the full range of their abilities and identity”. According to their theory, metacognition is a matter of systematic training.

**The Concept of Mindfulness: Towards A Metacognition Framework**

In recent years, a dialogue has begun regarding the concept of mindfulness. Kabat-Zinn et al. (2003) describe mindfulness as “the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment”. Vago et al. (2012) describe the concept in two ways: (a) as a method for developing a multidimensional skillset for the reduction of self-processing biases and as a continuous discriminative attentional capacity termed as “mindful awareness.

Mindfulness is considered either a state or a trait. As a state, it refers to the temporary state of non-judgmental, non-reactive, present-centered attention and awareness; As a trait, it can be described as a dispositional pattern of cognition, emotion, or behavioral tendency (Vago et al., 2012).

Mindfulness is strongly tied to systematic mental training, In addition, it is considered an important intervention strategy. Mindfulness training requires the practice of orienting one’s attention to the present moment and monitoring any thoughts, sensations, and emotions that arise in real-time experience (Tang et al, 2015). Mindfulness training aims at cultivating self-awareness, the ability to effectively modulate one's behavior (self-regulation), and a positive relationship between self and others (Vago et al., 2018).

According to Hölzel et al. (2011) mindfulness interventions are inseparably associated with the following metacognitive components which interact to establish a powerful self-regulation system: (a) attention regulation, (b) body awareness, (c) emotion regulation, and (d) change in perspective of the self. Lutz et al. (2008) highlight that the central mechanism involved in mindfulness techniques is attention. The key attentional processes involved are: (a)
attentional orienting (curiosity, openness, and acceptance), (b) engaging attention, and (c) sustaining—monitoring attention. Malinowski (2013) emphasized the central role of the attentional control mechanism. Other studies emphasize that mindfulness training activates inhibitory control capacity improving possibly some aspects of impulsivity (Soler et al., 2016). Moore and Malinowski (2009) emphasize the role of mental flexibility.

**The 8 Pillars Metacognitive Model of Mindfulness**

Drigas and Mitsea (2020) developed a new mindfulness model which described the metacognitive abilities and processes involved in mindfulness training (Figures 1,2). This model stands on the following eight pillars:

**Theoretical Understanding of Mindfulness:** Mindfulness is characterized by a broad theoretical background beginning from the ancient traditional systems of medicine to modern neuroscience. Mindfulness is not a one-dimensional concept. On the contrary, it requires an understanding of increasingly advanced and complex concepts.

**Experiential Understanding of Mindfulness:** Mindfulness is inseparably connected with practice in real circumstances. Practice helps people to apply the acquired knowledge taking into consideration the parameters that define a given situation. During this process, the subjects learn by experience. They realize their strengths and weaknesses. They are required to estimate the situations as well as the demands imposed by the external environment and make decisions about new opportunities.

**Mindful self-observation:** The meta-ability of self-observation requires real-time monitoring of the emotional and mental movements that arise moment by moment in the field of perception. This process requires the development and the engagement of a mental construction which is termed internal observer which is closely related to attentional processes.

**Mindful self-regulation:** Each time the observation procedure detects distractions, the subject employs self-regulation strategies to restore disturbances and re-establish relaxation.

Mindful adaptation: The individual's ability to respond flexibly to unexpected conditions and heavy stressors employing adaptive strategies.

**Mindful recognition:** The human meta-ability to identify automatic reactivity, cognitive bias, and distorted perceptions.

**Mindful discernment:** The meta-ability of filtering, to make wise judgments, to discern between thoughts and emotions, and deliberately chose those that assure physiological and psychological well-being.

**Mnemosyne:** A state of awakening and relaxed awareness in which cognitive processes operate without effort, liberated from distractions.
Virtual Reality

Virtual Reality (VR) systems are a sophisticated interplay of technology and human perception. Immersion, interactivity, and a sense of presence are the three major characteristics of VR systems that distinguishes VR from other representational technologies. (Savickaite, Donnell, and Simmons, 2022). Virtual reality (VR) is increasingly incorporated into psychotherapy, with the literature documenting its effectiveness in the rehabilitation of various
disorders such as autism spectrum disorder and anxiety. However, few studies have incorporated VR into mindfulness interventions, although there is a growing interest regarding the use of 3D interfaces in such training programs (Savickaite et al., 2022; Chandrasiri et al., 2020). Even less research has been conducted to investigate the impact of virtual reality mindfulness as an intervention strategy for people, especially, students, with learning difficulties and other disabilities (Huguet et al., 2019). According to our knowledge, limited knowledge exists about the effectiveness of VR mindfulness training interventions in the development of metacognitive skills among people with special education needs.

The principal objective of the present review is to investigate the role of mindfulness training strategies in the development of metacognitive skills for people with learning difficulties and related disorders. We summarize evidence about the effectiveness of traditional mindfulness strategies as well as virtual reality-assisted mindfulness interventions. In addition, we present mindfulness strategies, which are effective for metacognitive skills training and can be applied in several contexts, such as educational settings. Finally, we examine the attributes of VR that work in tandem with mindfulness training, as well as review experimental studies regarding the use of virtual reality mindfulness in populations with learning disabilities.

The present review attempts to summarize evidence to address two central research questions as follows:

a) Is mindfulness training an effective intervention for metacognitive skills training for people with learning disabilities, neurodevelopmental disorders, and intellectual and behavioral disorders?

b) Can Virtual Reality be an assistive tool in mindfulness training for people with disabilities?

In addition, we address two secondary research questions intending to shed more light on the previous questions:

c) What mindfulness strategies can be applied for metacognitive skills training?

d) What are the attributes that provide virtual reality the advantage as an assistive tool in mindfulness training?

2. Methods

The purpose of the current review study is to provide representative evidence regarding the effectiveness of mindfulness training strategies on the development of metacognitive skills for people with special education needs. In addition, we explore the role of virtual reality in the efficacy of mindfulness interventions among people with learning and other related disorders. To that end, we present a brief, representative, and non-exhaustive literature review. The methodology for the current review was based on the PRISMA guidelines (Page et al., 2021). However, the scope of our review is to summarize the key research, identify research gaps, and present proposals for future research.

2.1 Search strategy

Three databases were chosen: Scholar google, PubMed and Mendeley using a combination of the keywords. For the first main research question, we used the following research questions: mindfulness training, learning disabilities, mental retardation, autism spectrum disorder, dyslexia, and attention deficit hyperactivity disorder, giftedness, anxiety, metacognition, self-regulation, emotional regulation, flexibility, self-awareness. For the second research question, we utilized keywords such as virtual reality mindfulness, learning disabilities, pranayama, and breathing exercises, self-control. The search was applied to each database from 2000 up until August 2022.
2.2 Selection of Relevant Publications

Inclusion and exclusion criteria
Specific titles and abstracts of the studies retrieved from the three databases were screened based on the following criteria:

Inclusion criteria:
- The studies include randomized controlled trials, pilot studies, case studies
- The interventions focus on people with disorders and disabilities
- The intervention research questions and findings concern metacognitive abilities and skills
- The study incorporates mindfulness training with or without virtual reality

Exclusion Criteria
- Book chapters, posters, and review articles were excluded
- Interventions with healthy subjects
- We excluded non-English publications
- We excluded intervention with other technologies except for the virtual reality

2.3 Data Extraction
Following the preliminary screening of the titles and abstracts and references to other relevant studies, the studies were assessed to decide if they met the inclusion criteria. All the studies included in the review provide data on the research design, the participants, the type of interventions, the context of the intervention, the duration, the types of measurements and the main findings.

2.4 Search Results
For the first research question, the initial research revealed 2943 (scholar google: 1160 articles, pubmed:412, Mendeley: 1371), of which the common studies were removed. For the second research question regarding virtual reality mindfulness, the initial research provided 269 articles (scholar google: 85, PubMed:10, Mendeley:174) The titles and abstracts of the remaining studies were screened for inclusion and this process led to 50 studies for full-text screening. After the full-text screening, the 23 remaining studies were included in the final analysis. Figure 1 depicts the process and the results of the research strategy.
3. Literature Review

3.1 Mindfulness Strategies for Metacognitive Skills Training

Focused Attention techniques
This strategy involves sustaining selective attention moment by moment on a chosen object, such as a subset of localized sensations caused by respiration (Lutz et al., 2008). Trataka (Yogic Visual Concentration) is one of the strategies said to improve vision and alter cognitive processes. Trataka includes focusing one's concentration on a candle flame; the practice causes the mind to become one-pointed and awakens inner vision (Swathi et al., 2021). Swathi et al. (2021) that training for 20 min/day for 6 days a week can improve fundamental aspects of self-regulated learning such as working memory, spatial memory, and spatial attention.

Open Monitoring techniques
Open monitoring practices entail non-reactive observation of the moment-to-moment content of experience. The aim is to remain just in the nonreactive metacognitive monitoring state, paying attention to everything that occurs in the experience moment by moment without focusing on any explicit object. To reach this state, the practitioner gradually reduces the focus on an explicit object, and the monitoring faculty is correspondingly emphasized. These practices enhance control mechanisms including attentional and emotional self-regulation (Lutz et al., 2008).

Breathing exercises
Breathing, although non-conscious and often overlooked, comprises a central aspect of our whole being and one of our most vital functions (Drigas and Mitsea, 2022). Breathing problems are common indicators in various cases of learning disabilities and behavioral
disturbances. In some cases, early respiratory problems predict later disorders (Mitsea, Drigas, and Skianis, 2022). A growing number of studies, especially in the field of contemplative neuroscience, support the idea that breathing is to some extent under our control. Breathing techniques (i.e. Pranayama) train practitioners to directly and consciously regulate internal bodily states by altering one or more parameters of respiration (Zaccaro et al., 2018). Thus, breathing training results in physiological and neuropsychological benefits associated with the autonomic nervous system, improvements in antioxidant defense status, hormonal regulation, and growth factor release (Drigas and Mitsea, 2022). Breath control practices guarantee instant as well as long-lasting cognitive and metacognitive improvements for people with attentional deficits, behavioral problems, and intellectual disabilities (Mitsea, Drigas, and Skianis, 2022). According to Drigas and Mitsea (2022), breathing training constitutes an act of metacognition which consists of at least three metacognitive components: (a) observation of breathing, (b) regulation of breathing, and (c) adaptation of breathing.

Silence Techniques
Silence practices aim at the pacification of the mind boosting observation of the conscious experience, attentional flexibility, and self-regulation skills. Systematic silence training supports the interconnectivity of the neural networks that are responsible for attention control, emotional regulation, and learning and contributes to the neurogenesis of structures that are critical for fundamental memory and intelligence processes. Deep silence accelerates information encoding and enhances the ability of attention regulation both in meditation and non-meditative states with an additional impact on time perception (Dulcic, 2021; Wittmann & Schmidt, 2014). Kirste et al. (2013) found that two hours of silence for seven days contribute to hippocampal neurogenesis.

Visualization Techniques
Guided imagery combines relaxing methods with the evocation of mental pictures that also include the sensations of sight, hearing, touch, taste, and smell. It is used to deliberately evoke specific images to influence physiological and emotional states through the client's imagination (Mellenthin, 2021). Hudetz et al. (2000) applied guided imagery training to a sample of thirty participants (ages 17–56 years) and found that guided imagery significantly increased the performance on the working memory tests.

Deep Listening Techniques
Deep listening requires interaction between the speaker and the one who is listening. Deep listening constitutes a mindfulness practice that can help people with special needs such as gifted students. Deep listening establishes rapport and deepens understanding of others. In addition, it helps people to make more sophisticated decisions and solve complex problems with flexibility (Sisk, 2021).

Self-Affirmations
Self-affirmation is an act that manifests one’s adequacy and thus affirms one’s sense of global self-integrity. Self-affirmations bring about a more expansive view of the self and its resources. Affirmations remind people of psychosocial resources beyond a particular threat because, under normal circumstances, people tend to narrow their attention to an immediate threat. Self-affirmed people can see the many ordinary stressors of daily life in the context of the big picture. Affirmations can help people to deal with stressors, and defense mechanisms, by being more adaptive and adopting alternative strategies to overcome threats (Cohen and Sherman, 2014).
Gratitude practices
Gratitude refers to a state of recognition and appreciation resulting from appraising a received benefit as a positive outcome as well as recognizing that this positive outcome stems from a source (Jans-Beken et al., 2020). Gratitude practices contribute to neurophysiological regulation and train various meta-skills. Research has already shown that gratitude can lower the activity of the amygdala, which is a core factor in learning disabilities and behavioral disorders (Hazlett et al., 2021). According to Jans-Beken et al. (2020), gratitude downregulates the biomarkers of stress and inflammation, improves sleep quality, boosts mental and social well-being, and trains self-regulation skills. Finally, these practices help people with disabilities to feel hope and happiness.

Body scan training
In the body scan training, participants are instructed to initially concentrate on their breathing before shifting their awareness to other body areas, "scanning" their bodies from head to feet or from feet to head. During this process, they are encouraged to observe and accept the sensations they experience openly and nonjudgmentally and to gently bring attention back to their body if they are distracted (Gan et al., 2022). Schultchen et al. (2019), found, for instance, that an 8-week body scan intervention can help people to self-regulate psychological stress. It was also revealed that the body scan reduced the stress hormone cortisol and increased the hormone DHEA.

Mindful hypnotherapy
Researchers recognize that mindfulness and hypnotherapy share a common ground (Penazzi, and Pisapia, 2022), which can improve metacognitive skills and abilities activating the pathways of effortless self-regulation, in other words, non-conscious regulation which has an important impact on metacognitive processes in later conscious states. In addition, mindfulness and hypnosis utilize the power of attention and imagery. (Drigas, Mitsea and Skianis, 2021;2022). Olendzki et al., 2021 applied mindful hypnotherapy, a program that applied hypnosis to the practice of mindfulness.

NLP mindfulness techniques: Neuro-linguistic programming (NLP) is a psychological approach that aims to achieve behavioral modification using strategies that share several common features with mindfulness techniques. NLP training improves metacognitive skills and abilities not only in healthy subjects but also in people with learning and other disabilities (Wake & Leighton, 2014; Drigas, Mitsea, and Skianis, 2022; Drigas and Mitsea, 2021 ). NLP strategies focus on the power of observation and positive belief cultivation. Several techniques which can be characterized as mindful are the following: affirmations, visualizations, anchoring, and reframing (Drigas, Mitsea, and Skianis, 2022).

Positive psychology mindfulness techniques: Mindfulness and positive psychology techniques have a close relationship (Allen, Romate, and Rajkumar, 2021). These techniques include optimism exercises, kindness exercises, hope therapy, positive bibliotherapy, hopeful goal-directed thinking, well-being therapy, savoring the moment, positive future thinking, self-compassion exercises, and positive writing (Bolier et al., 2013).

3.2 Mindfulness Training for Metacognitive Skills Training in Special Education Attention Deficit Hyperactivity Disorder (ADHD)
In a preliminary study, Santonastaso et al. (2020) evaluated the effects of an eight-week mindfulness-oriented meditation on attentional and behavioral regulation. Twenty-five children with ADHD aged 7–11 years were recruited in the mindfulness group (n= 15), whereas 10 subjects in the control condition included Emotion Education Program. The meditation
strategies included “games” which aimed to train the self-observation and awareness of breath, body parts, and thoughts. Children were recommended to practice meditation generalize in daily life. In addition, they were asked to write about their experiences in a meditation diary. The neuropsychological evaluations revealed a significant improvement in the experimental group in inhibition control, emotional regulation, and attentional control.

Zaccari et al. (2022) investigated whether a mindfulness-oriented meditation could help people with ADHD to improve sleep and develop behavioral regulation skills. Twenty-five children with ADHD aged 7-11 years were divided into two groups: the mindfulness group and the control group. The intervention takes place three times per week for 8 weeks. The results indicated sleep improvements and better behavioral regulation.

Huguet et al. (2019) examined the efficacy of a mindfulness group intervention program on emotional regulation in children with attention deficit hyperactivity disorder (ADHD). Seventy-two children aged 7 to 12 years with ADHD were divided into 2 groups: mindfulness and a control group. The experiments group was trained in techniques such as breathing meditation, sensory awareness exercises, body scan, and thought and emotional awareness exercises. After the intervention, the children in the experimental group showed an improved ability for emotional regulation.

**Autism Spectrum Disorder**

Juliano et al. (2020) examined the efficacy of an 8-week school-based mindfulness program for improving inhibition control skills and selective attention in 27 children with ASD (mean age 13.60). The intervention included strategies such as mindful breathing, mindful postures, and mindful listening. Significant improvements were observed after the intervention for inhibition control as well as for selective attention. The researchers concluded that school-based mindfulness holds promise for enhancing specific executive functioning abilities in children with ASD.

Spek et al. (2013) evaluated the effects of a nine-weeks mindfulness-based therapy in high-functioning adults with an autism spectrum disorder. Forty-two participants were divided into two groups: the training and the wait-list control group. Results revealed better self-regulation skills for the intervention group, as opposed to the control group. Anxiety, rumination, and depression were significantly reduced in the mindfulness group. The intervention consisted of 8 weekly 2-hour classes and one 4-hour retreat in the fifth or sixth week of the program.

**Tourette Syndrome/ Tic Disorder**

Reese et al. (2015) conducted a pilot study to investigate the benefits of mindfulness in Tourette syndrome and chronic tic disorder. In a sample of eighteen people aged sixteen and above, the researchers used a modified form of mindfulness-based stress reduction. At baseline, post-treatment, and one-month follow-up, symptoms were assessed. Mindfulness was shown to be an effective and acceptable intervention. Participants could better control tic intensity and tic-related impairment. Treatment responders constituted 58.8% of the participants. At the 1-month follow-up, therapeutic benefits were sustained.

**Intellectual Disability**

Singh et al. (2003) created a self-control strategy based on mindfulness to help an adult with mental retardation and aggressive behavior. He was taught a simple meditation technique that required him to shift his attention and awareness from the anger-producing situation to a neutral point on his body, the soles of his feet. Afterward, the participant was asked to apply the technique in situations that he normally would respond aggressively. The results of this study showed that the participants developed better self-control.
Singh et al. (2007) evaluated the efficacy of a mindfulness technique (Soles of the Feet) for adults with moderate intellectual disabilities. The researchers applied a multiple baseline design, to 3 individuals with moderate mental retardation who were on the verge of losing their community placements due to their aggressive behavior. Initially, the individuals found it difficult to recall and visualize past anger-producing situations, but mastery was obtained when they incorporated ‘recreating the scene’ as a prompt and added a discriminative stimulus on the soles of the participants’ feet. The results showed that participants could better regulate their aggressive behavior after mindfulness intervention. The follow-up data revealed also that self-regulation skills remained for a long period.

**Dyslexia**

Tarrasch et al. (2016) studied the benefits of a Mindfulness-Based Stress Reduction (MBSR) intervention on reading, attention, and psychological well-being in 24 adults (mean age 30 years) with developmental dyslexia and/or attention problems. The participants attended eight weekly sessions during which they received mindfulness training through body scan meditation, sitting meditation, mindfulness stretching exercises and mindfulness eating. After the mindfulness exercises, participants could better control impulsivity, attention, and in turn, reading skills. The reaction time was improved to tasks measuring selective, sustained, executive, and orienting of attentional functions. Lastly, participants felt improvements in most of the psychological domains (such as relief of stress, rumination, sleep disturbances, and life satisfaction).

Pradham et al. (2017) evaluated the effectiveness of the Mindfulness-Based Rehabilitation of Reading, Attention & Memory program which employs focused attention enhancement and visual meditation techniques to rehabilitate reading deficits, visual inattention, visual motor incoordination, information processing speed, and visual memory. Three children between 8 and 10 years old were recruited. The main elements contained a visually fixative and retentive meditation technique that targeted visual skills deficits, and an open monitoring type of meditation for improving word associations, associative learning, and meaning-making in addition to reducing anxiety. The findings indicated improvements in improvements in school performance, impulse control, and behavior regulation.

**Giftedness**

Turanzas et al. (2020) developed and evaluated a mindfulness program for gifted students who experience symptoms such as existential anguish, anxiety, depression, experiential avoidance, and cognitive fusion. Twenty-two gifted students between 8 and 14 years old participated in this 8 weeks intervention. The program included 90-min group sessions during which participants were trained in strategies such as mindful breathing, compassion meditation, and loving-kindness meditation. After the intervention, students were more able to understand and regulate their emotions.

Olton-Weber et al. (2020) assessed the impact of a 6-week mindfulness intervention for 42 gifted and talented middle school children. The program was designed around the first six letters of BREATHE (i.e., Body, Reflections, Emotions, Attending, Tender, Habit). It was found that intervention helped students to have better self-awareness as well as better regulation of self-imposed forms of perfectionism.

**Anxiety**

Olendzki et al. (2020) investigated the effectiveness of mindful hypnotherapy on anxiety in a sample of forty-two college students with heavy stress. After the intervention, participants were more able to control stress and they were also more flexible to deal with stressful situations.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Type of Disorder</th>
<th>Participants: number (n), mean age (M), Duration</th>
<th>Mindfulness Program</th>
<th>Type of measurement</th>
<th>Research Design</th>
<th>Findings</th>
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</thead>
<tbody>
<tr>
<td>Santonastaso et al.</td>
<td>2020</td>
<td>Attention Deficit Hyperactivity Disorder (ADHD)</td>
<td>n=25, 7–11 years M = 8.9 3 times per week for 8 weeks</td>
<td>Mindfulness-oriented meditation</td>
<td>Academic, behavioral, emotional, and mindfulness ratings, before and after the two programs.</td>
<td>Preliminary Study</td>
<td>Improvements in attentional control, inhibition control, and emotional regulation</td>
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<td>Zaccari et al.</td>
<td>2022</td>
<td>ADHD</td>
<td>n=25, 7–11 years M = 8.9 3 times per week for 8 weeks</td>
<td>Mindfulness-oriented meditation</td>
<td>Behavioral and sleep ratings, before and after the two programs</td>
<td>Preliminary Study</td>
<td>Sleep improvements and better behavioral regulation</td>
</tr>
<tr>
<td>Huguet et al.</td>
<td>2019</td>
<td>ADHD</td>
<td>n=72 7 to 12 years M: 9 8 weeks, once a week, 75 min per session</td>
<td>Mindfulness stress reduction training and mindfulness cognitive therapy.</td>
<td>Child behavior, Attention/Anxiety-Depression/Aggression scales</td>
<td>Rando mized Control Study</td>
<td>Improved emotional regulation</td>
</tr>
<tr>
<td>Juliano et al.</td>
<td>2020</td>
<td>Autism Spectrum Disorder</td>
<td>n=27 11-16 years M= 13.60 8 weeks twice per week 30 min</td>
<td>School-based mindfulness</td>
<td>Walk/Don’t Walk test, Color-Word, cancellation test</td>
<td>Feasibility study</td>
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</tr>
<tr>
<td>Spek et al.</td>
<td>2013</td>
<td>Autism Spectrum Disorder</td>
<td>n=42 9 weeks 40–60 minutes daily</td>
<td>Mindfulness-based therapy for autism</td>
<td>Self-report, rumination, positive affect questionnaire</td>
<td>Rando mized controll ed trial</td>
<td>Better self-management of anxiety, depression, and rumination</td>
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<tr>
<td>Authors</td>
<td>Year</td>
<td>Condition</td>
<td>Participants</td>
<td>Intervention Details</td>
<td>Measures</td>
<td>Study Design</td>
<td>Findings</td>
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<tr>
<td>Reese et al.</td>
<td>2015</td>
<td>Tourette syndrome</td>
<td>n=18</td>
<td>8 weekly 2-hour classes and one 4-hour retreat</td>
<td>Mindfulness-based stress reduction –tics</td>
<td>Adult Tic Questionnaire, Social Adjustment Scale, Mindfulness Questionnaire</td>
<td>Pilot study of tic intensity</td>
</tr>
<tr>
<td>Singh et al.</td>
<td>2003</td>
<td>Mental Retardation</td>
<td>n=1</td>
<td>Twice a day for five days 30 minutes</td>
<td>Meditati on on the Soles of the Feet</td>
<td>Staff-reported behaviors, Self-reported behaviors</td>
<td>Case study of self-control</td>
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<td>Singh et al.</td>
<td>2007</td>
<td>Mental Retardation</td>
<td>n=3</td>
<td>1 week</td>
<td>Meditati on on the Soles of the Feet</td>
<td>Staff-reported behaviors, Self-reported behaviors</td>
<td>Multiple baseline design</td>
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<td>Tarrasch et al.</td>
<td>2016</td>
<td>Dyslexia</td>
<td>n=24</td>
<td>8 weekly sessions</td>
<td>Mindfulness-Based Stress Reductio n</td>
<td>Attention measures and psychologica l measures</td>
<td>Feasibility Study of impulse control, attentional regulation, better reading skills</td>
</tr>
<tr>
<td>Pradhan et al.</td>
<td>2017</td>
<td>Dyslexia</td>
<td>n=3, 8-10</td>
<td>10 sessions, 30 minutes</td>
<td>Mindfulness-Based Rehabilitation of Reading, Attention &amp; Memory</td>
<td>Intelligence Scale pre- &amp; post-intervention</td>
<td>Case study of self-regulation, observation skills, emotional regulation</td>
</tr>
<tr>
<td>Turanza s et al.</td>
<td>2020</td>
<td>Giftedness</td>
<td>n=22</td>
<td>8 weekly 90-min group</td>
<td>Mindfulness for Giftedness</td>
<td>Mindfulness, Depression, state anxiety, emotional</td>
<td>Pilot study of improved emotional understanding and emotional regulation</td>
</tr>
</tbody>
</table>
Olton-Weber et al. 2020
Giftedness
n=42
11 to 14 years
6 weeks
BREATHE
Child and Adolescent Mindfulness Measure
quasi-experimental design
Better recognition and regulation of self-imposed forms of perfectionism

Olendzki et al. 2020
Anxiety
n=42
8 weeks 1 hour sessions
Mindful hypnotherapy
Perceived Stress Scale, Acceptance and Action Questionnaire
Randomized Controlled Pilot Study
Improved self-regulation of anxiety, better flexibility

Table 1: Mindfulness strategies in the development of metacognitive skills in people with disabilities: A summary of studies

3.3 The Advantages of Virtual Reality in Mindfulness Training
Virtual Reality is starting to be used in psychological therapy around the world with many researchers seeking the reasons why VR is effective and what effect it has on the human psyche (Schuemie et al., 2001). For that reason, it is essential to identify the attributes that VR offers and how these features may enhance the effectiveness of mindfulness-based training interventions, especially for people with disabilities.

- **Safe, Relaxing, and Controllable**: VR environments minimize extraneous variables that may stress subjects out providing a predictable, safe, and supportive environment without posing patients with the threat of harm. In VR environments, perceptual stimuli are provided in a controllable way according to the patient's needs taking into consideration their sensory processing capacity (Yildirim et al., 2020; Savickaite et al., 2022). Mindfulness training considers the above features a condition precedent to the achievements of this program, especially in cases of people with disabilities who struggle against phobias.

- **Presence**: The therapeutic value of mindfulness lies in directing patients’ attention to the present moment (Kabat-Zinn et al., 2003). Virtual reality simulates reality and generates a sense of presence—the feeling of “being here and now” in the virtual world (Schuemie et al., 2001).

- **Embodiment**: VR can visibly replace a person's physical body with a life-sized virtual one, viewed from the first-person perspective (Biocca, F, 1997). Studies have already shown that embodiment in VR during mindfulness practices motivates subjects to continue practicing. In addition, VR embodiment in mindfulness training also improves self-awareness as well as recognition abilities (Navarrete et al., 2021).

- **Experiential Learning**: Experiential learning is the process of acquiring knowledge and skills from challenging situations through mindfulness training. Experiential learners benefit from engaging in multiple ambiguous experiences that can be emotionally charged.
and full of novel information (Griffith et al., 2017). Virtual reality is well-recognized as a pedagogical tool for enhancing students’ experiential learning (Asad et al., 2021).

- **Visualization**: Mindfulness practices utilize visualizations, and especially positive visualizations, to visualize idyllic environments as a means of relaxation and self-regulation (Hudetz et al., 2000). However, people with disabilities are characterized by low imagery skills, especially in making positive visualizations (Habak, et al., 2021). Virtual reality provides visual helping participants who had previously struggled with mindfulness because of the difficulty of imagining a visual environment (Seabrook et al., 2020). Virtual reality enables users to immerse and explore ancient temples or spectacular landscapes such as Alpine scenes, lush rainforests, tropical beaches, and deserts (Habak, et al., 2021; Choo and May, 2014; Bruggeman and Wurster, 2018).

- **Attentional Manipulation**: A central aim of mindfulness is to cultivate the ability to become aware of mind-wandering and learning to direct attention back to the present moment (Kabat-Zinn, 2003). Virtual reality facilitates attention regulation by reducing distractive stimuli and providing cues and anchors to implicitly direct attention toward the breath, the bodily senses as well as the present moment. In addition, VR holds attention with little effort due to the extraordinary and relaxing landscapes, or the use of features that maintain engagement (Seabrook et al., 2020).

- **Multisensory**: Mindfulness practices aim at sensory awareness training subjects to observe, recognize, and regulate sensory flow. Input/output devices, VR navigation devices, and visual, auditory, and haptic displays can enrich the experience. For instance, subjects can feel a warm breeze, intensifying sensory experience (Habak et al., 2021; Choo and May, 2014; Bruggeman and Wurster, 2018).

- **Distance learning mindfulness sessions**: Virtual reality allows people to get therapy from a distance. VR also protects privacy, as patients can use an avatar to stay anonymous. Psychologists and other professionals may offer instructions, observe users’ performance and make conversations with users. Furthermore, sessions might take place on an individual or group basis. Using cloud-based technology, sessions may be synced and managed in real-time (Cikajlo et al., 2017).

- **Gamification strategies**: Gamification strategies in virtual reality may be utilized to positively influence users’ behaviors and motivations during mindfulness practices. Games are useful for inducing a flow state, which can lead to mindfulness through relaxation, enhanced concentration, improved mood, reduced stress, and greater empathy (Cruea, 2020). For instance, games include the use of tasks, rules, goals, rewards, and badges that can motivate players, especially, children, for intensifying their effort to improve their performance (Kosunen et al., 2016, Choo et al., 2014).

- **Personalized data and real-time feedback**: Brain-computer interfaces (BCI’s) can increase mindfulness within virtual environments and helps achieve higher levels of concentration while entertaining the user. BCI’s 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). Several studies that apply virtual reality breathing training (pranayama) have found that respiratory biofeedback can facilitate the effectiveness of VR mindfulness breathing interventions (Michela et al., 2021).
3.4 Virtual Reality Mindfulness Interventions

Serra-Pla et al. (2016) designed and assessed the first VR mindfulness therapy for ADHD patients. In a preliminary trial, 25 patients enrolled in four 30-minute VR mindfulness sessions, while 25 others were treated with psychostimulants. The findings suggested that the experimental group experienced greater self-management skills.

Lunsky et al., 2022 developed a virtual group–based mindfulness intervention, adapted to the needs of autistic individuals, and assessed its feasibility. Thirty-seven autistic adults aged between 18 to 52 years took part in a six-week program. According to the qualitative feedback, participants reported that could better regulate anxiety, utilize coping strategies and make connections with other autistic adults. This study emphasizes the efficacy of synchronous mindfulness-based interventions for autistic adults, by demonstrating that they can be delivered virtually while retaining many of the in-person group aspects.

Cikajlo et al. (2017) investigated whether virtual reality (VR) could provide a fertile ground for group meditation-based stress and anxiety reduction therapy. They designed a cloud-based system, which offered a Web interface for the mindfulness coach and remote clients. Each participant joined the virtual mindfulness session through an avatar using a mobile phone and a basic head-mounted VR headset. The coach could give instructions over the Web interface with the participants utilizing the headset. The study recruited four employees and four participants with traumatic brain injury for 8 weeks in a Mindfulness-Based Stress Reduction course. The results showed that participants achieved better self-regulation of anxiety and attention. Therefore, they felt more self-satisfaction.

In a randomized controlled trial, Modrego-Alarcon et al. (2021) evaluated the effectiveness of a virtual reality mindfulness intervention on students’ ability to self-regulate their anxiety. A total of 280 participants were randomly assigned into three groups: VR mindfulness intervention, conventional mindfulness training and relaxation therapy. For six weeks, group sessions with 15 or 16 participants were held once a week for 90 to 75 minutes. According to the findings, VR mindfulness had a better impact on stress control, psychological flexibility, emotional balance, and academic engagement compared to the other two conditions.

In a case study, Nararro-Haro et al. (2016) explored the effectiveness of a VR mindfulness intervention in a 32-year-old female diagnosed with borderline personality disorder, a disease characterized by emotional fragility, aggression, and problematic interpersonal connections. To assist the patient concentrate her attention and practicing DBT® mindfulness skills, she was immersed in virtual reality and observed herself "floating down" a 3D computer-generated river while attending DBT® mindfulness training audios. The virtual reality mindfulness intervention helped the patient better regulate inclinations towards suicidal ideation, self-harm, abandonment therapy, abuse of drugs, and emotional distress. She was also more able to focus and transfer mindful skills such as observing, awareness, non-judgmental skills, and positive emotions in real life.

Chavez et al. (2020) intended to assess the feasibility of delivering virtual reality meditation and gathering outcome indicators like depression, anxiety, and physiologic stress (salivary cortisol). A sample of 30 depressed participants was divided into three conditions: (a) VR meditation, (b) audio meditation, or (c) virtual reality imagery. Anxiety levels dropped across all groups, with the virtual reality meditation group experiencing a greater reduction (difference=10.8) than the web-based meditation or virtual reality imagery groups (difference=5.8 and 5.0, respectively). Although self-reported anxiety was reduced in all groups, salivary cortisol levels did not decline.
Navarro-Haro et al. (2019) conducted a pilot study to examine the efficacy of VR mindfulness on self-regulation under extreme stress. An additional purpose was to assess the impact on depression, emotion management, mindfulness, and interoceptive awareness. 42 individuals with generalized anxiety disorder were randomly assigned to either mindfulness or mindfulness and 10 minutes of VR DBT® (Dialectical Behavior Therapy). The VR mindfulness intervention produced considerably improved effects in terms of anxiety and depression symptoms decreased, emotion control, mindfulness, and interoceptive awareness.

Mistry et al. (2020) evaluated the potential therapeutic application of virtual reality meditation in people with posttraumatic stress disorder (PTSD). In a within-group mixed-methods study, 96 young adults participated in both VR- and non-VR-guided meditations and reported on their affect, other meditative experiences, and perceived satisfaction-credibility of each meditation. Participants reported more positive affect.

Habak et al. (2021) conducted a pilot study to explore the impact of VR positive visualizations on mood regulation. A sample of 79 participants with depression took part in the study. The participants were immersed in extraordinary landscapes which induced a sense of relaxation. The results of the study showed the intervention helped subjects to improve emotional regulation and inhibitions of depressive symptoms.

Shiban et al. (2017) explored the effectiveness of VR mindfulness breathing on self-regulation in a sample of twenty-nine phobia patients. The participants received mindful breathing training either with or without virtual reality. The results indicated better outcomes for the VR relaxation breathing training.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Type of Disorder</th>
<th>Participants: number (n), mean age (M), VR Technology</th>
<th>Duration</th>
<th>Mindfulness Program</th>
<th>Type of measurement</th>
<th>Research Design</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serra-Pla et al.</td>
<td>2017</td>
<td>Attention Deficit Hyperactivity Disorder</td>
<td>n=55 VR goggles</td>
<td>Four 30-minute sessions</td>
<td>Mindfulness-Based Stress Reduction (MBSR) curriculum</td>
<td>Pre-treatment, post-treatment, and at 3- and 12-months post-treatment</td>
<td>Pilot study</td>
<td>Greater self-management skills</td>
</tr>
<tr>
<td>Lunsky et al.</td>
<td>2022</td>
<td>Autism Spectrum Disorder</td>
<td>n=37 18 to 52 Virtual meeting platforms</td>
<td>6 weeks, 60 min</td>
<td>Mindfulness-Based Stress Reduction</td>
<td>Participants complete pre, Feasibility study</td>
<td>Better regulation of stress, connected</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Year</td>
<td>Condition</td>
<td>Sample Size</td>
<td>Intervention</td>
<td>Duration</td>
<td>Outcome Measures</td>
<td>Design</td>
<td>Findings</td>
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<tr>
<td>Modrego-Alarcón et al.</td>
<td>2021</td>
<td>Anxiety</td>
<td>n=280</td>
<td>GEAR VR goggles</td>
<td>6 weeks, once a week, 90 min per session</td>
<td>Mindfulness-based program (MBP) for reducing stress</td>
<td>Multilevel mixed-effects models were performed to estimate the efficacy of the program</td>
<td>Randomized Controlled Study</td>
</tr>
<tr>
<td>Cikajlo et al.</td>
<td>2017</td>
<td>Anxiety</td>
<td>n=8 24-48 years M=9.37</td>
<td>3D VR headset s, 8 weeks, 30 min per session</td>
<td>Mindfulness-Based Stress Reduction</td>
<td>Scales of Mindful Attention Awareness, Satisfaction With Life, Mini-Mental State</td>
<td>Feasibility Study</td>
<td>Participants achieved higher levels of well-being, attention, and anxiety</td>
</tr>
<tr>
<td>Navarro et al.</td>
<td>2016</td>
<td>Borderline personality disorder</td>
<td>n=1, 32 years</td>
<td>Kaiser Electro-Optics VR goggles</td>
<td>4 sessions</td>
<td>DBT Mindfulness Skills training</td>
<td>Case study</td>
<td>Improved self-regulation, observation skills, emotional regulation</td>
</tr>
<tr>
<td>Chavez et al.</td>
<td>2020</td>
<td>Anxiety, Depression</td>
<td>n=30 18-24 years</td>
<td>Oculus Go headset</td>
<td>Single session</td>
<td>Guided meditation Brief survey, saliva samples, State-Trait</td>
<td>Pilot randomized controlled trial of</td>
<td>Anxiety regulation, no difference in cortisol levels</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Disorder/Disorder</td>
<td>Sample Size</td>
<td>Display Type</td>
<td>Sessions</td>
<td>Intervention</td>
<td>Scoring Tool</td>
<td>Study Type</td>
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<td>2019</td>
<td>Navarro et al.</td>
<td>Generalized Anxiety Disorder</td>
<td>n=42</td>
<td>Oculus Rift</td>
<td>6 sessions</td>
<td>DBT Mindfulness skills training</td>
<td>GAD-7 using mixed regression models</td>
<td>Pilot study</td>
</tr>
<tr>
<td>2020</td>
<td>Mistry et al.</td>
<td>Post-Traumatic Stress Disorder</td>
<td>n=96 M=24.02</td>
<td>Head Mounted Display</td>
<td>Single session</td>
<td>Guided meditation</td>
<td>Emotions Scale, Mixed-methods study</td>
<td>Pilot study</td>
</tr>
<tr>
<td>2021</td>
<td>Habak et al.</td>
<td>Depression</td>
<td>n=79 18 years and older</td>
<td>VR headset</td>
<td>3 sessions</td>
<td>Positive Visualizations</td>
<td>Mental Well-Being Scale, hopelessness self-report scale, Affect scales</td>
<td>Pilot study</td>
</tr>
<tr>
<td>2017</td>
<td>Shiban et al.</td>
<td>Depression, Phobia</td>
<td>n=29</td>
<td>Head Mounted Display</td>
<td>Single session</td>
<td>Mindful Breathing</td>
<td>Fear scales, Anxiety scale, heat and respiration rates, skin conductance</td>
<td>Pilot study</td>
</tr>
</tbody>
</table>

Table 2: Virtual reality mindfulness in metacognitive skills training for people with special needs: Summary of articles
Discussion & Conclusions

The purpose of the current review study was to investigate the effectiveness of mindfulness training strategies with and without virtual reality on metacognitive skills in people with learning disabilities, neurodevelopmental disorders, and other mental and behavioral problems.

In addition, we presented several traditional and innovative mindfulness training strategies, appropriate for metacognitive skills training in special education. Finally, we presented the features that possibly make virtual reality a fertile ground for the implementation of mindfulness training.

The results of the current review study revealed that mindfulness training can significantly help people with disabilities to develop metacognitive skills such as self-observation, self-regulation, and adaptation. Virtual reality mindfulness was shown to be an effective assistive tool for mindfulness interventions, especially for people with disabilities. Virtual reality, for instance, can help people who face difficulties with conventional mindfulness training due to attentional disorders, and low imagery skills. It can also help patients that avoid social interactions like people with autism.

Mindfulness interventions have increasingly been incorporated in elementary and high school classrooms to support students’ mental health and well-being (Carsley, Khoury, and Heath, 2018). This study gives pointers for the implementation of mindfulness strategies with conventional interventions as well as with VR-assisted mindfulness training as a means to help students with disabilities to improve various meta-skills and meta-abilities required to be inclusive in school, in the workplace in the social environment. According to Carsley et al., (2018) the success of school mindfulness interventions depends on the experience of trained educators/teachers. Thus, we conclude that teachers, parents, and caregivers should be trained too to apply these techniques in the classrooms. It is worth noting that mindfulness techniques can facilitate teaching processing when applied by teachers as means to improve their self-regulation skills and develop resilience strategies.

VR is no longer limited to costly laboratories. Numerous commercially accessible head-mounted displays (HMDs) have been developed, ranging from costly technologies such as the Oculus Rift and HTC Vive to low-cost technologies such as Google cardboard combined with a VR-compatible smartphone (Yildirim et al., 2020).

The use of VR-assisted mindfulness interventions in learning disabilities is still in its early stages. We conclude that there is a need for additional experimental research with randomized controlled trials. In addition, the use of additional measurements such as the physiological parameters (e.g., heart rate variability, hormones, oscillations), could provide trustworthy evidence. In addition, more research is needed to identify the effectiveness of virtual reality mindfulness in different settings such as in educational contexts, at home, or in the workplace. Another interesting topic concerns the VR mindfulness intervention not only at the individual level but also as a tool for group training.

Finally we underline that the incorporation of digital technologies in general and special education domains is very productive and successful, facilitates and improves the educational procedures via Mobiles [91-100], various ICTs applications [101-133], AI & STEM [134-145], and games [146-151]. Additionally the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [152-175] as well as with environmental factors and nutrition [87-90], accelerates and improves more over the educational practices and results.
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