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The role of mobile applications in managing everyday stress through breathing

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Abstract

The purpose of this paper is to investigate the role of mobile health applications as tools for managing or coping with stress. The research was conducted by searching a variety of databases, including Google Scholar, ResearchGate, and JMIR Mhealth Uhealth Publications.

Keywords: Stress; Stress Management Techniques; Breathing; Mobile Health Applications; MHealth (mobile health)

1. Introduction

In the age of modern technology and the fast pace of life, stress has become a common phenomenon, with significant impacts on the health and well-being of individuals. The need for effective stress management strategies is more urgent than ever, as chronic stress can lead to a range of mental and physical disorders, undermining individuals' quality of life. In this context, mobile health applications have emerged as an important tool in the fight against stress, offering an accessible and user-friendly solution for monitoring and managing stress.

This paper explores the role of mobile health applications as tools for managing and coping with stress. In the first part, we will examine stress and its effects on health, as well as the existing stress management techniques. Next, we will analyze the role of mobile applications in people's daily lives and how they can contribute to stress management. We will also present different categories of mobile applications that have been developed for this purpose, examining their advantages and limitations. Finally, we will propose various improvements and directions for future research, to increase the effectiveness of these applications in practice. While stress management is an ongoing challenge, technological advances offer new opportunities for effective coping strategies.

This work, therefore, aims to contribute to a deeper understanding of how modern technology can be effectively integrated into the fight against stress, offering an important tool for improving mental and physical well-being. With scientific rigor and practical application as its main axes, the work strives to bridge the gap between theory and practice in stress management through mobile applications.

2. Stress and its Effects on Health

2.1. Conceptual Clarification and Definitions

Stress is one of the most frequently mentioned concepts in the field of psychology and pathology, as well as in everyday human life [1]. However, despite the widespread use of the term, there is difficulty in finding a commonly accepted definition, as this concept does not represent the same phenomenon for everyone, but varies depending on the human organism and the conditions under which it is found [2]. The first attempt to clarify the term was made by Hans Selye, according to whom, stress is a "non-specific response of the body to any demand for change" [1], [3]. In recent decades,

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the concept of stress has evolved significantly. However, the current concept of stress is due to the pioneering contributions of Claude Bernard, Walter B. Cannon, and Hans Selye [4].

The term stress was first used in a bio-medical context in 1914 [5] by Walter B. Cannon [6]. The American physiologist Walter Cannon (1932) coined the term "homeostasis" to describe the theory of the organism's "internal environment" (milieu interieur) introduced by Claude Bernard. According to Bernard "The constancy of the internal environment is the condition for a free and independent life". Therefore, for the survival of the organism, it is necessary to adapt the milieu interieur to the constantly changing external environmental conditions [3].

Cannon, based on Bernard's theory, argued that the state of dynamic balance in the organism is ensured by the successful coordination of the body's functions [3]. In addition, he introduced the term "fight or flight". When an external condition threatens the balance of the organism, the "fight or flight" mechanism is activated. This term describes the physiological response of animals that increases their chances of survival in emergencies that cause pain, fear, or anger. During the "fight or flight" response, the body is stimulated by the activation of both the sympathetic nervous system and the endocrine system. This stimulation helps to prepare the individual to fight off the stressor [3], [4], [7].

Hans Selye was the first scientist to characterize these changes in the physiology of the individual to maintain homeostasis as "stress" [3].

Hans Selye, known as the "father of stress", began his research on stress as a sophomore medical student at the University of Prague [8] [9] [10]. He observed how many of the symptoms of chronically ill patients resembled the body's responses to exposure to a stressor. These clinical observations, in combination with his laboratory experiments on rats, laid the foundation for the concept of the "General Adaptation Syndrome" (GAS) introduced by Selye. Although the GAS hypothesis was proven wrong, it was the starting point for a worldwide focus on research on the concept of stress [8].

A few years later, in 1984, Richard Lazarus and his colleagues formulated a definition that played a significant role in the development of stress theory. According to Lazarus and Folkman (1984), stress is " a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being". To put it differently, stress is a mental or physical phenomenon that is formed through the cognitive appraisal of the stimulus and is the result of the interaction of the individual with the environment [1]. Stress is a process that occurs when an event related to an individual's well-being can cause harm or loss and requires psychological, physiological, and/or behavioral efforts to manage it and its consequences [11].

Today, the term stress represents an individual's experiences in which the environmental demands of a situation exceed their perceived, psychological, and physiological ability to cope effectively with it. An important distinction in the study of stress is the differentiation between the exposure of the organism to a stressor and its response to it [2]. The presence of stress depends on the presence of the stressor, i.e., the stimuli or events that cause stress [11]. Feng (1992) and Volpe (2000) defined the stressor as anything that challenges an individual's adaptability or stimulates their body or psyche [1]. Stressors, such as job loss or divorce, have the potential to alter or disrupt an individual's typical psychological functioning. The cognitive, emotional, and biological reactions of the human organism in response to stressors are called stress responses [2] and are a compensatory process aimed at restoring homeostasis [4].

In closing, according to Alexopoulou, Batsou and Drigas (2020), "stress is defined as the body's response to any strong, mental or emotional stimulus, of internal or external origin. It occurs whenever an individual faces a situation, on an emotional or physical level, that exceeds their ability to cope with it. Stress is stagnant and creates restlessness that leads to physical and psychological discomfort" [12], [13].

2.2. Stress and the Brain

The survival of the human organism depends on the maintenance of homeostasis, that is, the ability to constantly adapt to the changing conditions of the internal and external environment. In the presence of a stressor, to maintain homeostasis, adaptive homeostatic systems of the organism are activated. In order to cope with the stressor, a series of changes occur in the body, such as the release of hormones and the activation of the central and autonomic nervous system [14]. The stress response system plays an important role in coordinating this process [15].

The stress response system is a complex and multi-level adaptive mechanism to changing internal and external environmental stressors [5]. The initial detection and processing of potential threats or stressors that the individual receives from their environment is carried out by the amygdala. The prefrontal cortex assesses the magnitude of the

threat and adjusts the activity of the amygdala accordingly. This role is very important in preventing the continuous activation of the stress response. In response to a perceived stressor, the amygdala initiates the activation of the stress response mechanism [16].

In more detail, when an individual is faced with a stressor, two basic systems are activated: the sympathetic adrenal system and the hypothalamic-pituitary-adrenal (HPA) axis [14], [15]. The sympathetic adrenal system is responsible for the immediate and rapid response to the stressor. Its activation results in the release of norepinephrine and adrenaline from the adrenal medulla. Adrenaline is rapidly transported through the bloodstream to prepare the rest of the body and put it on alert, the so-called "fight or flight" response. This process is known as the sympathetic adrenal system (SAS) response [14], [17].

A few minutes after the SAS response, the HPA axis is activated. Specifically, the hypothalamus releases a hormone called corticotropin-releasing hormone (CRH). This process activates the synthesis and release of adrenocorticotropic hormone (ACTH) in the pituitary gland and its release into the bloodstream. ACTH travels to the adrenal glands where it triggers the synthesis and release of a hormone called cortisol from the adrenal cortex. The release of cortisol, also known as the stress hormone, causes a series of changes that help the body respond to stress, mainly through the activation of energy stores that are stored in the muscles and liver [5], [17].

2.3. Types of Stress

The initial conceptualization of stress was pioneered by Hans Selye in 1976. Selye and his, from the beginning of their research introduced the terms eustress and distress to distinguish between positive and negative forms of stress based on the body's adaptive responses [8].

Specifically, he used the term eustress to refer to the positive stress that individuals experience when faced with a new but desirable challenge [7], [19]. Positive stress refers to all the small challenges encountered daily by individuals while taking a risk [9]. These challenges contribute to the individual's development, as they make them stronger, more resilient, and enhance their ability to confront future challenges effectively [18]. The outcome of these challenges is usually positive and creates a sense of reward for the individual. However, even a negative outcome can be considered a developmental experience for individuals with characteristics such as decision-making ability, self-esteem, and impulse control. Desired stress motivates and mobilizes individuals to face this new challenge. The individual tends to feel positive stress when they feel confident about a task they are called upon to perform and believe they are adequate to complete it [19], [20].

The term "distress", meaning bad stress, refers to the discomfort that an individual feels when they are unable to cope with a stressor [20]. In contrast to eustress, distress has negative effects on the individual, characterized by chronic and repetitive stress that, according to the term introduced by Selye, leads to "exhaustion" [8]. During distress, the individual experiences negative emotions and serious unpleasant physiological changes at a physical level, such as psychosomatic symptoms [19].

In addition to the above classification, stress is also categorized into other types. Specifically, depending on the duration and intensity of the stressor, stress is divided into chronic or acute stress [21]. Acute stress is short-lived but intense, while chronic stress is long-lived but less intense. At the same time, depending on the time at which the individual experiences the stressor, stress is classified as situational stress and post-traumatic stress. In situational stress, the emotional intensity disappears after the removal of the stressor. On the contrary, in post-traumatic stress, the emotional intensity does not manifest during exposure to the stressor, but rather emerges within 24 hours thereafter, persisting over an extended period [10].

2.4. Factors Causing Stress

Stress is inevitable in an individual's life, as they face situations that cause them to stress daily [10]. Bernstein et al. (2008) defined the sources of stress as any event in the internal or external environment that threatens to disrupt the organism's balance, affecting an individual's physical and psychological functioning. These sources are called stressors [22]. According to a plethora of authors and researchers, stressors can be classified into different categories depending on the severity and duration of the stressful event [23].

One of the commonly accepted classifications of stressors is environmental and psychosocial stressors. Environmental stressors refer to natural disasters, such as earthquakes and floods, that occur suddenly and unexpectedly. At the same time, this category also includes all kinds of accidents, caused by human activities, such as car and industrial accidents. Psychosocial stressors are an extensive group of factors that are related to the individual's interaction with the

environment and the psychological consequences of this interaction. They are associated with critical changes in the individual's life, such as divorce, change of work environment, immigration, illness, or loss of a loved one [23].

Lazarus and his colleagues identified three distinct types of stressors, which differ in their duration and intensity. These types include "major cataclysmic changes," which affect a large number of people, "major changes," which affect a few or one person, and "daily hassles." "Major cataclysmic changes" are global events, such as war and natural disasters, which vary in duration depending on their nature. However, the psychological disruption can last for a long time regardless of the magnitude of the disaster. "Major changes," such as the loss of a loved one, a long-term illness, or job loss, can cause long-term stress reactions at both the psychological and physiological levels. "Daily hassles" refer to all the stressful events that occur in an individual's daily life, such as being late for an appointment and disagreements with a loved one [22].

Similarly, Wills and Shiffman (1985) have classified three types of stressors according to their impact and duration. The first is called "significant life events," which are acute but relatively short-lived, such as an illness, transition to a new educational environment, or the death of a loved one. The second type is "everyday life problems," such as the hassle of dealing with crowds on a bus, waiting in line, or arguing with a store employee. The third type is "chronic life strain" which refers to the long-term pressures associated with role performance, such as that of a student or adolescent [1].

Epel et al. classified stressors according to their time duration into "acute stressors," "daily hassles," "life events," and "chronic stressors." "Acute stressors" are of limited duration but intense, such as the stress that occurs when engaging in a dangerous sport or during a medical procedure. They usually have a specific duration of just a few minutes or hours. Daily hassles are relatively minor stressors that recur frequently. However, they can develop into chronic stressors if the threat that causes the stress occurs regularly. "Life events" are short-term events with a specific onset such as a divorce, a car accident, or a medical diagnosis. They can have long-term consequences and, if maintained, become chronic stressors. Chronic stressors are long-term in duration, ranging from weeks to months, such as financial instability, neighborhood safety concerns, or chronic illnesses [22].

Finally, Pereira (1997) categorized the sources of stress into four main areas, personal problems, such as anxiety, loneliness, suicide, shyness, and family problems, academic problems, which include lack of motivation, exam stress, withdrawal, and dropout, lectures and stress caused by other students, financial problems, such as financial and housing problems, and finally safety problems, which include sexual assault, violence at school social events, bullying, drugs and alcohol [1].

The complexity of stressors is evident in the various classifications devised by researchers of the concept of stress. Stress can arise from external situations and internal factors, affecting an individual's physical and psychological state. Categories such as environmental, psychosocial, economic, and personal stressors each exert distinct impacts on individuals. Recognizing these sources is crucial for effective stress management and enhancing overall quality of life and well-being.

2.5. Symptoms of Stress (Mental and Physical)

The individual's response to stress differs depending on their personality and experiences [1]. These responses occur before, during, or after the individual is exposed to a stressor. As research has shown, exposure to stressors can have negative consequences for both the individual's mental and physical health. Physical symptoms are associated with the activation of the autonomic nervous system and include immune, autonomic, and neuroendocrine responses, as well as neural changes related to exposure to stressors [2]. Psychological reactions derives from the individual's interpretation of stressors and include specific emotions triggered by the stressor, along with efforts to regulate these emotions [3]. At the same time, stress can also lead to behavioral changes, such as smoking, as the individual's response to cope with the negative emotions they experience [10], [2].

In further elaboration, on a psychological level, stress adversely impacts an individual's mood, often resulting in heightened fatigue, intense emotional reactions such as crying, and potential depression [14]. Those experiencing stress may also endure intense anxiety, discomfort, and prolonged stress, with severe and long-term cases potentially leading to suicidal tendencies. Furthermore, stress can significantly affect an individual's professional and academic pursuits, leading to decreased interest, difficulties with concentration, and reduced productivity [1].

Stress manifests physically in a variety of ways. Common physical reactions include physical pain, such as headaches, chest pain and stomach discomfort, a constant feeling of fatigue and weakness, cold extremities, "butterflies in the stomach," and increased heart rate. At the same time, the physical symptoms also include nervous habits like nail biting

and teeth clenching [1]. Stress is responsible for the appearance or exacerbation of certain diseases such as allergies, arthritis, multiple sclerosis, rheumatoid arthritis, vitiligo, and others [10], [7], as it reduces the ability of the immune system to fight off viruses and bacteria that enter the body [22]. Furthermore, stress is directly associated with cardiovascular problems such as high blood pressure, increased blood clotting, tachycardia, hypertension, atherosclerosis, coronary heart disease, and in severe cases can even lead to heart attack or stroke [10], [7]. Chronic stress is also associated with diseases of other systems, such as the digestive system. Such diseases are gastric ulcers, irritable bowel syndrome, gastritis, and others [10]. Additionally, stress is closely linked to sleep disorders such as insomnia and increases the risk of developing asthma, chronic pain, cancer, and HIV/AIDS [22].

Stress can also negatively affect people's behavior. It often leads to irritability, anger outbursts, nervousness, and a loss of self-control. Individuals frequently experiencing stress may encounter communication difficulties, social withdrawal, and isolation. Additionally, during stressful periods, individuals may adopt unhealthy behaviors such as consuming unhealthy foods, using alcohol and drugs, and starting smoking, which can lead to health problems and increase the risk of developing cancer [1]. Finally, stress can cause changes in appetite, concentration issues, memory disorders, and increased forgetfulness [10].

In conclusion, it is clear that stress can significantly affect all aspects of an individual's health, both physically and psychologically, and can have serious consequences, such as illness and unwanted behaviors. Therefore, it is deemed necessary to reduce and effectively manage the stressors that the individual comes into contact with daily. Stress can be managed through various techniques, such as breathing exercises, relaxation techniques, and proper nutrition. Thus, with effective stress management, individual can significantly improve their quality of life and protect their health.

2.6. Stress Management Techniques

The literature is replete with stress management techniques, most of which share certain stages such as practicing self-awareness, as well as concentrating one ones body and emotions. The techniques seem to be most effective when performed in an actively conscious manner.

The term mindfulness refers to the practice of conscious awareness of the individual’s mental, emotional and physical reactions to events happening to them and around them. It focuses on the monitoring of how the individual experiences those events and what the physical and mental (thoughts, feelings) reactions to them are, while at the same time not passing any judgment on them (positive or negative) [24]. To this end, the individual uses conscious breathing techniques with the aim to enhance their perception of the changes occuring, increase and enhance their focus, improve their perception skills and control how their mind and body reacts to the changes [25], [27]. According to [24] conscious breathing helps regulate the autonomous nervous system, focus the mind and increase self-awareness. Programs such as the one developed by Jon Kabat-Zinn at the Massachusetts University School of Medicine, use verbal guidance by the instructor and have been shown to have positive results.

Most of the techniques seem to consist of three basic stages: (a) relaxation of the body through breathing and the gradual release of muscular tension, (b) the use of stimuli such as images and sounds that evoke relaxing/peaceful feelings and calmness, and (c) returning to reality, to the "here and now", all the while knowing that it is possible to mentally return to the positive experience formed during the conscious breathing practice when needed.

There are many such techniques. Meditation, aims to focus the attention on non-analytical thinking, avoiding dialectical thinking, and maintaining a relaxed body position to achieve both mental and physical calm. The Self-Learning Technique, uses recorded instructions and repeated phrases to lead the practitioner to the relaxation of their body. The technique is composed of a series of six exercises, each one of which focuses on a different part of the body. Combined with positive phrases they lead to the achievement of deep physical calm [27]. Progressive Muscle Relaxation (PMR) focuses on controlling sixteen different muscle groups (with each muscle group tightening on inhalation and relaxing on exhalation) with the guidance of the instructor. This technique was identified by Jacobson and further developed by Wolpe Bernstein and Borkovec then combined the technique with behavioural therapy techniques and observed a reduction in stressful induced health conditions such as headaches and insomnia [28], [29].

There are also various techniques, called Interpersonal therapies, which have been shown to improve the individual's communication with others. Because the differences between them are subtle, it is important that they are performed under the guidance of an experienced professional (usually a psychologist) [30]. Cognitive behavioral therapy (CBT) focuses on replacing negative patterns of thought and behavior [30]. Its evolution, PRISM, aims to develop skills through sessions that focus on 'benefit finding' and 'cognitive restructuring'. In contrast, Behavioral Therapy aims to modify behaviors, while third-wave therapy focuses on the individual's relationship with thoughts and emotions.

Another technique is Hypnosis, which depending on the specific issue and condition of the patient, can be performed either in a clinical or a private setting. In the case of a private setting it is called self-hypnosis. In clinical hypnosis, the hypnotist uses suggested scripts to guide the individual through their internal experiences, whereas in self-hypnosis, the individual is more in control of the process, focusing on self-awareness and phenomenological control of the experience [31].

A more modern therapy technique, called Biofeedback, requires specialized equipment to measure physiological responses such as brain function, heart function, muscle activity and skin temperature. The doctor analyzes the data reformulates it to help the patient change their way of thinking and control these parameters without needing to use equipment. Some of these parameters can be measured with a smartwatch, avoiding the need for complex stationary equipment, but the need for educational and expert guidance remains.

Yoga is another method used in modern therapy. It uses a series of techniques linked with physical activity and has various forms, which range from mild to intense. During the exercises, emphasis is placed on controlling the breath and maintaining mindfulness. Studies have shown that yoga improves brain and neurotransmitter function and is associated with the reduction of symptoms of depression and inflammation caused by stressors [32].

Additionally, the playing of games has emerged, since Freud as well as psychodynamic psychotherapy, as an important therapeutic mechanism. Since the 1980s, it has been used as a key stress management technique for children. Nowadays, participation in creative play activities is seen as a therapeutic mechanism in itself. It is combined with education, biofeedback, behavioral therapy and exercise, integrating many different techniques in mobile applications [33].

All the above techniques are methods that can help the individual increase their awareness as well as provide increased control of the physical and mental processes associated with stress. Controlled breathing is an integral part of the majority of the above-mentioned methods. From muscle relaxation and mindfulness to yoga and biofeedback, controlled breathing plays an important role in every case. It should, therefore, be clasified as a separate technique in its own right [34].

Multiple variants of controlled breathing techniques have been identified through the literature, each producing different psychophysiological effects. For example, Deep slow breathing improves autonomic functions by increasing parasympathetic activity and re-synaptic activity, in particular by improving atrial tone, thus decreasing the heart rate and blood pressure [35]. Other variants include Paced breathing, Coherent or Resonant breathing, Resistance breathing, etc. [33]. These techniques affect the amygdala through complex neural pathways, enhancing attention, emotion regulation, and body awareness. [24].

2.6.1. The benefits of slow breathing and its associations with stress

Breathing is an essential function for life. During inhalation, air travels through a series of respiratory pathways until it reaches the alveoli, where the exchange of gasses with the bloodstream occurs, transporting oxygen into the bloodstream and carbon dioxide out of it. During the process, it enhances the energy metabolism and regulates the amount of carbon dioxide in the body, which helps maintain the acid-base balance. This regulation is automatic and occurs through chemical sensors in the arteries and brain that respond to carbon dioxide, and pH. [36].

Breathing can be split into metabolic and behavioral breathing. The brainstem controls metabolic breathing while the cerebral motor cortex controls voluntary behavioral breathing. Emotional responses to events are generated by multiple control networks, mainly in the forebrain. The role of a respiratory rhythm generator in the generation of emotional responses in the limbic system has also been investigated for decades. The relationship between the olfactory rhythm of breathing and emotion is considered key to understanding the relationship between breathing and emotion, and so voluntary control of breathing is considered essential for achieving emotional well-being [37]. Forms of breathing that change according to the emotional state we want to maintain, are also included in the behavioral breathing category. For example, in humans, the rate and intensity of breathing changes with various emotions, such as joy, anger, fear, and anxiety [37]. Therefore, regulating and controlling the breath when paired with awareness and mindfulness could be the ultimate "stress management technique", as it allows the individual to control and reduce the stress response, before it manifests strongly enough to be visible.

A multitude of studies have established a solid link between neurophysiological parameters and psychological/behavioral outcomes. One of them identified increased activity in many areas of the brain related to the increased blood oxygenation levels while breathing at a rate of 10 breaths/minute compared to the base level of 5.5 breaths/minute. [38]

Slow breathing practices have spread throughout the world because of their purported health benefits. This has sparked the interest of researchers and clinicians conducting research on their physiological and psychological effects. An aggregated table was created to document the effects of slow breathing on the body.

Table 1 The effects of slow breathing

Respiratory	Generally coincides with increased tidal volume and may enhance diaphragmatic excursion Enhances ventilation efficiency and arterial oxygenation *via* alveolar recruitment, and distension and reduction of alveolar dead space [39] Moderates chemoreflex sensitivity [40]
Cardiovascular	Increases venous return → increases filling of the right heart → increases stroke volume → increases cardiac output [41] Causes blood pressure pulse fluctuations to synchronise with heart beat rhythm [42] Synchronisation of vasomotion [43] Increases HRV and blood pressure fluctuations [44]
Cardiorespiratory	Augments LF HRV and baroreflex sensitivity [41] Increases RSA (maximises around 6 breaths per min (resonant frequency)) [41] Improves pulmonary gas exchange efficiency, minimises cardiac work, buffers blood pressure fluctuations [43] Clustering of heartbeats within inspiratory phase (cardiorespiratory coupling) [43] Synchronisation of pulse harmonics of blood flow and heart rhythm [42]
Autonomic nervous system	Increases vagal activity (vagal tone) Shift towards parasympathetic dominance [45] Augments vagal power (entrainment of cardiac resetting by vagus to respiration phases) [46] Enhances phasic modulation of sympathetic activity [46] Improves autonomic responsiveness to physical perturbations (*i.e.* standing) [47]

3. The Role of Mobile Apps in Daily Life

As an introduction we underline the fact that exploitation of digital technologies and epistemology in the enhancement of education [89-95] has accelerated the structural, transformation, both educational substructures and procedures, in one hand, as well as the ability of the educators, on the other hand, to assess and intervene in various students' cases, like learning disabilities, stress, attention disorders etc. [78-88]

Mobile devices – including phones and tablets – are the most widespread digital technology in the world. [48]. Over the past two decades, smartphones have become ubiquitous in personal, social, and professional life, regardless of gender, race and ethnicity, and socioeconomic status. According to research conducted in the United States, by 2022, 96% of adults own a mobile phone and 81% own a smartphone, checking it on average 150 times a day. [49]. It is also observed that even children under the age of 8 are increasing their time on mobile devices, with this time tripling since 2011. [48]. In this context, the number of mobile phone users was expected to reach 1.6 billion worldwide by 2020. [50]. This rapid expansion of mobile technology is impressive compared to the declining trends in desktop and laptop ownership, which fell to 73 percent in the latest Pew Research Center survey. [48].

Considering that 50-78% of individuals with mental health issues do not receive adequate treatment in Europe and the United States, particularly in middle- and low-income countries, the expansion of digital technology through mobile phones and apps emerges as a promising means for mental health interventions, bringing to the forefront the innovative field of mHealth (mobile health). [50], [51]. The definition of mHealth refers to supporting health, including mental health, through mobile technologies, while the concept of the "digitally engaged patient" is presented as the ability of people to manage their health through such technologies. Apps, websites, and text message health interventions are being widely developed, and according to the World Health Organization, they are defined as mental health services supported by mobile devices. [52], [53]. Mental health apps, therefore, are software programs accessible via a smartphone or mobile device and are used to provide a range of guided or self-help intervention strategies, provide information on mental health, and enable real-time communication with health professionals. [54].

With more than 75% of adults in the United States reporting significant stress and 19% facing mental disorders, psychosocial interventions through mHealth technology seem to be gaining increasing popularity. [49]. A survey in Australia revealed that 76% of people would use mobile phone apps to monitor and self-manage their mental health, highlighting the high demand for mHealth apps due to their convenience and accessibility. [55]. The number of health apps globally increased from 1.7 to 4.1 billion from 2013 to 2018. Mobile health apps focus on emotional health and managing anxiety and stress. Regarding anxiety management apps, it appears that more than 90% of the population in developed countries uses such apps daily. Once made available to the target audience, due to the widespread use of smartphones, such tools can attract many downloads from around the world. This potential is illustrated by tens of thousands of downloads of such apps. [49], [52], [56].

Due to the fact that mobile phone users have access anywhere and anytime, these apps can be utilized to provide valuable information on mental health issues such as stress. [51], [57]. The apps can empower individuals suffering from stress who cannot afford to seek treatment or are too busy, as most apps can be accessed for free and everywhere, without financial or geographical constraints, offering low-cost solutions. Indeed, in this context, an observational study highlights the advantages of providing anxiety management interventions via an app, such as more frequent use and access to more content. [49], [56], [58], [59].

In the same context, mobile health apps (mHealth apps) have opened a new paradigm in patient care and disease management and are increasingly being used to support interventions for physical and mental health. The interventions are based on a necessity in many cases, as many individuals lost regular, in-person access to medical care providers. Notably, amid COVID-19, overall smartphone usage increased by 70% globally, and telehealth visits have increased by over 50% since March 2020. The conditions imposed by the pandemic have made the role of mHealth apps more significant in healthcare. [60].

At the same time, mobile health apps are often used to complement traditional therapeutic methods, improving accessibility to treatment. Specifically, they can offer 24-hour availability, easier access and data entry, additional information to users, monitor human activity, and display daily progress, providing feedback, including visual and auditory feedback. They also enable integration with a wide range of technologies and functionalities, such as virtual reality, augmented reality, telemedicine, robotics, games, sensor-connected interfaces, social networks, real-time interactivity, geolocation, and more. [49], [51], [52]. Additionally, they can be used anonymously, which is appealing to those who fear stigmatization, and provide an affordable way to deliver mental health services, especially in hard-to-reach areas. Finally, mHealth apps allow for the use of gamification aspects that can potentially increase user motivation. As mobile phone technology develops rapidly, resulting in frequent app updates and consequently changing capabilities and functionalities, user-friendliness is optimized. [50], [57], [59].

Many apps have been developed to record, modernize, and promote mental well-being and manage stress. Mental health journals, for example, that are available for download provide a digital experience with new techniques, such as touch screens, volume buttons, and monitoring notifications. However, using a phone in public is more socially acceptable than filling out a printed form, allowing monitoring to be completed discreetly in real-time, unlike forms that are often filled out retrospectively, resulting in the recording of less accurate data. [55].

Considering that anxiety disorders affect up to 30% of people worldwide, leading to significant social and economic burden, there is a crucial need to enhance the provision of mental health support. [49]. As a result of the high demand for mental health support and inadequate supply, there has been a rapid increase in investments in the mental health and wellness space. This has led to an increase in the number of such apps available on the market. About half of these apps focus on specific health conditions, of which nearly half are based on mental health, diabetes, and cardiovascular problems. In conclusion, mHealth technology is a growing phenomenon. In 2021, the global mHealth market was valued at USD 50.7 billion and is expected to expand at an annual growth rate of 11% from 2022 to 2030. [53], [54].

Following this direction, psychosocial interventions through mHealth technology offer accessibility without geographical or economic constraints. Stress management interventions via mobile phones have the potential to bring cost savings to the healthcare system if proven effective. [57].

3.1. Mobile Stress Management App Categories

The diversity of digital interventions can be found both on websites and mobile apps. However, the advantages of the latter category make it more effective for users. According to the research of Morrison et al. (2018), significant differences in use and effectiveness emerge between the two different digital interventions, the Healthy Paths website and the Healthy Mind app, which was modeled after the website. Initially, we observe that app users log in twice as often

as website users. This suggests a preference for the ease of access and immediate availability that the app offers to mobile phone users. It is likely that immediate access to content through the mobile phone encourages users to log in more frequently, as the app is more easily accessible from anywhere and at any time.

However, despite the frequency of logins, app users spent half the time on the intervention compared to website users. This suggests that app use is shorter and more focused, perhaps due to the nature of the mobile platform and the way content is presented. Simplifying navigation and encouraging regular use through notifications can lead to shorter but more frequent use. Overall, the analysis highlights the important role of mobile apps in stress management and psychosocial support. Ease of access, short duration of use, and comprehensive content delivery are critical factors contributing to the effectiveness of the intervention. [61]

The free mobile app Positive Technology, which aims at self-management of psychological stress, also falls within this framework. According to the research of Gaggioli, A. et al (2014), Positive Technology consists of the following three main components: a) Guided relaxation, b) Biofeedback, c) Self-report and stress monitoring. The results of this study show that the relaxation exercises performed with the app were effective in reducing stress, as indicated by the significant reduction in self-reported stress levels and the increase in positive scores after the relaxation session. Positive Technology is the first free mobile stress management platform available on the market, combining relaxation training, biofeedback and interactive 3D content. [62].

In addition to the research mentioned previously, the study by Coulon, M. S., Monroe, M. C., and West, D. S. (2016) conducted the first review to provide guidance on mobile stress management apps that can offer evidence-based stress management strategies. They recommended the Breath2Relax app, which is based on diaphragmatic breathing techniques. Diaphragmatic breathing has recently been shown to be cost-effective in reducing stress in the Department of Veterans Affairs. In fact, once at least 1,600 people used the app, it saved $1 million annually compared to standard care. [63]

Baker, D., and Rickard, N. (2018) examined the effectiveness of a mobile self-monitoring app, investigating the relationships between app engagement and mental health outcomes. They studied the MoodPrism app for iOS and Android, which is freely available in Australian app stores. MoodPrism is designed to help users track their mood over time and collect data from users about their emotional states over time in natural everyday settings. The results from this app were positive, as participants reported positive and engaging experiences and mental well-being using MoodPrism, as well as reductions in depression and anxiety. [51]

Based on a body of research, the effectiveness of the meditation app Headspace in improving mental health and well-being is undeniable. Headspace is a smartphone app that provides hundreds of hours of guided and unguided mindfulness meditations delivered by Andy Puddicombe, a former Theravada monk and fully ordained Tibetan Buddhist monk. However, despite the positive findings, researchers emphasize the need for further research. The consensus on the effectiveness of meditation training through apps remains unclear, and studies should consider any digital effects that may play a role in the results. Additionally, it is important to investigate the long-term effectiveness of these apps and their impact under more natural usage conditions. Nevertheless, the studies offered suggest that meditation apps can have a positive impact on the mental health and well-being of their users. [64]

Another popular self-help app is Pacifica.expand_more According to the study by Moberg et al. (2019), the app is effective in reducing symptoms of depression and anxiety, especially among individuals who track their thoughts and do not take psychiatric medications. Specifically, Pacifica is a mobile app that provides a guided self-help tool for managing stress, anxiety, and depression.expand_more It is not considered a treatment for a specific diagnosis or a substitute for professional therapy. When using it, individuals select up to three goals from a list of eight options. The app prompts users to rate their mood once a day and, based on this rating, suggests activities to improve mood through suggested activities. The results of the study showed that this intervention is effective after one month of use, as users reported reductions in symptoms of depression, anxiety, and stress, and increased feelings of self-efficacy. Additionally, the benefits of treatment were maintained for two months after the end of the one-month intervention period, especially for anxiety symptoms. These results are particularly significant according to the researchers given the light nature of the study, the limited duration of the intervention period, and the small sample of individuals. [65]

Flowy is the first mHealth app that teaches users breathing exercises in a game format [66], [67]. The company Playlab London designed Flowy based on the idea that gamification can significantly enhance user interaction with the app and therefore improve its effectiveness in improving health [67], [68]. Flowy consists of a series of minigames that utilize diaphragmatic breathing exercises to relieve stress and help users manage situations such as panic attacks and hyperventilation [69]. The themes of the minigames range from navigating a boat down a river to sending balloons into

the sky. Users touch the screen with their finger as they inhale and remove it from the screen as they exhale [67]. By default, the game sets six breaths per minute, but users can adjust this setting [66]. A "breathing indicator" appears on the screen in the form of a circle that visualizes the user's breaths, expanding when they inhale and contracting when they exhale. This provides the user with a guideline for the breathing exercise to follow. The goal of each minigame is for the user to follow the breathing indicator as the game's narrative progresses. Users progress to the next level when they are able to take correct breaths and remain calm. Flowy also includes an in-game interactive tutorial on how to perform diaphragmatic breathing correctly [67].

In terms of the app's effectiveness, Pham et al. conducted a randomized trial with a sample of 63 individuals. The intervention group (n = 31) received free access to Flowy for 4 weeks, while the control group (n = 32) was placed on a waitlist for 4 weeks before being offered free access to Flowy. The results of the study showed that Flowy can significantly reduce the stress experienced by individuals, improving their quality of life. Users rated Flowy as a fun, useful, and easy-to-use app [67], [69], [70].'

Smiling Mind is a free mobile app designed by psychologists and educators that offers a wide variety of guided and unguided meditation practices for different age groups (16-18 years old, adults, etc.). The app provides a variety of themes, such as meditation in the classroom, in the workplace, and more. Each meditation session varies in length from one minute to 45 minutes [64], [68].

Flett et al. conducted a randomized trial to examine whether mobile meditation apps can actually improve an individual's mental health. One of the three apps they used in their study was Smiling Mind. Participants (n = 208, ages 18-49) were asked to use the app for 10 minutes each day for 10 days. After 10 days, users were given access to the app for 30 days to continue practicing at their own discretion. The results of the study showed that regular use of the app can improve an individual's mental health. Specifically, the measures showed a reduction in stress and symptoms of depression and an increase in an individual's resilience [64], [71], [72].

In addition to Mood Prism, two other MHapps are MoodKit and MoodMission. MoodKit and MoodMission are apps designed to manage depression, anxiety, and stress based on cognitive behavioral therapy. Both apps provide personalized goals based on the user's mood and emotional state analysis, from which the user chooses to work towards [68].

In more detail, in MoodMission, the user enters their current emotional state and the app provides them with a list of five different activities called "Missions" from which to choose. The MoodKit app contains a large collection of activities and a journal, which encourages users to track their mood and thoughts to cope with stress [73].

Backer et al. studied the effectiveness of these apps on individuals' mental health through a randomized trial. Participants (n=226) completed a baseline assessment, downloaded the MHapp they were assigned, and completed a second assessment 30 days later. At the end of the study, participants reported feeling an improvement in their mental health, while one group reported a reduction in symptoms of depression [73], [74], [75].

Happify: For Stress and Worry is another app that aims to improve an individual's well-being and reduce stress and anxiety. The goal of the app is to help users improve their overall well-being and boost their mood using activities based on the principles of positive psychology, cognitive behavioral therapy, and mindfulness. Users earn points and rewards by completing happiness activities [74].

Parks et al. conducted a study to investigate the effects of using the app on people with or without chronic conditions. They collected data from 821 app users who used the app for at least six weeks. The data from the study support the conclusion that users with chronic conditions showed significant improvement over time. Despite having lower overall well-being at the beginning of the study than those without chronic conditions, their progress was equivalent. Additionally, users who completed more activities for a longer period of time showed the greatest improvement. In short, the presence of a chronic condition did not prevent users from improving their well-being using Happify [71].

Insight Timer is a mobile app designed to help people who feel overwhelmed by reducing their sense of mental fatigue. The app has a number of positive features, including being free to use, allowing users to track their progress, having a built-in timer, and having an interactive community for users. Insight Timer also includes sleep stories, music, and over 30,000 guided meditations. Finally, there is the option to purchase specific mindfulness training courses.

O'Donnell et al. conducted a randomized controlled trial to investigate the effect of daily use of Insight Timer on reducing stress in participants during the COVID-19 pandemic. Participants in the intervention group were asked to use the app

for 30 days, 10 minutes per day. After this period, they were asked to complete a questionnaire. Then, two months after the end of the intervention, they were asked to complete a second questionnaire. The control group completed the same questionnaires as the intervention group, however, they were not given access to the app during the first month of the study, and after 30 days, participants were asked to use the Insight Timer app if they wished. The results of the study showed that using the app can reduce stress and improve user well-being [76].

Foqus is a smartwatch app that aims to help adults with attention deficits improve their focus and reduce stress through timed and haptic cues that help them regulate their breathing [70]. Foqus chooses meditation as a mental health tool because of the benefits it offers. Users can adjust the duration of the inhale/exhale cycle for deeper meditation. Foqus has the ability to calculate and evaluate the user's heart rate [77]. Through this feature, the user is presented with their average heart rate before and after completing a session as an objective measure of its effectiveness. This immediate feedback on the quality of the session, combined with the visualization of progress and the encouraging comments provided to the user, helps to improve their motivation and effort. To evaluate the usability of Foqus, a functional prototype was developed on the Samsung Gear 2 smartwatch. Ten participants with attention deficits were asked to perform breathing exercises for 7 days. 80% reported reduced stress levels after each meditation session [70].

3.2. Limitations and Suggestions for Improvement

As discussed, stress and anxiety apps hold great promise and offer clear clinical benefits, both as standalone interventions and as adjuncts to therapy. Indeed, a majority of research highlights the potential of mobile apps as effective platforms to enhance therapy and improve mental health interventions among individuals [51], [52]. However, beyond the opportunities presented by the use of technology in the field of mental health, it is crucial to consider the challenges that arise, making this area a subject of further research.

One of the primary concerns surrounding mental health apps is their reliability and effectiveness. While many studies have focused on the feasibility and acceptability of these apps, there is a lack of rigorous research that examines their actual effectiveness, often with small sample sizes. Traditional evaluation designs, which can be time-consuming to complete, may be too restrictive for app developers who prioritize rapid commercialization [52]. This pressure for immediate monetization may incentivize developers to bypass thorough evaluation processes, potentially compromising the quality and efficacy of their apps.

According to the literature, mental health apps are becoming increasingly profitable businesses. A typical example is the case of the Calm exercise application. Although Calm was recently valued at $1 billion, the lack of clinical trials or evaluations confirming its benefits on mental well-being make it an essentially unreliable app. Despite this lack of scientific evidence, however, Apple and Google have expressed support for the Calm app, raising the risk that it will become necessary for the general public. So while there are studies demonstrating the benefits of mental health-oriented technology, there has yet to be an evaluation of Calm's benefits compared to other scientifically validated apps. This suggests the need for further research and scientific verification of the reliability and benefits of Calm as well as other similar applications [55], [57].

On the contrary, interest was also raised by the presence of scientifically validated applications whose validation studies were only a few weeks old. Headspace has recorded an impressive number of downloads, highlighting the popularity of mobile wellbeing apps. Unlike other apps like Calm, Headspace has published research findings supporting its ability to reduce stress, increase the user's positive emotions, reduce aggression as well as improve concentration. However, many of these studies were small-scale and had limited follow-up of subjects. In fact, in some cases the follow-up period was only thirty days. In conclusion, the lack of follow-up after the initial studies, combined with the short duration of some studies, raises concerns about whether the positive results may be applicable only during the initial period of use of the application. Therefore, despite the encouraging findings, further research is needed to confirm and extend these results. It is therefore necessary to develop advanced classifications that will allow the comparison of stress management applications and interventions. [55], [57].

Also, according to the literature, future studies should focus on high users of mental health apps, especially youth and young adults. Despite the popularity of the apps, we do not yet have concrete information about their effectiveness and actual use with these subgroups of people. [52].

The challenges faced by users, health professionals and researchers in the field of mental health applications are therefore diverse. Mediocre information quality and a rare trust base are significant problems, while limitations in data privacy and security features, as well as high application volatility, are additional challenges. Despite these issues, the researchers point to the apps' scalability and potential to help a wide audience, although they have few results regarding

their effectiveness. For the above reasons, more evidence-based approaches to the design and promotion of these digital mental health interventions are needed, as well as strengthened evaluation frameworks to ensure their reliability and effectiveness. [49], [56]

4. Conclusions

In the context of this work, the concept of stress, the techniques for its management, as well as the role of mobile health applications in managing and dealing with the phenomenon were thoroughly examined. From the above analysis, important conclusions emerge which are summarized as follows:

The evolution of the concept of stress from the original theories of Selye, Bernard, and Cannon to today, highlights the complexity and multi-layered nature of stress as an adaptive mechanism to changes in the internal and external environment. Various stress management techniques, focusing on mindfulness, muscle relaxation, yoga, and biofeedback, emphasize the central importance of breathing in effective stress management.

The role of mobile health applications in daily life and mental health support is essential, with the global m-health market expected to expand significantly in the coming years. Apps like Calm, Pacifica, Smiling Mind, Moodprism, and Flowy show the potential of technology in supporting people with anxiety disorders and improving mental well-being.

Nevertheless, the limitations and challenges associated with information quality, data security, and application reliability call for a more science-based approach and the development of enhanced evaluation frameworks.

In conclusion, this work demonstrates the need for further research and development in the field of mobile health applications, with the aim of improving the quality, reliability, and effectiveness of available digital interventions for stress management, thus contributing to the improvement of mental health. and physical well-being of the population.

Compliance with ethical standards

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The Authors proclaim no conflict of interest.

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