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Cutting-Edge Technologies in Breathwork for Learning Disabilities in Special Education

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Abstract. The purpose of the current review study is to shed light on the relationship between breathing and learning disabilities, to investigate the efficacy of breathwork as an intervention strategy, and finally, to identify the role of assistive technologies in breathing training interventions. The results of this study revealed a close relationship between breathing problems and learning, mental or/and behavioral disorders. In addition, it was found that breath-control training can help people with various disorders to improve cognitive and metacognitive abilities, to better manage emotional and behavioral problems, and achieve better learning outcomes. Technologies such as robots, virtual reality, mobile apps, and digital games were found to assist breathing training in various ways fostering therapeutic outcomes. We conclude that breathing training should constitute not just an alternative method of intervention but an essential practice for prevention and intervention in daily life, in school settings, at home, and workplace. It is essential to train appropriate breathing habits as early as possible in young children because many of the damaging effects on cognitive functions by disordered breathing can have lasting consequences.

Keywords. Learning disabilities, breathing disorders, virtual reality, robotics, brain-computer interface, biofeedback, mobile apps, digital games, telehealth services, metacognition in breathing, academic achievement, cognitive and emotional regulation

1. Introduction

Respiration is the process by which air moves into and out of the lungs providing a pathway for gas exchange. Ventilation occurs automatically in a continuous rhythmic pattern without any conscious effort. It is modulated by both neural and chemical inputs and is associated with the homeostasis of oxygen and carbon dioxide as well as playing a role in the acid-base balance (Davies & Misra, 2014). Respiration has a vital role in human health since it participates in most physiological and neuropsychological processes as a pivotal factor (Drigas, Mitsea & Skianis, 2022).

Recent years have witnessed a significant increase in the occurrence and severity of breathing disorders. Li et al. (2020) found that the number of deaths from chronic lung diseases and related respiratory diseases rose sharply by 18% over the past three decades, from 3.3 million in 1990 to 3.9 million in 2017. For instance, in the USA, more than 25 million people

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have asthma (Bloom et al., 2012). Recent research reveals that breathing disorders may be the cause or just the precursor of severe disease. A growing number of studies indicate a close relationship between chronic breathing problems and mental disorders, depression, anxiety, or cognitive deficits (Singh et al., 2013; Kunic et al., 2005).

Common factors that affect breathing are the following: (a) anthropometric factors (weight, height, sex, and age), (b) physical parameters (circadian rhythms, chest diameter, trachea size), (c) social and healthcare considerations (workplace exposures). (d) environmental factors (air pollution, climatic conditions, natural disasters, altitude), (e) lifestyle (nutrition, level of physical activity, smoking, breathing habits), (f) diseases (diabetes, muscle or hormone disorders), (g) physical position, (h) genetic factors and even influencing factors occurring during childhood or pregnancy (Barroso, Martín, Romero & Ruiz, 2018).

The last decade has seen the emergence of literature documenting the effects and potential clinical benefits of breathing techniques, predominantly in disease states. However, the act of controlling one's breath to restore or enhance one's health has been practiced for thousands of years in Eastern and Western cultures. For example, yogic breathing (pranayama) is a well-known ancient practice of controlled breathing (Russo, Santarelli & O'Rourke, 2017).

Control of breathing implies modifications of the (a) rate of respiration, (b) depth of respiration, (c) rate or velocity of airflow, (d) timing (inspiratory and expiratory phase, duration, and pause), (e) the rhythm of respiration, and (f) primary area of movement (upper or lower chest, and abdomen). Either single or multiple modifications may be needed to get the desired effect on a case-to-case basis (Sankar & Das, 2018)

Technology has paved the way and provided an easy and accessible method for the treatment of various disorders and learning disabilities (Drigas et al., 2013-2022). Smartphones are increasingly seen as a versatile m-health instrument for treatment and training and some authors predict that the mobile phone will emerge as the preferred personal coach for the 21st century. Breathing training mobile apps are always available to support users anywhere and at any moment. There are several applications available specifically made for breathing training, whereas stress and anxiety management apps often include breathing exercises as well (Drigas & Mitsea & Skianis, 2022; Anagnostou & Drigas, 2022; Coulon et al., 2016). The cost is typically low, and it is relatively easy to find free apps. However, mobile apps for breathing training lack formal evaluation in the literature (Chittaro & Sioni, 2014; Morris & Guilak, 2009). Another novel approach is the "gamification" of mHealth apps engaging badges, leaderboards, points, levels, and challenges seem extremely promising, In addition, most applications use musical elements, which relax, motivate and facilitate the breathing experience (Pham et al., 2016, Theodorou & Drigas, 2017).

Virtual reality (VR) can be defined as an interactive 3D "imaginal system" that replaces a real-world environment with a virtual one. VR is different from other media because it induces a sense of presence, the feeling of being inside the virtual experience (Riva et al., 2016). VR technology has various applications in different areas of research (Lan, Li & Cheung, 2021). In digital mental health, various studies explore the effectiveness of VR in the context of biofeedback protocols (Rockstroh, Blum & Göritz, 2021). VR also utilize virtual avatars as training elements alternating users' perspective or creating a feeling of embodiment known as body ownership illusion (Czub and Kowal, 2019). In recent studies, virtual reality breathing-based biofeedback training adds engaging game-like action contexts (Michela et al., 2021).

Learning disabilities refer to a set of neurodevelopmental disorders with a biological origin that is the basis for abnormalities at a cognitive level associated with the behavioral signs of the disorders (American Psychiatric Association, 2013). Learning disorders includes a wide

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range of disorders that impact learning (Muktamath, Hegde & Chand, 2021): 1) physical disabilities, 2) sensory impairments, 3) moderate /severe cognitive disabilities, 4) autism, 5) learning disabilities, 6) attention deficit, 7) behavioral disorders, 8) Giftedness. People with disabilities very often face cognitive deficits in domains such as attention, perception, and memory, behavioral problems, mood disorders, and heavy anxiety. 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). It is noteworthy that recent studies reveal that learning disabilities are associated with disorders related to physiological processes such as (a) Autonomic Nervous System, (b) Hormonal and Endocrine system, (c) Immune System & Metabolism (Drigas & Mitsea, 2021; Stavridou, Driga & Drigas, 2021; Driga & Drigas, 2019).

Patients often claim that medication or existing interventions does not reduce the symptoms. In addition, the adverse effects worry patients and parents, who seek alternative strategies (Doulou & Drigas, 2022).

2. Methodology

The purpose of the current review study is to shed light on the relationship between breathing and learning disabilities, to investigate the efficacy of breathwork as an intervention strategy, and, finally, to identify the role of assistive technologies in breathing training intervention. The method used to write the article was the bibliographic review method. We searched articles through search engines: Google Scholar, Mendeley, PubMed, Scopus, Science Direct and ResearchGate. One of the limitations of the research is that there is a lack of large-scale experimental research studies assessing the effectiveness of breathing techniques in learning disabilities as well as similar studies focusing on the role of tech-assisted interventions.

Literature Review

The Influence of Dysfunctional Breathing Patterns on Learning Difficulties & Disorders Burden

The state of a child's airways and their breathing habits play a crucial role in raising healthy children. Respiratory health and breathing habits can influence either positively or negatively health, facial attractiveness, postural development, and most important cognitive function and development. Poor respiratory health, functional breathing disorders and inappropriate breathing habits are very often associated with chronic health problems creating a vicious cycle that increases the risk of the incidence of related disorders. Specifically, mouth breathing, breathing pattern disorders, and sleep-disordered breathing have detrimental consequences on cognitive abilities (Courtney, 2013).

Fensterseifer, Carpes, Weckx & Martha (2013) found that children when they habitual breathe through their mouths tend to develop easier learning difficulties rather than children with normal breathing. Growing numbers of studies show that people with Attention Deficit/Hyperactivity Disorder (ADHD) commonly face breathing problems such as sleep-disordered breathing (Sedky, Bennett & Carvalho, 2014). Many researchers recognize that there is a close relationship between breathing problems and ADHD, while others emphasize that breathing problems in early childhood (i.e sleep-disordered breathing due to enlarged adenoids) may predict later ADHD symptoms such as lack of attention and concentration, low school efficacy, speech problems, impaired eating, poor school performance, hyperactivity, irritability, anxiety and depression (Sedky et al., 2014; Vera et al., 2006; Marques, 2019; Courtney, 2013). Bonuck et al. (2012) examined more than 11.000 children from infancy to 7 years old and found

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that children with snoring, apnea and mouth breathing were 40% to 100% more likely to develop ADHD with severe behavioral problems. Breathing disorders are also associated with autistic-relating behavior in disorders such as Autism, Prader-Willi Syndrome,

Mental Retardation, Obsessive-CompulsiveBehavior, and conduct disorders (O'Donoghue et al. 2005). Other studies associate poor breathing with working memory deficits and consequently poor reading comprehension and mathematic skills (Kuroishi et al., 2014).

In this connection, it is important to highlight that these breathing problems may be due to factors such as allergies, poor immune system health, asthma, and upper respiratory tract infections. Another important point concerns the impact of breathing on the quality of sleep. Studies show that people with learning disabilities such as Dyslexia face greater sleep disturbances related to breathing problems (Carotenuto et al., 2016). The nose, for instance, plays a crucial role in keeping the immune defense system healthy, because it acts as a filter that takes part in the immune response against viruses, bacteria, and fungi releasing chemical substances that destroy pathogens while playing a role in functions such as oxygen transport, nerve conduction, even in memory and learning (Rappai, Collop, Kemp & deShazo, 2003). According to Zelano et al. (2016) nasal respiration is associated with better attention, memory and conscious perception than mouth breathing. On the contrary, during mouth breathing, the air passes into the lungs without purification, humidification and warming resulting in the growth of abnormal bacteria in the mouth, the throat even in the gut. In addition, mouth breathing results in lower levels of oxygen transport (Courtney, 2013; Lundberg et al., 1995).

It is important to stress that it is not only the breathing patterns that alter behavior but also anxiety, behavioral disturbances and negative emotional states that can bring breathing instability and other physiological alterations (Vidotto et al., 2018). Even cognitive load, when people carry out a mentally demanding task can lead to over-breathing (Grassman et al., 2016).

The physiological benefits of Correct & Conscious Breathing Training

Drigas & Mitsea (2022) investigated the physiological and neuropsychological benefits of conscious breathing training techniques. The results of their review showed that breathing training techniques help subjects to:

- Improve the functions of the Autonomic Nervous System by regulating the functions of sympathetic or parasympathetic activity. Breathing exercises can stimulate either the parasympathetic nervous system which is responsible for stress reduction and deep relaxation (Pal & Velkumary, 2004), or the sympathetic nervous system (Pal et al., 2014).
- Modify hormones as well as neurotransmitters that play a crucial role in cognitive abilities, behavior, and anxiety. For instance, studies show a reduction of the stress hormones (cortisol, ACTH, norepinephrine) and an increase in the antistress hormones (melatonin, GABA) (Martareli et al., 2011; Ma et al., 2017; Kox et al., 2014).
- Increase neurotrophic factors (BDNF) and growth factors, such as the VEGF which participate in a series of neurogenesis phenomena and determine whether the brain remains healthy or not (Helan et al., 2014; Malshe, 2011).
- Improving antioxidant defense status since breathing exercises reduce inflammatory markers, boost anti-inflammatory mediators and natural killer cells, lower free radicals, and therefore oxidative stress (Bhattacharya et al. 2002).

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The effectiveness of Breathwork in the treatment of Learning Disabilities

Intellectual Impairments

Wang et al. (2020) evaluated the therapeutic efficacy of a breathing training method known as intermittent oxygen therapy on mild cognitive impairments. Seven patients with cognitive impairments alternately breathed 10% O2 and room-air, every 5 minutes, for 8 cycles/session, 3 sessions/wk for 8 weeks. The patients' resting arterial pressures fell and cerebral tissue oxygenation increased following breathing training. Intermittent hypoxia training enhanced hypoxemia-induced cerebral vasodilation and improved mini-mental state examination and digit span scores. In addition, verbal learning test scores tended to increase. The researchers concluded that lower oxygen breathing exercises enhance cerebral oxygenation and hypoxia-induced cerebrovasodilation while improving short-term memory and attention in patients with cognitive impairment.

Laborde, Allen, Göhring & Dosseville (2017) examined the effect of slow-paced breathing in alleviating cognitive stress symptoms experienced by fourteen adolescents (Mage = 17.39 years, range 15–19 years) with intellectual disabilities during a cognitive task under time pressure. Participants took part in two conditions: a slow-paced breathing session (experimental condition) and an audiobook session as a calming strategy (control condition). Using heart rate variability (HRV) as stress management and cognitive performance indicator, vagal tone was measured. The participants in the experimental group followed a pacer regulating their inhalation and exhalation phases, with exhalation lasting slightly longer than inhalation. The results showed that vagal tone was significantly higher during the breathing training conditions compared to the control group. The authors concluded that regulating breathing at a specific pace (6 cycles per minute) during cognitive tasks reduces stress-related factors that degrade cognitive performance and helps adolescents with intellectual disabilities to develop stress regulation skills.

Pise, Pradhan & Gharote (2018) investigated the effects of 12 weeks of breathing training intervention along with yoga practices on the psychomotor abilities of intellectually disabled children. Seventy intellectually disabled children were divided into an experimental group and a control group. The breathing exercises for experimental group participants were Bhastrika, dirgha swasana, and Bhramari pranayama. The result revealed significant improvement in static balance, eye-hand coordination, agility, and reaction time in the experimental group compared to the control group.

Singh & Singh (2014) investigated whether 60 days of pranayama practice could benefit five mild intellectually impaired children of age ranges 7 - 10 years. The children were diagnosed also with autism, ADHD, and Down syndrome. The children practiced right and left nostril breathing. They have instructed the chanting "Omkar" by keeping their fingers on the closed eye-lids, "Omkar" was chanted by closing the ears with the palm. The results showed that breathing exercises had a positive impact on fine motor abilities (i.e. eye-hand coordination, hand-to-hand coordination), concentration, body awareness, and tolerance among children with intellectual impairments.

Attentional Disorders (ADHD/ADD)

In a randomised controlled pilot study, Kiselev (2020) investigated the effects of breathing training on attention in 6-7 years of age children with ADHD. 14 children with ADHD between 6 and 7 years of age were included and randomly assigned to training conditions

according to a 2×2 cross-over design. The researchers made a comparison between breathing training and conventional motor exercises. After a total of 36 training sessions lasting 30 minutes, the results revealed that breathing training has a positive effect on attention in 6-7 years age children with ADHD.

Huber et al. (2018) evaluated data collected from a total of 91,642 interviews and 73,123 children to support the hypothesis that means state altitude is a significant predictor of ADHD prevalence. In other words, they aimed to show that low oxygen breathing may reduce ADHD symptoms. Analysis of two large CDC datasets indicated that ADHD prevalence decreases with mean state altitude. The symptoms of ADHD may be ameliorated by hypoxic breathing which in turn modulates dopamine, an important hormone in ADHD.

Autism Spectrum Disorder

Scroggins, Litchke & Liu (2016) examined the effectiveness of breathing exercises on behavior in a male child with Asperger syndrome showing difficulties to follow directions, lack of emotions, irritability, shyness, and poor coordination. The researchers utilized breathing exercises such as lion's breath to promote calmness and focus along with repetitive rhythmic chants and clapping to increase vocalization and engagement. The results showed a positive impact on this young boy's behaviors related to physical, social, and emotional well-being.

Visual Impairments

Pradhan, Mohanty & Hankey (2018) assessed the effectiveness of Bhramari Pranayama and breath awareness on 19 students with visual impairments as an intervention strategy to train the attentional processes which seem to be underdeveloped. Bhramari Pranayama through long exhalation and short inhalation aims to slow breathing rhythms. The researchers utilized a modified Braille version of the six-letter cancellation test that measures sensory information processing from a wide visual field such as focused attention, psychomotor speed, and fine motor coordination. The results showed that both exercises had positive outcomes. However, bhramari Pranayama showed more positive effects on attentional performance.

Memory Deficits

Naveen, Nagendra & Telles (1997) evaluated the effects of uninostril breathing on the performance of verbal and spatial memory. One hundred school children *(*10 to 17 years) were randomly assigned to four breath training groups: (i) right nostril breathing, (ii) left nostril breathing, (iii) alternate nostril breathing, or (iv) breath awareness without manipulation of nostrils. After ten days, it was revealed that participants in breathing training groups improved spatial memory skills.

Garg, Malhotra, Tripathi & Agarawal (2016) explored the effects of left, right, and alternate nostril breathing on verbal and spatial memory. Fifty-one subjects were divided into three groups following one type of nostril breathing exercise for a week, for 45 minutes daily. Results showed that there was an improvement to both verbal and spatial memory. Specifically, it was found an increase in recall of digit span-forward, digit-span backward, associate learning and spatial memory scores with all the three types of yoga breathing practices.

Joshi and Telles (2008) evaluated the effects of right and left nostril breathing on verbal and spatial memory, considered hemisphere specific. Forty-five participants were randomly divided into three groups (right nostril yoga breathing, left nostril yoga breathing, or breath awareness as a control intervention). Results revealed better spatial memory scores after left nostril yoga breathing. Hence, breathing through the left nostril increased performance in a

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spatial cognitive task, corresponding to the cerebral hemisphere contralateral to the patent nostril.

Language Disorders

Marshall, Basilakos, Williams & Love-Myers (2014) explored whether a 10-week unilateral nostril breathing program could improve among others language skills in a sample of post-stroke patients with brain damage, some of which with aphasia (n=6). Aphasia refers to a language disorder related to difficulties in language expression or comprehension. The results indicated a significant improvement in performance on language measures for individuals with aphasia. Specifically, it was found improvements in lexical retrieval, phrase length, reading, and listening comprehension. The authors observed better attention and memory as well as reduced anxiety and better emotional regulation, and this has led them to the conclusion that breathing exercises improve several physiological and neuropsychological factors which in turn boost language processing. They also proposed breathing training as an effective adjunct treatment strategy to use with traditional speech-language therapy.

Tasan, Mede & Sadeghi (2021) investigated the impact of pranayama breathing (PB) on the reduction of language anxiety of students, on listening and reading comprehension skills as well as on learners' and their instructor's perceptions of using these techniques in their classrooms. 140 students were divided into two groups, the experimental and the control group. The breathing techniques implemented in the experimental group for 7 days were Nadi Shodhana Pranayama and Bhramari Pranayama. The results showed that the implementation of breathing techniques reduced language anxiety and improved listening and reading comprehension skills. Teachers and students characterized breathing training as a useful and practical medium for alleviating anxious feelings, promoting the general class atmosphere, and regulating daily habits.

Anxiety, Panic Disorders & Depression

Hamilton-West, Pellatt-Higgins & Sharief (2019) evaluated the therapeutic options of a Sudarshan Kriya Yoga-based breath intervention on people with mild-to-moderate depression and anxiety disorders. In a total of 991 participants, it was found to statistically significant improvement in depression and anxiety.

Divya, Bharathi, Somya and Darshan (2021) examined the effectiveness of Sudarshan Kriya Yoga, a controlled cyclic rhythmic breathing technique, on the reduction of symptoms of depression, and anxiety. Ninety-two subjects participated in a 4-day online breath workshop. The results indicated that breathing training reduced anxiety and depression, while participants reported an increased feeling of resilience, self-satisfaction, and better quality of sleep.

Sharma et al. (2017) conducted a randomized pilot study to evaluate a breathing-based meditation intervention for 25 patients with major depressive disorder following inadequate response to antidepressant treatment. Breathing exercises through the slow, medium, and fast rhythmic breathing cycles brought subjects into a deep, restful state. The results showed that, after two months, breathing exercises helped to alleviate severe depression in participants who did not fully respond to antidepressant treatment.

Tiwari et al. (2019) assessed the feasibility and efficacy of 12 weeks of breathing training intervention (*Pranayama*) in nine patients with treatment-resistant generalized anxiety disorder. The results showed a significant reduction in anxiety and depression symptoms. The researchers also observed a reduction in errors to negative stimuli in the antisaccade task

suggesting an improvement in attention control during the intervention accompanying the reduction in symptoms.

Nemati (2013) investigate the effect of doing *pranayama* on test anxiety and test performance. 107 students were randomly assigned to the control and experimental groups and the experimental group practiced pranayama for one full semester. Before starting the regular classes, the teacher asked the students to breathe deeply and easily, hold their breath and slow exhale. The teachers used also positive visualizations. They were also asked to chant positive mantras such as, 'I can, I can do, I am successful, and I am the best in the world'. After the intervention, 67% of the participants experienced lower levels of anxiety. Test anxiety and test performance showed that the students of the experimental group had significantly lower mean test anxiety scores and higher test performance.

In a randomized controlled trial design, Novaes et al. (2020) explored the impact of a 4-week *Bhastrika pranayama* training program on emotion processing, anxiety, and affect using a sample of 30 participants. The results showed that *pranayama* significantly decreased states of anxiety and negative affect. Furthermore, the functional magnetic resonance imaging showed a modulation in the activity as well as the connectivity of brain regions involved in emotional regulation, attention, and awareness and particularly the amygdala, anterior cingulate, anterior insula, and prefrontal cortex.

The efficacy of Assistive Technologies in Breathing Training

Biofeedback App-Based Breathing Interventions

Faust-Christmann et al. (2019) developed and assessed a biofeedback app, the *Breath Mentor*, as a tool to instruct abdominal breathing. Among the benefits of the app is that it combines visualization of the instructions with biofeedback, based on the mobile phone's accelerometers. In this study, biofeedback refers to the feedback about the abdomen during a breathing task. A total of 40 untrained participants took part in a pilot study. The results showed immediate effects on relaxation levels.

Plans et al. (2019) investigated whether commercial biofeedback mobile apps, known as BioBase, could augment post-stress physiological recovery. A total of 75 participants completed a stressor speech task and were randomly assigned to one of three conditions: control, rumination, or an app-based relaxation breathing conditions. The BioBase program provided coaching to the users through Papworth breathing exercises, both audibly and visually. Papworth breathing focuses on diaphragmatic breathing to use the full lung capacity and slow down breathing as well as trigger vagus nerve stimulation and consequently, the relaxation response**.** Heart rate variability (HRV) was assessed as a measure of autonomic function at baseline (6 min), during stress (6 min), and during recovery (6 min). The results revealed a significant reduction in anxiety symptoms.

Chelidoni et al., (2020) conducted a randomized experiment to assess the efficacy of a biofeedback breathing app in the physiological recovery of 75 employees who were induced by cognitive and emotional stress. Heart Rate Variability (HRV) changes were measured. The participants in the breathing condition performed a 5-min guided diaphragmatic breathing exercise including attention on breathing, usage of the full lung capacity, and decrease of breathing rate. The results showed that there was a significant difference between the app-based intervention group demonstrating higher HRV compared with the control group.

Azam, Latman & Katz (2019) conducted a two-arm randomized controlled trial to evaluate the efficacy of a 12-minute smartphone-based mindful breathing task on heart rate variability for students with clinically relevant chronic pain, depression, and anxiety. In the

Technium Social Sciences Journal
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study 60 participants with chronic pain, anxiety and depression were randomly assigned by a 1:1 ratio to a Mindfulness Meditation App condition or Mindfulness Meditation condition without the app. In the mindfulness meditation app group, the participants practiced mindful breathing with a smartphone. HRV and respiration data were measured and the participants completed psychological self-report inventories before and after the stress induction and after the meditation condition. The authors concluded that breathing apps could be beneficial for psychiatric conditions developing self-management skills for patients with depression.

Biofeedback Gameful Breathing Apps

Sonne and Jensen (2016) evaluated the feasibility of *ChillFish*, a breath-controlled biofeedback game designed in collaboration with ADHD professionals, which combines breathing exercises and game design. In a pilot study, 16 adults played ChillFish intending to train beneficial breathing patterns. Indeed, the intervention had a positive effect, helping the participants to keep their attention active and reach a relaxed state similar to the one offered by traditional breathing exercises.

Zafar et al. (2018) discussed the design, implementation, and assessment of three respiratory biofeedback games *(Pacman Zen, Dodging Stress* & *Chill Out)*. Specifically, they examined whether players of these games can multitask to learn paced breathing while simultaneously playing a challenging game and whether they can utilize this skill in a subsequent stressful activity. To achieve this objective, they compared breathing rates across 100 male participants (23 years ± 3.2 years) playing biofeedback and audio pacing versions of these games as well as a paced breathing app. Their results indicated that biofeedback contributed to better breath control during play as well as during the subsequent cognitively stressful task. In addition, biofeedback led to a better attentional-cognitive performance in the subsequent task. The multi-game experiments demonstrated that using respiratory biofeedback in video games is an efficient strategy to learn paced breathing, to self-regulate stress levels and be adaptive.

Virtual reality

Yüksel et al. (2020) evaluated the efficacy of virtual reality slow breathing in anxiety and sleep disorders in high-school adolescents. Twenty-nine 16-18-year-old adolescents with (N=9, 6 girls) and without (N=20, 11 girls) sleep difficulties were engaged in slow diaphragmatic breathing whilst passively experiencing a relaxation immersive VR environment, designed to promote cognitive relaxation/distraction (20min). The VR breathing intervention resulted in a significant immediate increase in perceived relaxation and reduced worry. Heart rate dropped and sleep efficiency increased. The authors outlined the potential for combining cognitive relaxation/distraction strategies, using immersive VR technology and physiological downregulation, to promote relaxation and improve overall sleep quality in adolescents with relevant difficulties.

Virtual Reality Biofeedback Video Games

Weerdmeester et al. (2021) conducted a pilot study with 86, children, to evaluate the efficacy of a virtual reality biofeedback video game that offers deep breathing training in an immersive and relaxing environment without explicit tasks and goals. It also aimed at embodied, intuitive, and exploratory learning. Another major innovation was the mild exposure to stressful situations (i.e., dark caves) as a means of enhancing self-regulation skills in case of phobias. The results of the study showed improvements in internal control and engagement

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which demonstrates heightened levels of attention. In a similar study, Van Rooij et al. (2016) found better awareness of the states of breathing, more conscious attention to breathing, and more effective regulation of attention.

Michela et al. (2021) presented a virtual reality breathing-based biofeedback training in which participants performed deep and slow diaphragmatic breathing in an engaging game-like action context. Nine subjects participated in a total of ten sessions for four weeks. The VR game aimed to train response inhibition (shooting accuracy) in high arousal situations. Biofeedback is aimed at maintaining a slow breathing pace. The slower and deeper the breathing, the less constrained peripheral vision became facilitating accurate responses. The results revealed better voluntary attention to breathing control, physiological awareness, and positive arousal in an active decision-making context. VR breathing training helped subjects to gain attentional control in prefrontal regions in high arousal and stressful situations.

Virtual Reality Breathing Training through Avatars

Czub and Kowal (2019) examined whether breathing training in a virtual environment with the aid of an avatar could help people to improve interoceptive attention as well as the ability to adjust respiratory rate. Participants observed a virtual breathing avatar body from the first-person perspective while their own respiratory was recorded. The avatar showed the user a correct breathing pattern for 60 seconds and afterward participants had to imitate regulating their respiratory rate. Then, participants had to synchronize respiration with the visual cues derived from the avatar. The results showed that the virtual avatar entrained participants' respiratory rates helping them to better sustain attention to the avatar's breath while at the same time they could better be aware of and adapt their breathing patterns.

Lan, Li and Cheung (2021) evaluated a slow-breathing training system based on virtual reality with multimodal feedback to motivate users' engagement in a regular practice of breathing control. In this system, a realistic human model of the trainee (virtual avatar) was provided to mirror their actions. It was revealed that the trainees could more effectively regulate their breathing to achieve a slower and more stable breathing rate. The results of the Stroop task also showed less mind wandering, a better allocation of attentional resources, greater focus along better and more accurate reaction times.

Breathing Training during Virtual Reality Exposure Therapy

Shiban et al. (2017) investigated the effect of diaphragmatic breathing as a relaxation technique during VR exposure treatment. Twenty-nine patients with phobia were randomly assigned to VR exposure treatment either with or without diaphragmatic breathing (six cycles per minute). The group that experienced VR exposure combined with diaphragmatic breathing showed a higher tendency to effectively overcome the fear.

Robot-assisted Breathing Training

Støre et al. (2021) investigated whether a robot-assisted breathing intervention could reduce hyperarousal which is a common cause for various disorders such as insomnia, anxiety, depression, and learning difficulties (Drigas & Mitsea, 2021). The Somnox sleep robot looks like a bean-shaped cushion to hug, and it gives physical and auditive guidance to calm down the users' breathing. In a randomized waitlist-controlled trial the researchers recruited 44 adults with insomnia and sleep-disturbing arousal. According to the researchers, the Somnox sleep robot could be a promising tool for breathing training for therapeutic purposes. In addition, it is

Technium Social Sciences Journal
Vol. 34, 136-157, August, 2022
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an attractive alternative for those people with severe neurodevelopmental or neurodegenerative disorders.

Asadi, Niebuhr, Jørgensen & Fischer (2022) investigated whether holding a soft robot can help participants synchronize their breathing rhythm with the robot. Twenty-eight participants engaged with the robot, which either was inflated and deflated, thus simulating breathing, or remained inactive. During the experiment, data were collected through two breathing belts and an EEG device. The findings showed higher arousal associated with positive emotional valence for participants in the breathing robot condition compared to the control condition. The participants in the experimental condition breathed more deeply and regularly and blinked fewer times, a finding that suggests lower stress levels.

Discussion & Conclusions

The incorporation of digital technologies in various aspects of education domain including mental training and breathing training is very productive, successful and facilitates and improves the educational procedures via Mobiles [88-97], various ICTs applications [98-130], AI & STEM [131-141], and games [142-147]. Additionally, the combination of ICTs with theories and models of metacognition, mindfulness, meditation, and emotional intelligence cultivation [148-171] as well as with environmental factors and nutrition [84-87], accelerates and improves more over the educational practices and results.

More specifically the purpose of the current review study was to shed light on the relationship between breathing and learning disabilities, to investigate the efficacy of breathwork as an intervention strategy and, finally, to highlight the role of assistive technologies in breathing training intervention.

The results of the current review study revealed that there is a close relationship between disrupted breathing and learning, mental or/and behavioral disorders. Specifically, there is significant evidence that people with breathing problems risk developing cognitive deficits such as attentional disorders, mild cognitive impairments, and memory problems. The same applies to behavior. People with incorrect breathing patterns tend to develop symptoms of heavy stress and depression. And vice versa, people with learning disabilities and heavy stress show abnormal respiratory patterns, specifically related to over-breathing.

Breath control training interventions were found to be very beneficial for a wide range of disorders. Specifically, breathing exercises improved fundamental cognitive abilities such as attention, working memory, and perception. The experimental research showed a significant reduction of symptoms related to emotional and behavioral disturbances. Less anxiety, reduced depressive symptoms, and fewer panic crisis were observed. Most important, breathing training helped subjects to gain awareness about the role of breathing in mental health, the way breath works, and, most importantly, voluntary control of breath as a means of self-regulation.

It is crucial to point out that not all breathing exercises are suitable for everyone. Contrarily, a key conclusion of the current research is that the type of exercise is the one that ensures successful outcomes. We create the groundwork for a fruitful intervention by identifying the proper parameters following the disorder in which we are requested to intervene. These variables relate to the oxygen-to-carbon dioxide ratio, rhythmicity, intensity, and speed. For instance, slow-pace breathing exercises can help people with autism and anxiety to relax. Low oxygen breathing exercises can help people to improve mild cognitive impairments and attentional disorders. Although it seems contradictory, as the brain has the highest metabolic rate and oxygen demands, low oxygen breathing exercises not only prevent neurodegenerative disorders related to cognitive declines but also augment cognitive functions, including attention

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and short-term memory. Nostril breathing and especially left nostril breathing may help people to improve visuospatial memory.

Finally, we found that edge technologies like Virtual Reality, Robots, Mobile Apps, Digital Games, and BCIs foster breathing training and open new pathways in the treatment of learning and other disabilities.

We conclude that breathing training should constitute not just an alternative method of intervention but an essential practice for prevention and intervention in daily life, in school settings, at home, and workplace. Breathing training can be brief at a low cost. Furthermore, it is essential to train appropriate breathing habits as early as possible in young children because many of the damaging effects on cognitive functions by disordered breathing can have lasting consequences.

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