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Effectiveness of a Low-Impact Digital Therapeutic on the Negative Psychological Effects Caused by the COVID-19 Pandemic: Savoring and Virtual Reality for Promoting Emotional and Psychological Well-Being

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INTRODUCTION

The COVID-19 pandemic has had a significant impact on mental and physical health globally. Indeed, measures taken to counter this coronavirus, such as social distancing, lockdowns and suspension of daily activities, have had profound effects on mental health, causing an increase in disorders such as anxiety, depression, stress and loneliness. In particular, specific populations have been negatively affected, such as emerging adults, who are engaged in major life transitions, and patients with chronic diseases, who are already physically and emotionally vulnerable.

In this context, it is necessary to develop innovative and accessible interventions to promote emotional and psychological well-being as suggested by the Mental Health Continuum Model, taking advantage of the potential offered by digital technologies. Among these, digital therapeutics (DTx) and virtual reality (VR) offer promising solutions. Indeed, DTx can be considered a valuable option because of their low environmental impact and their ability to reach various populations and age groups remotely, while VR offers several opportunities to enhance mental health by fostering relaxation, positive emotions and personal change. At the same time, positive emotions have been shown to be effective tools in promoting well-being as highlighted by the literature and in line with the perspective of enhancing well-being emphasized by the Mental Health Continuum Model, and in particular savoring, that is the ability to voluntarily intensify and prolong positive emotions, represents a promising approach focused on mental health promotion that can also be delivered online.

This thesis therefore aims to integrate VR and savoring to develop innovative digital interventions that can improve emotional and psychological well-being and counteract the negative psychological effects caused by the pandemic. Specifically, this thesis is therefore divided into six chapters. In particular, **Chapter 1** provides a theoretical foundation, analyzing the negative psychological effects of the COVID-1 pandemic, especially in two particularly vulnerable populations, namely emerging adults and patients with chronic respiratory diseases, and the potential of DTx as an innovative digital solution to promote mental health. VR as a tool to promote emotional and psychological well-being is explored, and the potential of positive emotions and particularly their amplification through savoring is outlined.

Following this, Chapters 2, 3, 4 and 5 contain four studies that have been published or submitted to indexed scientific journals except for Chapter 5 that contains on ongoing study. Hence, these chapters follow the usual structure of research papers, including abstract, introduction, methods, results, and discussion. Specifically, **Chapter 2** presents a scoping review of the literature on the combined use of breathing techniques and VR to promote mental health. It explores how breathing, a compromised element during the pandemic and a central tool for relaxation and emotional regulation, was integrated into VR experiences and what effects it had on various psychological and physical outcomes. This scoping review identifies gaps in the literature and provides insights for the design of future interventions. **Chapter 3** describes an experimental study that developed and tested an online savoring intervention for emerging Italian adults, a population particularly affected by the pandemic. This chapter outlines the methodological principles and details of the intervention, laying the groundwork for the application of positive psychology techniques such as savoring through digital platforms.

Chapter 4 focuses on a pilot RCT integrating VR and savoring to improve the emotional and psychological well-being and respiratory outcomes of patients with chronic respiratory diseases, one of the categories most vulnerable to the effects of COVID-19, laying the foundation for the development of a DTx aimed at mental health. **Chapter 5** explores how virtual transformative experiences experienced through VR can influence the practice of savoring and well-being in Italian and Spanish young adults trying to achieve a greater understanding of how VR influences the amplification of positive emotions, especially in the post-pandemic period, while building the foundation for the development of a digital solution targeted at enhancing emerging adults' well-being. Lastly, **Chapter 6** summarizes the main findings of the thesis, highlighting their theoretical and practical implications. The strengths and limitations of the studies conducted are discussed, as well as outlining future directions. This thesis thus provides valuable new insights regarding the integration of VR, savoring and digital technologies to promote emotional and psychological well-being in the post-pandemic time period.

CHAPTER 1

Theoretical Background

1.1 The negative psychological effects of the COVID-19 pandemic

The Mental Health Continuum Model (MHCM) is a conceptual framework that views mental health as a continuum rather than a single state of sickness or well-being (Keyes, 2002, 2007). Specifically, the MHCM represents mental health as a continuum ranging from flourishing (optimal mental health) to languishing (poor mental health), and includes a variety of positive psychological functioning, such as emotional well-being, psychological well-being, and social well-being (Keyes, 2002, 2007). Consequently, this dual continuum approach allows for a more comprehensive assessment of the mental health status of individuals which is considered as a dynamic process. The MHCM also recognizes that people may experience different degrees of mental health and illness simultaneously and highlights that people may be in different positions along this continuum based on individual, environmental, and social factors (Westerhof & Keyes, 2009) and this was evident during the COVID-19 pandemic, which has had a profound negative impact on mental health across various populations. Indeed, in December 2019, a new coronavirus named SARS-CoV-2 (COVID-19) spread in Hubei, China. The spread of COVID-19 has caused a high level of mortality worldwide and has had a significant impact on the level of stress, fear, and anxiety experienced by people with respect to the possibility of infection (Brooks et al., 2020; Esakandari et al., 2020; Graziano et al., 2020). Indeed, people infected by this coronavirus initially reported symptoms related to the respiratory system (e.g., cough, breathlessness, chest pain, sore throat, and fever), and then symptoms related to the nervous, digestive and cardiovascular systems (Weng et al., 2021). For example, in the study conducted by Huang et al. (2020), patients with COVID-19 mainly exhibit fever (98%), cough (76%), and dyspnea (55%). In response to the growing number of cases and deaths, most countries have implemented measures to counter and contain the pandemic, including full and partial lockdowns, distance working and online education, and social distancing. These interventions, which have been unquestionably effective in slowing the spread of the virus and protecting physical health (Nussbaumer-Streit et al., 2020), have required significant changes in individuals' behavioral patterns. Indeed, the loss of normal routines, reduced activities, saturation of newspapers, televisions, and social media with negative information about the virus, and a severe economic downturn have threatened the mental health and well-being of individuals, causing a burden of mental conditions, including anxiety, depression, irritability, reduced sleep quality, and psychological distress (Asmundson & Taylor, 2020; Graziano et al., 2020). The first study in China on the impact of COVID-19 found elevated depression and anxiety in a sample of 1210 individuals: 17% reported moderate-to-severe depression and 29% moderate-to-severe anxiety (Wang et al., 2020). Similar increases in psychological distress have been documented worldwide (Graziano et al., 2020). For example, a meta-analysis was conducted by Wu et al. (2021) to investigate the prevalence of mental health problems linked with the pandemic all around the world and involved 221,970 participants. Results showed a prevalence of distress (41.1%), insomnia (37.9%), anxiety (31.9%), and depression (31.4%). Indeed, the COVID-19 pandemic has also deeply affected the mental health of the Italian population, which has been subject to social distancing for a substantial period of time (Remuzzi & Remuzzi, 2020; Landi et al., 2020). For example, a study of an Italian sample of 18,147 people found that 37% of participants experienced posttraumatic stress, while 23% reported high levels of anxiety, perceived stress, insomnia, and adjustment

disorders (Rossi et al., 2020). Another study, conducted by Fiorillo and colleagues (2020), involved 20,720 participants, and 12.4% of respondents reported severe or extremely severe levels of depressive symptoms, 17.6% reported anxiety symptoms, and 41.6% reported feeling moderately stressed. In addition, research conducted during the first week of COVID-19 dissemination in Italy by Pagnini and colleagues (2020) among a sample of 2886 people found that high levels of cognitive rigidity and emotional instability were associated with higher levels of pandemic-related concerns. Indeed, the COVID-19 pandemic challenged the psychological and emotional well-being of the general population (Robinson et al., 2022), although some age groups have been particularly affected by it. For instance, emerging adults (aged 18-30) are especially vulnerable because of the several changes in all life domains that they have to face, such as completing education, finding a job, reaching financial independence, and nurturing friendships and romantic relationships. These life changes are frequently connected with increased stress, anxiety, and mental health issues and, for these factors, emerging adults experienced worse mental health compared to other age groups during the COVID-19 pandemic (Varma et al., 2021; Graupensperger et al., 2022; Foster et al., 2023). Indeed, several studies found that emerging adults' mental health deteriorated over time, with increasing sadness, anxiety, negative affect, and loneliness, and decreasing psychological well-being following the pandemic (Kauhanen et al., 2023; Busetta et al., 2023).

Furthermore, older adults (aged 65 and over) were particularly negatively influenced by the pandemic. Indeed, older adults can also be considered vulnerable because of the challenges that have to face during this life stage, including the changes of roles and social status, the loss of autonomy, the loss of loved ones, and a consequent decrease of their social network (De Beni e Borella, 2015). Moreover, during the COVID-19 pandemic, they had a higher risk of developing severe and dangerous forms of COVID-19 compared to other age groups. In addition, social distance didn't allow them to see their relatives and friends, and they had to deal with several personal losses (Atzendorf & Gruber, 2021; Amelio et al., 2023). All these elements had a significant negative effect on older adults' psychological, emotional, and social well-being leading to an increase of depression and anxiety symptoms, and feelings of hopelessness and loneliness, especially on older adults with chronic diseases (Seckman, 2023; Amerio et al., 2023).

The COVID-19 pandemic has therefore shown how social and environmental factors can influence the mental health continuum suggesting that interventions need to be put in place to counteract the negative psychological effects caused by the pandemic (Zammitti, Imbrogliera, Russo, Zarbo, & Magnano, 2021) employing, as highlighted by the MHCM, a mental health promotion approach focused on enhancing well-being rather than simply treating illness (Keyes, 2002, 2007). This implies that interventions should be aimed at strengthening people's psychological and emotional resources that contribute to nurturing flourishing. In this context, digital therapeutics can be a valuable way to promote well-being especially for the more vulnerable age groups.

1.2 Digital therapeutics

According to the Digital Therapeutics Alliance (DTA), an organization that manages digital therapeutics (DTx), DTx represent a new frontier in digital health and refer to evidence-based medical or mental health

interventions that use software applications to diagnose, treat, manage, and/or prevent diseases (Fürstenau et al., 2023). They can be used alone or integrated with traditional therapies including drugs or other devices for several disorders including medical conditions such as neurological, cardiovascular, oncological, and endocrinological pathologies, and mental health conditions including depression, insomnia, panic disorder, substance abuse, and post-traumatic stress disorder (Recchia et al., 2020; Dang et al., 2020 ; Hong et al., 2021; Fürstenau et al., 2023; Lee et al., 2023 ; Phan et al., 2023). Furthermore, DTx can be based on different technologies, for example they are currently offered primarily through mobile or web applications, but also through virtual reality (VR), video-games, and artificial intelligence (AI) (Fürstenau et al., 2023; Phan et al., 2023). Particular DTx can also be utilized in conjunction with other hardware or medical equipment. For instance, biofeedback can be applied using a carbon dioxide gas analyzer in the Freespira mobile app for the management of panic attacks, or a digital inhaler with built-in sensors (ProAir Digihaler) can be used for patients with asthma or chronic obstructive respiratory disease (Fürstenau et al., 2023). Some DTx are linked to consumer devices such as smartwatches. Moreover, some DTx can be used in self-help mode, while others can require for example the online presence of a professional at some stages of the DTx fruition (Schultz et al., 2023). Furthermore, DTx are held to the similar clinical evaluation requirements as prescription medications or other medical devices, and their creation consists of several steps in order to test their effectiveness, safety and quality (Fürstenau et al., 2023). According to Lee et al. (2023), finding the target physical or mental health condition is the initial stage in creating a DTx. Once the target disease has been established, researchers should determine the target user's demands and make design-related deductions. When using “patient-centered design” techniques, which involve patients in the development process, it is essential to comprehend the patients' perspectives regarding the use of digital health products in order to incorporate what they require for creating the DTx (Birnbaum et al., 2015). The theoretical basis and available data supporting the intervention's design must also be identified. These provide the justification for choosing particular target diseases and behaviors, target users, and the techniques included. The application of the chosen methods and the selected techniques and tools marks the start of the second phase. This process should also take into account the intervention's delivery frequency, timing, and medium to use. Pilot studies on patients with the target disease should be carried out as part of an iterative development process to assess the feasibility and acceptability of DTx intervention and user participation (Lee et al., 2023). In order to minimize potential biases, randomized controlled trials can be used to test the effectiveness of DTx between treatment and control groups. The degree of disease prevention or treatment and the extent to which patient well-being and behaviors change are examples of endpoints that can be measured by the efficacy evaluation.

In this scenario, regulatory approval requires healthcare practitioners to prescribe DTx to patients, like pharmaceuticals, and they need to be first approved by regulatory organizations such as the American Food and Drug Administration (FDA) (Fürstenau et al., 2023). Specifically, while the FDA has had an active precertification program for DTx since 2017, there are no explicit regulatory requirements in place in Europe to ensure the safety and integrity of data collected. The European Medicines Agency (EMA) and the European Commission (EU) are now investigating DTx as a potential treatment option (Orsolini et al., 2024). At the

national level, the new German Digital Healthcare Act (DiGA), approved in November 2019 and enacted in January 2020, governs specific DTx usage requirements (i.e., quality, security, and data protection) and makes Germany the first country to allow reimbursement for DTx products (Dang et al., 2021). German insurance provides reimbursement within a 12-month time span for producers. German insurers guarantee reimbursement within a 12-month time frame during which manufacturers of the instruments (which must be approved at least as medical devices in order to be clinically safe) must provide evidence of clinical effectiveness from randomized controlled clinical trials. France is considering a similar act, and in the United Kingdom, the National Institute for Health and Care Excellence (NICE) established a working group under the National Health System (NHS) to assist regulatory boards in determining which types of evidence are most relevant to the assessment of DTx (Orsolini et al., 2024). In Italy, a parliamentary intergroup on digital health and digital therapies was created on the initiative with the task of defining a common regulatory direction for digital therapies, ensuring homogeneous access and reimbursability, both nationally and regionally, to digital health tools (Camera dei Deputati, 2024). This working group has filed a bill “Provisions on digital therapies” (No. 1028) in June 2023 to be considered by the Italian Parliament.

1.2.1 Examples of current DTx for enhancing mental health

The COVID-19 pandemic, as mentioned earlier, has had a negative impact on well-being by causing increased levels of depression, anxiety and insomnia and several other symptoms in both patients with prior illnesses and the general population. Thus, the pandemic has underscored the importance of creating new digital mental health solutions (Dang et al., 2021). A recent example, not approved by the FDA, can be represented by DigiCOVID, a remote telemedicine intervention designed to support COVID-19 patients' and their families' psychological well-being (Cantù et al., 2022; Phan et al., 2023). After completing a preliminary telephone screening to make sure the requirements for inclusion are fulfilled, participants are assigned to a psychotherapist who provides eight weekly 50-minute teletherapy sessions via videoconferencing software. The first session of DigiCOVID includes an examination of the patient's present experience, and the identification of the areas in which the patient is suffering (e.g., loss, critical care hospitalization, and fear for one's own or a loved one's life). The second session aims to establish objectives for the therapeutic process. Validating interpersonal and personal resources linked to a higher level of stress adaptation is the goal of session three. Defense mechanisms are examined and clinically significant issues are treated in sessions four through six. The goal of session seven is to incorporate the lived experience into the self's coherent story, and in session 8 the patient is guided to reflect on what emerged in the previous sessions. In addition, there are several DTx in the literature that have been created to help people manage mental health conditions such as depression. For example, Deprexis, has shown efficacy in lowering depression symptoms of American and German adults with mild, moderate or severe depression (Twomey et al., 2017). It is an integrated 10-module web-based intervention built to provide coping strategies to manage depressive symptoms. Specifically, it focuses on several elements such as cognitive-behavioral therapy (CBT) (e.g., behavioral activation and cognitive modification), psychoeducation (e.g., exploration of healthy nutrition, physical exercises, and

relaxation), acceptance and mindfulness, problem solving, interpersonal skills, and positive psychology (e.g., discovering and nurturing personal strengths). In particular, a meta-analysis of eight randomized controlled trials (N = 2402) highlighted the effectiveness of Deprexis in decreasing depression levels in the post-intervention (Twomey et al., 2017). Moreover, after 10 weeks of use, the experimental group demonstrated that using Deprexis increased daily activity and was released from outpatient therapy much earlier (Richter et al., 2023; Liu & Schueller, 2024).

Another example of DTx can be represented by Somryst, an web intervention based on cognitive behavioral therapy for adult patients with chronic insomnia that has been approved by the FDA (Ritterband et al., 2009; Orsolini et al., 2024). In the study conducted by Ritterband et al. (2009), participants were randomly assigned to the waiting-list control group (N=23) and to the experimental group (N = 22) and they followed the intervention for 9 weeks. This DTx has 6 modules presented through texts, graphics, vignettes, and quizzes. The first two cores focus on stimulus control and sleep restriction to provide rules to follow to control the sleep-awake cycle, the educational core includes a general sleep education, the cognitive core focuses on addressing and modifying the harmful beliefs and thoughts regarding sleep and insomnia, and the final core includes elements to promote adherence, identify risk situations, and implement techniques to avoid relapse. The results showed lower levels of insomnia, wake after sleep onset and higher levels of sleep efficiency in the experimental group, while these dimensions didn't change for the control group.

1.2.1.1 Ecological advantages of DTx

To date, the majority of DTx are delivered through mobile or web applications (Fürstenau et al., 2023) and research shows that these digital interventions can effectively reach people who experience significant barriers to traditional face-to-face treatments, such as geographical distance, stigma, and lack of resources (Kazlauskas et al., 2020; Arjadi et al., 2015), and consequently have a low impact on the environment. For example, a systematic review found that internet-based interventions can reduce treatment obstacles by allowing people to access digital interventions from the comfort of their own homes, decreasing the need for travel (Kazlauskas et al., 2020; Rauschenberg et al., 2021). This is especially important for people in distant or underserved locations, where access to mental health care is frequently limited (Rojas et al., 2019). In addition to accessibility, internet-based interventions may provide a less stigmatizing alternative to traditional mental health services while avoiding the environmental costs associated with in-person treatment (Wallin et al., 2016; Fitzpatrick et al., 2017). The use of internet-based interventions can also lead to better self-management for people with mental health conditions. These interventions frequently include features such as psychoeducation and self-monitoring tools, and by facilitating self-management, internet-based interventions have the potential to reduce the frequency of in-person meetings, further reducing the carbon footprint associated with mental health care (Hermes et al., 2018; Williams et al., 2019). Indeed, all these elements can contribute to the shift from in-person to internet-based interventions leading to lower carbon footprints associated with travel, as well as enhanced access for persons who may otherwise encounter barriers to receiving care.

In this scenario, research highlights that the use of internet-based interventions is associated with a lower environmental impact. According to Ozcan and Apergis (2018), greater internet access appears to be associated with decreased pollution levels. Indeed, digital interventions have been linked to increased ecological efficiency, reduced fuel consumption, and lower greenhouse gas emissions as a result of less travel and commuting (Coroama et al., 2015; Xu et al., 2022). Similarly, Cao (2023) underlines the importance of digital technology for knowledge exchange and technological innovation in pollution reduction and, as highlighted by Lin et al. (2021) and Sun et al. (2022), the development of digital solutions is associated with fewer emissions due to less traffic, more efficient resource use, and lower PM2.5 pollution. Accordingly, the ability to implement digital solutions not only benefits people's mental health but also contributes to public health efforts by reducing the strain on healthcare systems, potentially leading to lower overall resource consumption and environmental impact (Rauschenberg et al., 2021). As a result, DTx not only helps individuals but also contributes positively to environmental sustainability by lowering travel-related emissions and improving access to care.

As has emerged from this section of this thesis, the creation of effective online protocols with a low environmental impact becomes crucial in order to enhance mental health especially in the post-pandemic time period. As previously stated, another technology with a low environmental impact that can serve as the foundation for a DTx or be integrated into a DTx aimed at promoting well-being is virtual reality (VR).

1.3 Virtual reality

Virtual reality (VR) can be defined as a computer-simulated environment that allows for interaction between users (Riva et al., 2020). Indeed, this technology enables the creation of interactive computer-generated worlds that substitute digitally created sensory experiences for real-world ones, creating the impression that one is physically present in new, life-size settings (Freeman et al., 2017). A key feature of virtual reality systems is immersion (Steuer et al., 1995; Mütterlein & Hess, 2017). Specifically, immersion refers to an objective quality of VR, specifically the ability of the technology to produce a sensory-rich mediated environment. It implies isolation from physical reality and concerns the extent to which it is able to provide realistic feedback, generating an illusion of inclusive, extended, surrounding, and vivid reality by allowing the user to move and behave as the user normally would (Slater & Sanchez-Vives, 2016; Wilkinson et al., 2021). Thus, the more a system provides a sensory experience that closely mirrors reality, the more immersive it can be considered. There are three primary levels of immersion (Di Natale et al., 2020). Conventional devices such as desktop PCs can be used to access non-immersive virtual reality systems. Utilizing a keyboard, mouse, or controller, individuals interact with the virtual environment while viewing it on a computer screen. Although this experience lacks complete sensory engagement and absorption, it can offer a partial sensation of immersion. By bolstering sensory inputs or encouraging active engagement with the virtual world, semi-immersive VR systems seek to improve the sense of immersion. Lastly, the term "fully immersive VR" describes a degree of immersion that usually entails the use of head-mounted displays (HMDs) that obscure the user's field of vision and the outside world. By using HMDs, fully immersive VR allows users to experience a high level of sense

of presence, which can be defined as the subjective perception of "being there" within the virtual environment, that is, the feeling of being immersed in the technological experience (Riva et al., 2012; Riva et al., 2016). Other features of VR are interactivity and embodiment. The former refers to the extent to which a user can influence the form or content of the mediated environment. Specifically, especially through fully immersive VR, interactivity allows users to move their bodies to interact with and control virtual objects (Slater, 2009). The sense of agency and control is enhanced by this greater degree of interactivity, which makes the virtual experience more engaging and immersive. Moreover, the second feature refers to embodiment, that is the perception that the user's self is contained in a virtual body, controlling it and belonging to it (Kilteni et al., 2012; Gall et al., 2021).

1.3.1 The role of virtual reality in promoting mental health

Because of the abovementioned features, VR can offer numerous opportunities to both reduce negative states and promote emotional and psychological well-being. For example, several studies have shown the effectiveness of virtual reality in decreasing levels of anxiety (Maples-Keller et al., 2017), depression (Zeng et al., 2018), stress (Soyka et al., 2016; Valmaggia et al., 2016; Riches et al., 2023; Ioannou et al., 2020; Baghaei et al., 2021). For example, Virtual Reality Exposure Therapy (VRET) is particularly useful for people suffering from phobias (for instance, fear of flying). In VRET, as in the traditional modality, the user is gradually exposed to the anxiety-provoking stimulus, with the advantage that virtual environments provide of being able to experience even situations that are difficult to implement in the real environment (such as flying), as well as proposing a scenario that is highly customizable and controllable by the therapist, immersive and realistic for the patient, and at a lower cost (Pallavicini, 2020; Riva, 2022). On the other hand, VR allows for a mental health promotion approach focused on enhancing well-being and aimed at improving people's emotional resources, as outlined by the Mental Health Continuum Model (Keyes, 2002, 2007). Indeed, VR enables the development of calming environments, which have been successfully used to promote relaxation. Specifically, VR offers accessible ways to enable relaxation through visualization, engagement, and immersion in pleasant and non-alarming virtual environments along with the practice of various relaxation techniques, which can also move users away from stressful situations, promoting their management and recovery from stress, as well as a decrease in anxiety (Villani et al., 2007; Riva et al., 2016; Riches et al., 2021). Moreover, many studies that have been shown to be effective in increasing relaxation have included natural elements, demonstrating that the combination of natural audiovisual elements in virtual environments activates the parasympathetic system and facilitates relaxation, also when used in combination with other techniques such as meditation or mindfulness (Valtchanov et al., 2010; Annerstedt et al., 2013; Anderson et al., 2017; Zang et al., 2024). VR has also demonstrated significant potential for increasing and regulating emotional well-being, and mood, and positive emotions such as joy, wonder, and awe (Villani & Riva, 2012; Riva et al., 2012; Herrero et al., 2014; Chirico et al., 2016; Pizzoli et al., 2019; Riches et al., 2021; Chirico, Clewis, Yaden, & Gaggioli, 2021; Malighetti et al., 2023). Furthermore, relaxing VR integrated with other techniques has been shown to be effective in reducing negative states and enhancing mental health outcomes during the COVID-19 pandemic.

For instance, a study conducted by Riva et al. (2021) investigated the effectiveness of a self-help intervention in VR to reduce psychological burden during lockdown in Italy. For a week, forty participants who had undergone rigorous social distancing for at least two months adhered to the "COVID Feel Good" program. In particular, participants were instructed to watch the 360° VR scenario *The Secret Garden* every day accompanied by a relaxation induction narrative. Following each VR exposure, participants were initially asked to focus and acknowledge their emotional discomfort and concerns regarding the COVID-19 pandemic. They were then given guidance to strengthen their coping mechanisms and boost their self-esteem, and in the final days, they received support in discovering personal meaning even during challenging times. Results showed improvements in depression and stress levels, as well as an increase in social connectedness highlighting the potential of VR-based interventions to counteract the negative psychological states caused by the pandemic.

1.3.2 Virtual reality and DTx

Virtual reality is also a promising new alternative to web-based DTx. For instance, VR-based DTx have been implemented to promote physical health and an example can be represented by Kalron et al. (2016) who evaluated the efficacy of a training program used for improving balance in patients with multiple sclerosis through a pilot RCT. 32 patients with this pathology were randomly assigned to either the virtual reality-based intervention group or the control group, which received conventional rehabilitation treatment for balance issues, in a randomized controlled experiment. For six weeks, each group received twice per week, 30-minute balance training sessions. The CAREN Integrated Reality System was employed in the VR-based intervention group, and participants were instructed to maintain their balance when the virtual road in front of them changed in slope or direction. Additionally, patients had to maintain their balance while attempting to intercept eighteen virtual red balls that appeared above the road. Results showed that the clinical balance tests and posturography measurements improved for both groups. Additionally, the functional reach test and the fear of falling questionnaire improved more in the group that used the VR-based DTx than in the control group (Karlon et al., 2016; Abbadessa et al., 2022).

In this context, to our knowledge, there are no VR-based DTx aimed at enhancing mental health or targeting a mental health condition, although in the Invirto smartphone app for phobic anxiety disorders VR has been integrated as a tool in one of the modules (Dang et al., 2020; Fürstenau et al., 2023; Schreiter et al., 2023). Specifically, patients are given virtual reality glasses, headphones, instructions for use, and an access code for the Invirto app so that they can use it on their own (for example, from home). This DTx has eight modules with over 12 hours of audio and video content based on anxiety disorder CBT treatment guides (Schultz et al., 2023). The first three lessons explain panic disorder, define symptoms, and discuss the costs and advantages of modifying behavior. The fourth and fifth modules cover relaxation and breathing techniques for panic attacks, as well as cognitive restructuring exercises, while the sixth module covers virtual reality activities that simulate circumstances that people with panic disorder find difficult and frequently avoid. These include simulated scenarios like riding the train or using an elevator. It also involves interoceptive exposure techniques

to help the patients re-evaluate their physical symptoms of anxiety. Each VR exposure exercise is guided by an audio-recorded therapist and can last up to 90 minutes. Furthermore, the seventh and eighth modules aim to assist patients comprehending the role of emotions, reviewing the treatment and what has been accomplished, and planning the next phase of exercise. In addition, all patients receive two video-conference individual sessions with clinical psychologists (each lasting around 50 minutes). In the first personal interaction, the therapist leads the patient through an introductory guided exposure exercise and prepares them to continue self-directed exposures, while the second videoconference occurs at the end of the intervention. Moreover, patients will have access to the Invirto app's content for another year, and the software will digitally remind them to continue practicing. An RCT will be done to assess the effectiveness of the Invirto app to traditional care as normal (Schultz et al., 2023). In this scenario, Invirto represents a great and unique example of how VR can be integrated into DTx targeting a mental health disorder, particularly in a self-help approach. As highlighted by this section of the thesis, at the moment there are a few examples of DTx addressing mental health in the literature, some of them are in a preliminary study phase while others have already been tested with RCTs. In this context, many of these DTx were created for managing or treating existing mental health disorders and were based on changes in the person's behavior or lifestyles. Specifically, alongside the abovementioned classic digital cognitive-behavioral protocols, whose effectiveness has been established in recent years (Richards et al., 2020), to our knowledge there are no DTx in the literature exclusively aimed at enhancing well-being or preventing specific mental health conditions. Indeed, the Mental Health Continuum Model underscores the importance of a mental health promotion approach focused on enhancing well-being and fostering people's optimal functioning (Keyes, 2002, 2007). Specifically, within this framework, a promising approach is represented by savoring which is a positive psychology technique.

1.4 The potentialities of savoring to foster mental health

Savoring can be defined as the ability to voluntarily intensify and prolong positive emotions and the ability to appreciate and increase positive experiences in one's life (Bryant, 1989, 2003; Bryant, Chadwick, & Kluwe, 2011). This ability, since it includes an amplification of positive emotions, plays an important role in promoting mental health especially in the post-pandemic time period because it does not exclusively include the focus on the positive aspects of life while ignoring the negative ones: indeed, the benefits of savoring are visible in the ability to notice and appreciate positive moments despite and during the life difficulties (Smith & Bryant, 2017, 2019). In particular, it is necessary to make a distinction between savoring and pleasure: in fact, the first is a conscious process, which requires meta-awareness of pleasant feelings and allows them to be amplified or dampened, prolonged or shortened, while the second alone does not necessarily produce savoring (Smith, Harrison, Kurtz, & Bryant, 2014). Theoretically, savoring has been identified as a mechanism strictly connected to the well-known theories of positive psychology, the broaden and build theory of positive emotions and the undoing hypothesis (Quoidbach, Berry, Hanesenne, & Mikolajczak, 2010; Smith, Bihary, O'Connor, Basic, & O'Brien, 2020), and, therefore, does not directly represent the pleasure experienced, but rather the cognitive and behavioral strategies by which people respond to positive experiences and emotions. Indeed,

savoring allows for the development and amplification of positive emotions, which may improve well-being (Smith et al., 2020). These theories explain how positive emotions may impact well-being over time, by encouraging individuals to engage in a broader range of thoughts and actions, neutralizing the damaging effects of negative emotions, and allowing them to create long-term resources. As a result, they actively contribute to improved well-being and life satisfaction while also increasing resilience in the face of stressful circumstances (Fredrickson, 1998, 2001; Tugade & Fredrickson, 2004; Quoidbach et al., 2010). This evidence suggests that savoring is essential in this process because it helps people to amplify and extend the advantages of pleasurable experiences and emotions (Smith & Bryant, 2019).

It is possible to savor through three temporal orientations. The first one is to savor through positive reminiscence. In this case, the memory of positive events allows one to relive in the present the same positive emotions experienced in the past and to experience new ones. For instance, thinking about a nice past holiday can elicit in the present the joy and enthusiasm experienced then and there is the possibility to experience a new positive emotion such as satisfaction. The second one is to savor the present moment, for instance during a walk it is possible to listen to the sounds, pay attention to the scents, the warmth of the sun on the skin and appreciate the beauty of the sky and nature. Finally, the third temporal orientation consists of savoring through the anticipation of an imminent positive event (Bryant & Veroff, 2007). In fact, it is possible to appreciate in the present the positive emotions elicited by the prefiguration of a future positive experience which could be meeting a close friend or relative or eating a tasty food (Bryant & Veroff, 2007). People can also improve the quality of an ongoing positive experience by remembering how long they were waiting for that moment (recalled anticipation) or how they waited to remember it later (anticipated recall). In any case, the positive emotions experienced during savoring are in the here and now (Bryant et al., 2011). Therefore, savoring can involve a form of "mental journey through time" through which individuals can generate positive emotional states in the present thanks to the imagination of past or future positive events (Quoidbach et al., 2010).

1.4.1 Savoring experiences, processes, strategies and beliefs

Analyzing the essence of savoring, a distinction can be made between savoring experiences, savoring processes, savoring strategies and savoring beliefs (Bryant & Veroff, 2007; Bryant et al., 2011). Savoring experiences are sensations, perceptions, thoughts, behaviors and emotions that are experienced when paying attention in a conscious way and appreciating a positive stimulus. They include for example listening to a beautiful musical performance, receiving a compliment and spending time with a friend (Bryant et al., 2011). Bryant and Veroff (2007) also distinguish savoring experiences depending on where the focus is placed: whether it is directed toward events related to the outside world (for instance, watching a beautiful sunset) or related to the self (for example, feeling proud in winning a race).

Savoring processes are more abstract dimensions than experiences. The process is “a sequence of mental or physical operations that unfolds over time and transforms a positive stimulus into positive feelings to which a person attends and savors" (Bryant et al., 2011). Some examples of processes are reported by the authors: thanksgiving generates gratitude, wonder regulates awareness and amazement and self-gratulation forges

pride. In particular, the process of thanksgiving is a form of cognitive reflection focused on the world as well as savoring the process of wonder, while the savoring process of self-congratulating and is a self-focused form of experience (Bryant et al., 2011).

On the other hand, savoring strategies are behaviors or thoughts that can amplify or dampen the intensity of positive emotions and prolong or decrease their duration (Bryant et al., 2011). Bryant and Veroff (2007) identified ten savoring strategies: sharing with others, memory building, self-congratulation, sensory-perceptual sharpening, comparing, absorption, behavioral expression, temporal awareness, counting blessing, kill-joy thinking. Thus, people can savor through multiple behavioral and cognitive strategies (Hurley & Kwon, 2013). Bryant and Veroff (2007) affirm that both amplification and inhibition responses are dimensions of savoring, but they produce opposite effects on positive emotions. People can therefore savor through the increase in thoughts and behaviors that amplify positive feelings such as memory building and counting blessing or reducing the thoughts and actions that dampen them (Smith & Hanni, 2019). Bryant and Veroff (2007) developed the Ways of Savoring Checklist (WOSC), a scale that has been shown to have reliability and discriminant validity in measuring savoring strategies and includes 60 items reflecting possible ways of thinking or acting when experiencing a positive event.

Savoring beliefs reflect people's perceptions of their capacity to enjoy positive events (Bryant, 2003). According to Bryant (2021), “savoring beliefs involve a conscious awareness of one’s ability or inability to experience and manage positive experience”. Empirical evidence suggests the presence of individual differences in assessing one's ability to savor the positive affect: generally, in fact, people differ in the type and number of emotions they want to experience (Bryant & Veroff, 2007; Palmer, 2014). Ramsey and Gentzler (2014) state that perceived savoring skills are positively correlated with the use of savoring strategies. Moreover, when asked to evaluate their savoring abilities, people typically consider themselves more able to savor through reminiscence, moderately at savoring the moment, and less able to savor through anticipation (Bryant, 2003). To measure savoring beliefs, Bryant developed the Savoring Beliefs Inventory (SBI), which is a 24-item self-report instrument comprising 3 subscales reflecting people's beliefs about the ability to enjoy positive events through anticipation, savoring the moment or reminiscence (Bryant, 2003). Specifically, this instrument involves a 7-point Likert scale (from “strongly disagree” to “strongly agree”) used to assess the degree of agreement with 12 positively and 12 negatively worded statements.

Several empirical evidence suggests that savoring correlates positively with a greater locus of internal control, higher self-esteem and higher levels of optimism (Bryant, 2003). In addition, the ability to savor positive experiences and emotions is positively associated with frequent and intense happiness, infrequent neutral and unhappy mood, and extroversion, while it is negatively related to neuroticism and hopelessness (Bryant, 2003; Hurley & Kwon, 2013; Ramsey & Gentzler, 2014). Another element related to savoring is age. Indeed, the ability to savor positive events and emotions seems to play an important role throughout the life span and it can change during adulthood. For instance, in emerging adult population, the perceived ability to savor thought anticipation is strictly connected to optimism than perceived abilities of reminiscence (Geiger et al., 2017). However, this cannot be generalized to older people as they may have several difficulties in using future-

focused savoring due to the decline in episodic memory and the decrease in the time left to live (Rendell et al., 2012). They could get more benefits from exercises focused on reminiscence: in fact, recalling positive memories from the past seems to increase well-being in old age (Geiger et al., 2017).

1.4.2 The effectiveness of savoring interventions and their digitalization

Savoring can be considered as a tool through which people can capitalize positive emotions and enhance their well-being (Jiao, Kim, & Pitts, 2021) and it is possible to consider it as a mechanism of positive psychology. As Seligman (2002) states, positive psychology promotes psychological interventions that aim to increase happiness and well-being and aims to identify, study and enhance the processes, conditions, strengths and virtues that allow individuals, communities and societies to thrive and flourish (Seligman & Csikszentmihalyi, 2000; Froh, 2004; Gable & Haidt, 2005).

According to the literature, savoring predicts better well-being, a greater number of positive emotions and positive reflections on life, a lower intensity of negative emotions and lower depressive symptoms (Hurley & Kwon, 2012; Cheung et al., 2019). Furthermore, to savor positive emotions has a positive influence on the quality of interpersonal relationships and can be considered as a mechanism that supports the ability to find meaning in difficult situations such the pandemic time period and the post-pandemic (Borelli et al., 2015; Smith et al., 2020). People who know how to use savoring well can experience a greater number of positive emotions that consequently have the power to motivate and involve them in more activities (Fredrickson, 2013; Smith et al., 2020), and to increase longevity (Danner et al., 2001; Bryant, 2003; Ramsey & Gentzler, 2014; Smith & Hollinger-Smith, 2015)**.** Starting from this evidence, numerous interventions have recently been conducted to enhance the savoring capacity in people especially in the American context.

In a meta-analytical review conducted by Smith and colleagues (2014) emerges the consistent impact of savoring interventions on the increase of positive emotions and well-being. In addition, Salces-Cubero et al. (2019) state that, compared to other intervention techniques such as gratitude and optimism, savoring produces the strongest effects in increasing the positive affect, happiness, life satisfaction as well as in reducing negative affect. Such interventions can take different forms, for instance activities aimed at increasing anticipation of positive future events, increasing awareness of positive stimuli and emotions in the present, and promoting positive reminiscence of past events (Smith & Hollinger-Smith, 2015). For instance, Lyubomirsky et al. (2006) created a training to investigate the best way to implement savoring focused on the past: after choosing an experience considered very happy, participants were asked according to the group they belong to a) write about the positive experience, b) talk about it by registering, c) simply think about the event by exploring the deepest thoughts and emotions, or d) not remember any experience, for 15 minutes a day for three consecutive days. The results indicate that simply thinking about the positive event and becoming more aware of it is the best strategy to increase well-being and positive affect after four weeks from the start of the intervention (Lyubomirsky et al., 2006).

Savoring can also be facilitated by raising awareness of the positive events that have just happened in the day: the intervention of the “Three Good Things” can be a valid example of this (Seligman et al., 2005; Smith et al., 2014). In this study, participants belonging to the "Three Good Things" condition wrote down three positive events that occurred during the day every day for a week. Compared to the control condition, in which it was asked to write about childhood memories, the experimental condition was more effective at improving happiness levels after one month, three months and six months after the training.

Daily worries and responsibilities can distract people from the positive events in their lives, so savoring interventions focused on the present moment aim to provide cognitive and behavioral strategies to increase awareness and appreciation of ongoing positive experiences (Smith et al., 2014). For example, in a study conducted by Bryant and Veroff (2007), college students assigned to the savoring condition were asked to notice the greatest number of pleasant aspects in the environment around them during a 20-minute walk. When they noticed some positive elements (the flowers, the good weather, the sun), they had the task to recognize the experience and to think about what elements made it particularly pleasant. A week later, students belonging to the savoring condition reported higher levels of happiness than those belonging to the neutral condition and the negative focus condition. In another research, participants were trained to use the ten savoring strategies through recorded or written instructions, and after two weeks, the group that received the savoring training reported significant lower levels of depression and negative affect than the control group (Hurley & Kwon, 2012). Thinking about the future can also have a strong and positive impact on the ability to savor the present (Van Boven & Ashworth, 2007) as emerges from the study carried out by Quoidbach et al. (2009). Adults who accurately imagined four positive events that could reasonably happen in the following day for 15 consecutive days, reported significantly higher levels of happiness after two weeks. In contrast, the levels of happiness of groups belonging to the neutral condition and to the prefiguration of negative events have not changed. This study therefore suggests that imagining positive future experiences can make feel better in the present (Smith et al., 2014).

In recent years, some savoring interventions designed for the elderly population were conducted. For instance, Smith and Hanni (2019) involved 111 adults between the ages of 60 and 93. They were asked to carry out a savoring activity five minutes in the morning and five minutes in the evening every day for a week. In this exercise, they had to think about something positive (a beautiful event of the present, a pleasant memory or something positive that could happen in the future). Later, they had to pay attention to the positive feelings aroused by the thought of that experience (interest, excitement etc.). Finally, it was advised to take a moment to appreciate the experience and think about how special it was. The results indicated that this savoring intervention allowed the reduction of depressive symptoms and thoughts and behaviors that inhibit savoring and positive emotions. These activities also helped the participants to become more aware of the positive experiences that take place in their daily lives (Smith & Hanni, 2019).

In addition to in-person interventions, savoring can be promoted through online interventions. Specifically, in online interventions, savoring is usually integrated together with other positive psychology techniques such as practicing mindfulness, focusing on character strengths, or practicing prosocial actions (Heintzelman et al.,

2020). Recently, only a few online interventions focused exclusively on savoring exercises and none of them involved Italian participants. For example, Park (2019) conducted a pilot study involving emerging adults with the goal of teaching the elements of savoring via a website that offers a variety of psychoeducational resources to encourage the daily practice of savoring (books, videos, and articles). The 21-day experiment demonstrated how an online self-managed savoring intervention could improve subjective well-being and savoring. In other research conducted by Yu et al. (2020), Taiwanese college students were advised to engage in a pleasurable activity by focusing on their good feelings for 20 minutes three times a week. Participants were then invited to use a photo and/or words to express and share these feelings on a social media platform, such Facebook. Comparing the experimental group to the control condition, the study discovered a substantial decrease in depression and an increase in positive affect in the post-test.

In this context, savoring appears to be a valuable approach to promote mental health across different ages groups and through various modalities (e.g., in-person interventions, online interventions), and its integration into DTx is particularly promising given its practicality and sustainability. Indeed, savoring techniques can be easily incorporated into DTx, making them accessible and engaging.

1.5 Outline of the thesis

The overall goal of this doctoral thesis is to lay the foundation for the development of digital therapeutics integrating VR and savoring and aimed at counteracting the negative effects of the COVID-19 pandemic and promoting emotional and psychological well-being, as well as expanding our knowledge about the relationship between VR and savoring. As this chapter shows, the COVID-19 pandemic has had a significant impact on people's mental and physical health with effects still visible to this day thus highlighting the need to develop innovative digital solutions, such as digital therapeutics (DTx), aimed at promoting mental health and improving people's emotional and psychological resources as outlined by the Mental Health Continuum Model. In particular, DTx can be based on technologies such as VR that, due to its characteristics, offers unique opportunities to improve mental health. Related to this, **Chapter 2** of this thesis presents a scoping review having the objective of analyzing how breathing, a particularly compromised element during the pandemic and an important tool in promoting well-being, has been integrated with VR to promote mental health. This chapter investigates the type of VR used, the methodologies applied, the mental health outcomes investigated, and the implications of the interventions, identifying gaps in the literature and providing directions for future research. Shifting the focus to the content of the protocols, the chosen approach is based on positive emotions because of their potential on promoting well-being established in the literature. Indeed, positive emotions have been shown to be effective in enhancing well-being, and savoring in particular can be considered an interesting approach focused on mental health promotion that can also be delivered online as demonstrated by few previous studies, suggesting the opportunity of integrating it into digital interventions such as a DTx. In fact, **Chapter 3** describes an experimental study that developed and implemented an online savoring intervention aimed at promoting well-being targeting Italian emerging adults, a population particularly affected by the pandemic. Taking advantage of the well-established literature on VR and savoring and information obtained

from previous studies of this thesis, **Chapter 4** describes the development and implementation of a pilot RCT that tested the efficacy of an initial draft of a VR-based DTx integrated with savoring to improve emotional and psychological well-being and peripheral oxygen saturation in patients with chronic respiratory disease, another population particularly affected by the COVID-19 pandemic. Following this, to better understand the relationship between VR and savoring and in particular how VR influences the amplification of positive emotions, **Chapter 5** explores the potential of virtual transformative experiences in VR in promoting well-being and savoring practice in Italian and Spanish emerging adults aiming to better understand the effects of VR on the practice of savoring strategies. Finally, **Chapter 6** summarizes the main findings of the thesis, highlighting theoretical and practical implications, discussing strengths and limitations, and outlining future prospects (Table 1).

Table 1. The outline of the thesis.

Chapter	*Article/research*
2	Pancini, E., Di Natale, A. F., & Villani, D. (under review from July 2023). Breathing in Virtual Reality for Promoting Mental Health: A Scoping Review. *Virtual reality*.
3	Villani, D., Pancini, E., Pesce, F., & Scuzzarella, L. (2023). Savoring life during pandemic: an online intervention to promote well-being in emerging adults. *BMC psychology*, *11*(1), 196.
4	Pancini E., Fumagalli A., Maggiolini S., Misuraca C., Negri D., Bernardelli L., Villani D. (under review). Integrating Virtual Reality with Savoring to Promote Well-being of Patients With Chronic Respiratory Diseases: a Pilot Randomized Controlled Trial. *Journal of Medical Internet Research*.
5	Ongoing study, article in preparation. (2024). The Role of VR-Based Transformative Experience on Emotional and Psychological Well-Being, Positive Emotions and Savoring Practice in Italian and Spanish Emerging Adults: Preliminary Results.

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CHAPTER 2

Breathing in Virtual Reality for Promoting Mental Health: A Scoping Review

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Introduction

As highlighted in the previous chapter of this doctoral thesis, the pandemic had a strong impact on both physical health and mental health. With regard to physical health, the pandemic particularly affected breathing. In fact, there have been numerous cases of both healthy and previously ill people reporting respiratory issues either immediately after COVID-19 infection or many months after infection combined with other symptoms as well (Weng et al., 2021). With regard to mental health, the pandemic had a significant impact on the increase of several mental health conditions including anxiety, depression, stress, and insomnia especially in certain populations (Wu et al., 2021). In response to these issues, there is a need to find innovative digital health solutions with a low environment impact which allow to reach different populations (e.g., clinical, and subclinical populations) and age groups, and an example can be represented by the digital therapeutics (DTx). Specifically, DTx are mental health interventions that use software applications to diagnose, treat, manage, and/or preventing mental health conditions (Fürstenau et al., 2023). They can be based on technologies such as mobile or web applications or virtual reality (VR). In particular, VR, due to its properties (e.g., sense of presence, immersion, interactivity), creates immersive environments that allow users to engage with simulated scenarios in a controlled manner and encourages their active participation generating engagement. Consequently, VR offers several possibilities for enhancing mental health, for instance it has been shown to effectively reduce symptoms of several mental health conditions such as depression and anxiety, and to effectively enhance well-being by fostering relaxation, stress reduction, and emotional regulation (Herrero et al., 2014; Riches et al., 2021).

In particular, VR can be used as a technology through which to promote breathing, a tool that is among the most widely used in the literature to enhance relaxation and well-being (Hopper et al. 2019). For instance, breathing has been shown to be effective in decreasing anxiety and stress levels and also in promoting positive mood and emotional regulation suggesting its usefulness in both clinical settings and healthy populations (Ma et al., 2017; Fincham et al., 2023; Chaitanya et al., 2023). Furthermore, breathing, in addition to being an effective tool for fostering well-being, was also a particularly compromised element during the pandemic.

For these reasons, we decided to conduct a scoping review in order to map studies aimed at promoting mental health in the literature that integrated VR and breathing, and to better understand how breathing techniques have been integrated with VR in the literature and what mental health-related outcomes these VR and breathing interventions have addressed. Furthermore, other goals were to investigate the potential effects of these studies on mental health-related outcomes, type of VR (e.g., non-immersive, semi-immersive, fully immersive VR) and other devices used, session length, and user experience, and to discover potential gaps in the literature. Hence, this chapter provides a broad and in-depth overview of possible ways in which VR can be integrated with breathing for mental health promotion.

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Breathing in Virtual Reality for Promoting Mental Health: A Scoping Review

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2.1 Abstract

Background. Breathing techniques have long been recognized as effective strategies for promoting mental health-related outcomes such as relaxation and emotional regulation. Virtual reality (VR), with its immersion and interactivity, offers the possibility to amplify the effectiveness of breathing techniques in promoting mental health. Recently, there has been an increasing use of VR to support breathing, although a formal summary of this integration is lacking.

Methods and results. Following the PRISMA-ScR reporting guidelines, this scoping review aims to investigate the integration of breathing techniques and VR experiences and examine their potential effects on mental health-related outcomes. The synthesis of the reviewed studies (n = 18) reveals that different VR experiences can be used to strengthen breathing techniques. VR can, for example, reduce distractions and enhance focus during breathing exercises, provide direct, real-time feedback on the practice, and be used to create personalized environments, allowing users to train their breathing techniques in various contexts, from calming virtual nature settings to safe environments for practicing breathing skills that can be applied to real-life situations. Furthermore, this scoping review reveals the positive effects of VR-based breathing interventions on reducing clinical symptoms and increasing well-being and physical health outcomes.

Conclusions. Overall, while acknowledging some methodological heterogeneity in the existing studies, the findings demonstrate the unique and promising potential of integrating breathing techniques with VR experiences. Future research is recommended to understand long-term effects, user experience, and the potential customization of interventions for diverse clinical and well-being contexts.

Keywords: breathing, virtual reality, VR, mental health, well-being.

2.2 Introduction

Breathing is a simple but powerful activity in our daily lives that has a direct effect on our heart and our body, even if we are not aware of it (Patibanda et al., 2017). Specifically, according to literature, deep and paced breathing is a core element of many breathing exercises, and it is based on consciously slowing down the breath and reaching a frequency of six or seven breath cycles per minute (around 0.1 Hz) (Zaccaro et al., 2018). For example, diaphragmatic breathing and slow-paced breathing employ this type of breathing as a key

component. Therefore, they can be considered simple and effective methods to enhance both physical and mental health (Zaccaro et al., 2018; Hopper et al., 2019).

Regarding physical health, they are related to the cardiovascular system and help maintain or restore equilibrium between the sympathetic and parasympathetic branches of the autonomic nervous system (Russo et al., 2017; Blum et al., 2020). Inhaling reduces vagal tone, which is the largest contributor to the parasympathetic branch, increases heart rate, and decreases blood pressure. Exhaling, on the other hand, increases vagal tone, which lowers heart rate and raises blood pressure (Blum et al., 2020). Thus, slow-paced breathing modulates the parasympathetic nervous system, and restores the equilibrium of the autonomic nervous system (Vaschillo et al., 2006).

Regarding mental health, it is an essential component of overall well-being. According to the dual continuum model of mental health, it refers to our emotional, psychological, and social well-being, affecting how we think, feel, and act (Keyes, 2002). Specifically, emotional well-being can be defined in terms of positive affect and satisfaction with life. Psychological well-being includes for example self-acceptance and positive relationships with others, and social well-being refers to dimensions such as social coherence and contribution (Keyes, 2002). People who experience good mental health thrive in life psychologically and socially and experience positive emotions. On the contrary, people experiencing bad mental health have low well-being levels, languish in stagnation and may feel, for example, stress, anxiety, depression, and negative emotions (Żemojtel-Piotrowska et al., 2018). In this context, diaphragmatic breathing and slow-paced breathing have been proven effective in reducing negative outcomes such as stress, anxiety (Chen et al., 2017; Toussaint et al., 2021), depression, negative affect (Jerath et al., 2015; Ma et al., 2017) as well as mind wandering (Burg & Michalak, 2011). Furthermore, diaphragmatic breathing and slow-paced breathing have been found to foster positive outcomes such as breathing awareness, self-awareness, emotional regulation, as well as relaxation, positive mood, and well-being (Busch et al. 2012; Hopper et al. 2019).

The ability to act on both physical and mental levels makes these types of breathing a versatile and advantageous approach in both non-clinical and clinical settings. For instance, they have been applied to healthy participants (Busch et al., 2012), cancer patients (Shahriari et al., 2017), participants with chronic obstructive pulmonary disease (COPD) (Holland et al., 2012), and asthma patients (Holloway & Ram, 2004). Moreover, they have been used with different age groups, such as adolescents (Laborde et al., 2017) and young adults (Goldstein et al., 2016), as well as adults (Ma et al., 2017) and older adults (Shahriari et al., 2017).

Overall, the benefits of breathing techniques for physical and mental health are recognized. Nevertheless, people can have difficulties keeping the correct timing or frequency or maintaining focus on breath during the exercises (Blum et al., 2020). Thus, providing guidance to sustain people's breathing rhythm and awareness can be crucial. The possibility of integrating breathing techniques into virtual experiences represents a possible solution. Virtual reality (VR) allows the creation of computer-generated interactive worlds that replace real-world sensory perceptions with digital ones, thus producing the feeling of being inside digital environments (Freeman et al., 2017). A key process elicited by VR is *immersion*, which refers to the extent to which a VR

experience can fully engage and absorb users in a virtual environment. Three main levels of immersion have been identified (Di Natale et al., 2020). Non-immersive, or desktop VR systems, can be accessed through traditional devices like desktop computers. The interaction with the virtual environment is mediated by a keyboard, mouse, or gamepad, and they view the virtual environment on a computer screen. This experience can provide a partial sense of immersion, but it lacks full sensory engagement and absorption. Semi-immersive VR systems aim to enhance the feeling of immersion by strengthening sensory inputs or promoting active interaction with the virtual environment. Finally, fully immersive VR refers to a level of immersion that typically involves the use of head-mounted displays (HMDs) that cover the user's field of view and block out the real-world surroundings. These HMDs often have motion-tracking sensors for natural exploration and interaction in the virtual environment. By using HMDs that cover the user's field of view and motion-tracking sensors, immersive VR experiences create a heightened *sense of presence* (Villani et al., 2007; Riva et al., 2016), making users feel physically present in the virtual environment. *Interactivity* (Steuer, 1992) also plays a crucial role in fully immersive VR setups, offering both active and passive forms of interaction with the virtual environment. Interactivity, facilitated by fully immersive VR setups and motion tracking sensors, enables users to engage with and manipulate virtual objects using their own body movements (Slater, 2009; Kardong-Edgren et al., 2019). This increased level of interactivity enhances the *sense of agency* and control, making the virtual experience more engaging and immersive. The ability to directly interact with and manipulate objects within the virtual world can also be strengthened by avatar *embodiment* (Slater et al., 2008; Gall et al., 2021). Embodiment defines the impression that users' selves are located inside a virtual body, that they control this body, and that it belongs to them (Kilteni et al., 2012; Gall et al., 2021). The ability to directly interact with and manipulate objects within the virtual world through embodied actions enhances the sense of presence, agency, and immersion, creating a more engaging and immersive VR experience.

Because of these elements and the well-established literature, VR can contribute to mental health on several levels and offers several opportunities for enhancing mental health. For example, VR has also been effective in reducing anxiety, depression, and stress (Riches et al., 2023; Ioannou et al., 2020; Baghaei et al., 2021). Additionally, VR allows the creation of relaxing scenarios and has been successfully employed in promoting relaxation and stress reduction. It has also shown relevant potential in improving and regulating emotional well-being, mood, and positive emotions (Villani, 2009; Villani & Riva, 2012; Herrero et al., 2014; Pizzoli et al., 2019; Riches et al., 2021; Malighetti et al., 2023). Over the past few years, the use of VR to support breathing has been increasing, even though the literature describing how breathing techniques are currently integrated into VR experiences has not been formally summarized, making it difficult to assess how they have been combined. Furthermore, it is unclear which mental health-related outcomes are assessed and whether the interventions using these strategies are effective in improving these psychological outcomes. Moreover, it is unclear whether breathing techniques integrated with VR are employed in clinical populations or if their use is limited to lab-based interventions in healthy populations.

2.2.1 Objectives

A scoping review following the PRISMA-ScR reporting guidelines (Tricco et al., 2018) was carried out to map the research done in this area and identify any existing knowledge gaps. The following research questions have been developed: (RQ1) How have breathing techniques been integrated with VR experiences in the literature? (RQ2) What health-related outcomes have these VR and breathing interventions addressed, and what are their effects on these outcomes?

2.3 Methods

2.3.1 Research method and paper selection

A comprehensive search was conducted in four different databases: PsycINFO, Scopus, PubMed, and Web of Science. The string of words used to perform the search were those resulting from the combination of two groups of words: group 1 referred to the dimension of breathing and its synonyms, and group 2 to the dimension of VR and its synonyms in psychological contexts. The search included studies published until June 17th 2024 with no limits placed on country of origin, using the following search string: (“respirat*” OR “breath*”) AND ("virtual reality" OR {vr} OR "digital environment?" OR "virtual environment?"). The search was performed for the abstract, title, and keywords. Citations were retrieved from each search in each database and imported into Endnote to remove duplicates. Afterward, they were exported to Rayyan (Ouzzani, Hammady, Fedorowicz, & Elmagarmid, 2016) for the first screening and for applying selection criteria.

2.3.2 Selection criteria

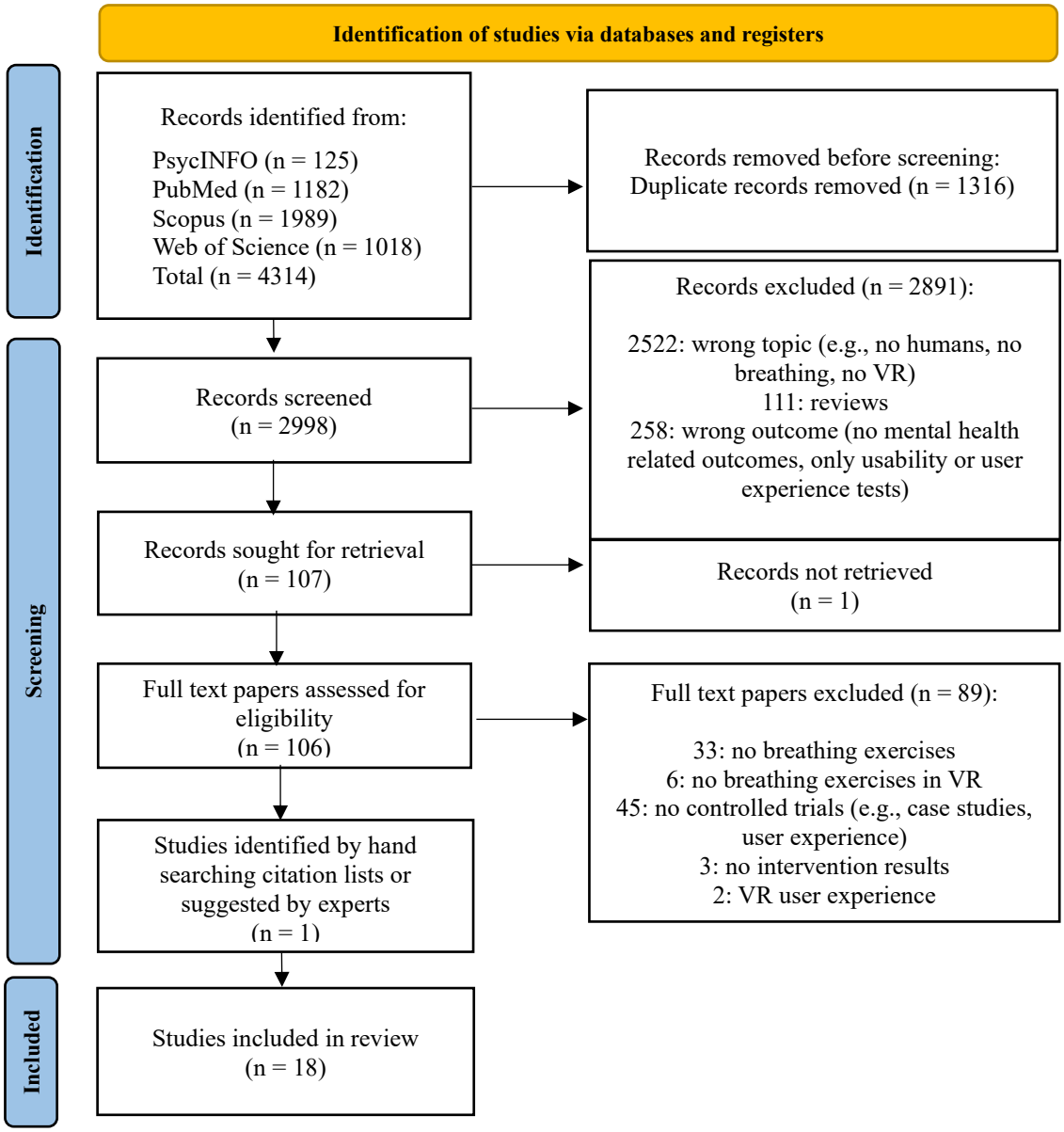
Papers were selected based on the following inclusion criteria: (1) articles involving human participants; (2) written in English and/or Italian; (3) controlled studies (i.e., studies including both the experimental and the control group - randomized controlled studies and non-randomized controlled studies - thus allowing for the comparison of achieved outcomes) using breathing during the VR experience; (4) mental health related outcomes (i.e., stress, anxiety, depression, negative emotions, self-awareness, positive emotions, psychological well-being, etc..). We excluded the following manuscript types: reviews as they are not empirical papers, meeting abstracts, notes, and letters to editors, as they are not peer-reviewed papers and may lack quality and scientific rigor. There were no exclusion criteria related to year, sample size, age group, location, type of breathing, type of VR (e.g., non-immersive, semi-immersive, fully immersive), or type of population (e.g., clinical, subclinical or healthy).

2.3.3 Data extraction

In order to guarantee a fair review process, the PRISMA-ScR reporting guidelines for conducting scoping reviews were followed. EP, DV individually screened the title and abstract of the retrieved records before analyzing the full papers that met the inclusion criteria. Disagreements were resolved through consensus. From a total of 4314 original search results, 18 studies were selected for inclusion. See Fig. 1 for the PRISMA flow diagram. Data extraction was agreed upon, including sample descriptive data, methodology, information about

the intervention, and outcomes and measures. Following that, the authors reviewed the included articles, created the tables, and filled them in with relevant information (EP, DV, AFDN).

Fig. 1. PRISMA flow diagram.



2.3.4 Ethical considerations

No ethical approval was sought because this scoping review is based on previously published studies. The authors did not register the review with PROSPERO, a database of registered health and social care systematic reviews, because scoping reviews do not meet registration criteria.

2.4 Results

The results of the present PRISMA scoping review are presented in Table 1 (Description of the studies) and Table 2 (Study goal, psychological and physiological measures, and main results).

Only 18 studies of VR combined with breathing exercises that included mental health outcomes met the eligibility criteria. All 18 studies were written in English, and no studies written in Italian were found. Five studies were conducted in the United States (de Zambotti et al., 2022; Hu et al., 2021; Kniffin et al., 2014; Russel et al., 2014), 5 in Germany (Blum et al., 2019, 2020; Shiban et al., 2017; Soyka et al., 2016; Schrempf et al., 2022), 3 in The Netherlands (Tinga et al., 2019; Weerdmeester et al., 2021, 2022), 2 in Switzerland (Blanke et al., 2022; Weibel et al., 2023), one in Taiwan (Lan et al., 2021), one in Australia (Barton et al., 2024), and one in Turkey (Savas et al., 2024). Eight studies were published from 2014 to 2020, 3 were published in 2021, 4 in 2022, one in 2023, and 2 in 2024. Regarding the presentation of the results, we dedicated a paragraph to the study design and the participants involved. In addition, we analyzed the interventions' length and the measures used. Then we mapped the use of VR, the types of breathing, and the integration of VR and breathing in the interventions. Finally, we analyzed the outcomes considered by the 18 studies.

The results are presented by delineating the study design and participants involved, followed by a description of the intervention length and the measures used for data collection. The usage of VR and breathing in the interventions is then mapped out, highlighting different types of breathing, as well as how specific breathing techniques are integrated with VR. Outcomes are discussed in terms of relaxation, arousal reduction, breathing awareness and focus on breath, and reduction in perceived physical symptoms. Finally, the overall user experience is examined to provide comprehensive insights into the effectiveness and acceptability of the interventions.

Table 1. Description of the studies.

First author (year)	Sample size	Gender	Age	Region	Setting
Barton (2024)	58	25 Females, 32 Males, 1 n.s.	M = 42.1, SD = 14.7 (total sample)	Australia	Non-hospital setting
Blanke (2022)	26	7 Females, 19 Males	Mdn = 55, IQR = 18 (total sample)	Switzerland	Hospital setting
Blum (2019)	60	31 Females, 29 Males	M = 33.5, SD = 9.4 (total sample)	Germany	Non-hospital setting
Blum (2020)	72	56 Females, 16 Males	M = 21.6, SD = 4.3 (total sample)	Germany	Non-hospital setting
de Zambotti (2022)	52	32 Females, 20 M Males	M = 18.4, SD = 0.7 (total sample)	United States	Non-hospital setting
Hu (2021)	40	21 Females, 19 Males	M = 28, SD = 4 (total sample)	United States	Non-hospital setting
Kniffin (2014)	63	63 Females, 0 Males	M = 18.97, SD = 1.20 (total sample)	United States	Non-hospital setting
Lan (2021)	20	10 Females, 10 Males	M = 20.6, SD = 2.3 (control group) M = 22.0, SD = 1.2 (experimental group)	Taiwan	Non-hospital setting
Russel (2014)	60	48 Females, 12 Males	M = 18.8, SD = n.s. (control group) M = 19, SD = n.s. (experimental group)	United States	Non-hospital setting
Schrempf (2022)	54	20 Females, 34 Males	M = 60.9, SD = 10.5 (control group) M = 63.4, SD = 8.2 (experimental group music) M = 55.8, SD = 10.2 (experimental group VR)	Germany	Hospital setting
Shiban (2017)	29	24 Females, 5 Males	M = 43, SD = 9.96 (control group) M = 34.2, SD = 9.81 (experimental group)	Germany	Non-hospital setting
Savas (2024)	62	30 Females, 32 Males	M = 9.33, SD = 2.08 (experimental group) M = 9.74, SD = 1.76 (control group)	Turkey	Hospital setting
Soyka (2016)	21	10 Females, 11 Males	M = 29, SD = n.s. AR = 20-45	Germany	Non-hospital setting
Stromberg (2015)	43	35 Females, 8 Males	AR = 18-27	United States	Non-hospital setting
Tinga (2019)	60	37 Females, 23 Males	M = 22.07, SD = 3.03 (total sample)	The Netherland	Non-hospital setting
Weerdmeester (2021)	112	101 Females, 11 Males	M = 20.84, SD = 2.42 (control group) M = 20.58 SD = 2.51(experimental group)	The Netherland	Non-hospital setting
Weerdmeester (2022)	67	48 Females, 16 Males, 3 n.s.	M = 21.27, SD = 2.84 (total sample)	The Netherland	Non-hospital setting
Weibel (2023)	107	48 Females, 59 Males	M = 22.52, SD = 3.33 (total sample)	Switzerland	Non-hospital setting

M = mean
SD = standard deviation
Mdn = median
IQR = interquartile range
AR = age range
n.s. = not specified

Table 2. Study goal, psychological and physiological measures, and main results.

First author (year)	Study goal	Study design	Psychological measurements	Physiological measurements	Results
Barton (2024)	The study aimed to assess the feasibility of restorative environments in VR to promote mindfulness and well-being.	*RCT (between subjects)* Participants were assigned to one of three VR conditions: Interactive VR (participants' breathing could influence the virtual scenario), Passive VR (participants had no control over the scenario), or Nature VR (participants watched a 360° nature video).	• Positive and negative mood, mental fatigue and focus (*ad-hoc VAS scale*) • State mindfulness (*ad-hoc version of the State Mindfulness Scale*) • Awareness of the present moment (*five items from the State Mindfulness of Mind factor*) • Perceived restoration of the VR scenarios (*modified version of the Perceived Restoration of Activities Scale*)	-	No significant differences between groups were found, but mental fatigue and anxiety decreased and calmness and relaxation increased in all conditions. The Interactive VR group reported increased focus and decreased sadness, while there were no changes in the other groups.
Blanke (2022)	The study aimed to evaluate the efficacy and feasibility of a VR intervention based on breathing synchronization via gender-matched virtual bodies to alleviate dyspnea in patients recovering from COVID-19 pneumonia.	*RCT (cross-over)* Participants were randomly assigned either to the "asynchronous - synchronous" sequence or the "synchronous - asynchronous" sequence.	• Breathing comfort and discomfort (*ad-hoc items*) • Breathing awareness and agency *(ad-hoc items*)	• RR • RRV	The study demonstrated that VR intervention improved patients' breathing comfort and satisfaction, indicating its potential as a safe respiratory rehabilitation tool.

Blum (2019)	The study aimed to determine if incorporating VR in biofeedback therapy using heart rate variability (HRV) improves relaxation and attentional resources.	*RCT (between subjects)* Participants were divided into two groups, with one receiving treatment through a standard computer screen and the other through a VR headset in a virtual beach setting.	• Relaxation (*State Trait Anxiety Inventory*) • Relaxation self-efficacy (*ad-hoc VAS scale*) • Mind wandering (C*ognitive Interference Questionnaire*) • Focus on the present moment (*State Mindfulness Scale*) • Attentional resources (*modified Stroop task*)	• HRV • RMSSD • Cardiac coherence	The results showed that both implementations effectively increased relaxation, but there was no significant difference between them. However, the VR-based implementation led to greater improvement in relaxation self-efficacy, focus on the present moment, and reduced mind wandering compared to the standard implementation. Participants in the VR-based implementation also performed better in a Stroop task, indicating improved attention. There was no significant difference between the two implementations in terms of cardiac coherence and vagal tone.
Blum (2020)	The study aimed to investigate the efficacy of a VR-based diaphragmatic breathing biofeedback algorithm.	*RCT (between subjects)* Participants were assigned to a focused breathing exercise with and without respiratory biofeedback in VR.	• Focus on the breath (*ad-hoc VAS scale*)	• HRV • RMSSD • LF and HF • Abdominal movement	Participants in the feedback group reported greater success in maintaining their attention on the breath compared to the control group. Objective measurements showed a higher relative share of abdominal movements in the feedback group, indicating increased utilization of the diaphragm. The feedback group also exhibited a slower breathing rate and increased heart rate variability, suggesting a more calm and regular breath with enhanced parasympathetic activity.

de Zambotti (2022)	The study aimed to investigate the effects of a VR-based mind-body approach on reducing bedtime arousal in adolescents with insomnia.	*Counterbalanced* Participants completed two counterbalanced sessions: an intervention session involving nature-based VR-guided meditation and paced breathing, and a control session without any intervention (watching tv or reading a book).	• Cognitive arousal (*Pre-Sleep Arousal Scale*) • Alertness, positive and negative mood and sleepiness (*Daytime Insomnia Symptom Scale*)	• EEG • HR • HRV • LF and HF • Salivary cortisol • SBP and DBP	The study found that the VR-guided meditation and paced breathing intervention led to increases in HRV, indicating vagal activation, as well as changes in EEG activity, including suppression of alpha power and increases in high-frequency synchronization (beta and gamma activity). These changes reflected attentional processes and information processing during meditation. Pre-to-post intervention analyses showed reductions in heart rate and cortisol levels, suggesting relaxation and downregulation of the autonomic nervous system. The intervention did not significantly affect cognitive arousal or EEG measures related to cortical hyperarousal.
Hu (2021)	The aim of the study was to compare the effectiveness of the two methods in modulating the patients' pain thresholds in the same study design and clinical environment.	*RCT (between-subjects)* The study involved healthy subjects, with one group engaging in mindfulness-based (TMB) and another in VR-based (VRB) through an in-house-developed 3D VR lung that synchronized with breathing cycles in real-time.	• Pain (*McGill Pain Questionnaire*) • Serenity and fatigue (*Positive and Negative Affect Schedule*)	• fNIRS • HRV • Pain threshold	Both interventions effectively increased pain thresholds in the participants, although they had different effects on serenity scores. The TMB group showed increased serenity accompanied by increased fatigue, while the VRB group did not show a significant change in serenity scores. The brain activation patterns during pain stimulation suggested that TMB modulates attention and contextual evaluation of internal sensory events, inhibiting sensory-discriminative pain processing. VRB induces immersive exteroception, diminishing functional connections with the S1 and weakening its pain processing function.
Kniffin (2014)	This study discussed the use of VR to explore how self-regulatory skills, such as diaphragmatic breathing, can influence female participants' reactions to	*RCT (between-subjects)* Female undergraduate students were randomly assigned to either diaphragmatic breathing training or attention control.	• Negative affect (*negative affect items from the Positive and Negative Affect Schedule*) • Level of confidence of	• HR • HRV • RR	The study found that training in diaphragmatic breathing led to slower respiration rates and higher HRV compared to the control group. Participants in the breathing group had stable self-regulation capacity, while the control group showed gradual improvement over time. During the stressful VR role-play, both groups reported increased negative affect, but contrary to expectations, the control

	a high-risk encounter with an aggressive male.		resisting and avoiding sexually risky situations (*Sexual self-efficacy rating*)		group reported higher self-efficacy for managing the confrontation. Following the VR role-play, the breathing group exhibited higher HRV and slower respiration rates.
Lan (2021)	The aim of the study was to evaluate the effectiveness of a VR multimodal system, providing users with tactile feedback based on real-time sensor data from pressure sensors, in improving the user's breathing control, sleepiness and changing EEG.	*Between-subjects* Participants were assigned to the feedback group or the control group with no feedback	-	• RR • EEG • Eye-blinking frequency	Participants in both the control and feedback groups improved their breathing rate. The feedback group showed a significant decrease in breathing rate compared to the control group. The standard deviation of breathing rates also decreased over time for both groups. However, no statistical difference was observed in the theta-to-alpha power ratio, indicating that the system did not significantly affect the meditation aspect. Eye-blinking frequency was used as an indicator of sleepiness, and the feedback group had a significantly lower frequency, suggesting that the system helped reduce sleepiness during training.
Russel (2014)	The study aimed to apply diaphragmatic breathing as a self-regulatory strategy and measure its effects on physiological, cognitive, and behavioral responses in a motion sickness-inducing environment.	*RCT (between subjects)* Participants were randomly divided into the diaphragmatic breathing condition, receiving instructions on diaphragmatic breathing techniques, and the control condition, receiving instructions on being aware of their surroundings as an attention control manipulation.	• Motion sickness management self-efficacy (*ad hoc items*) • Perceived motion sickness (*Motion Sickness Assessment Questionnaire*) • Perceived motion sickness during VR (*self-rating scale*)	• HR • HRV • RR	The diaphragmatic breathing protocol increased parasympathetic nervous system tone, slowed respiration rate, and decreased development of motion sickness symptoms as compared to the control condition. In the diaphragmatic breathing condition, a significant positive correlation indicates that an increased respiratory rate was associated with more motion sickness symptoms.

Savas (2024)	The study aimed to evaluate the impact of a biofeedback-based VR game (BioVirtualPad) on anxiety, fear and pain during port catheter needle insertion in pediatric oncology patients.	*RCT (between-subjects)* Participants were randomly assigned to the VR condition or the control group who did not experience VR during the port needle insertion.	• Anxiety (*Child Anxiety Scale-State*) • Fear (*Child Fear Scale*) • Pain (*Wong-Baker FACES Pain Rating Scale*) • Satisfaction with the port catheter needle insertion procedure (*ad-hoc VAS scale*)	• RR	Results showed that patients in the intervention group reported significantly lower anxiety, fear, and pain levels compared to patients in the control group who did not experience VR, as well as their mothers. Moreover, the intervention group, during the procedure, experienced a significantly lower average respiratory rate than the control group and was significantly more satisfied with the port needle insertion procedure than the control group.
Schrempf (2022)	The study aimed to investigate the feasibility of a VR intervention for promoting quality of life and positive mood in cancer patients undergoing surgery.	*RCT (between-subjects)* Participants were randomly assigned to the VR-breathing condition, the classical music condition, or the control group receiving standard treatment.	• Overall mood (*self-rating scale*) • Health-related quality of life (*European Organization for Research and Treatment of Cancer Quality of Life Questionnaire and additional items to measure sleeplessness, fatigue and emotional functioning*)	• HR • RR • Blood pressure	No significant differences in quality of life, HR, RR, and blood pressure between the three groups were found, but the VR-breathing group was significantly less bored after the intervention compared to the classical music group. The VR-breathing group showed low HR and RR levels after the intervention and high adherence to the sessions.
Shiban (2017)	The goal of the study was to investigate the role of a relaxation technique, diaphragmatic breathing (DB), as a	*RCT (between-subjects)* Participants were randomly assigned to one of the two treatment groups: VRET (informed	• Fear of flying (*Fear of Flying Scale*) • Self-efficacy (*ad-hoc items*)	• HR • SCL • RR	Both the VRET group and the VRET + DB group showed a significant reduction in fear of flying, with a slightly greater reduction observed in the VRET + DB group. Patients in both groups experienced a reduction in subjective fear ratings

	coping mechanism during VR exposure therapy (VRET) of aviophobia.	about the importance of exposure without distraction) or VRET + DB (receiving information about DB as a coping strategy during exposure).	• Fear during the VR flights (*ad-hoc VAS scale*)		and heart rate during exposure therapy sessions, indicating the effectiveness of VRET. The study also found that heart rate decreased during exposure trials, while skin conductance level remained relatively constant, reacting only at the onset of turbulence. Self-efficacy did not differ significantly between the groups, indicating that other cognitive and physiological factors may contribute to the enhanced treatment effects observed in the VRET + DB group.
Soyka (2016)	This research aimed to evaluate the efficacy of a VR application, specifically focusing on an underwater virtual world for paced breathing techniques, compared to standard breathing techniques, for stress management.	*Between-subjects* Participants were divided into the Under Water Environment (UWE) condition and the control group (JELLY condition)	• Stress level before and after going into virtual reality (*ad hoc item*) • Perceived relaxation (a*d hoc item*)	• HR • HRV	No differences were found in relaxation.
Stromberg (2015)	This study aimed to investigate the effectiveness of a visually and audibly mediated slow diaphragmatic breathing (DB) intervention in a motion sickness inducing environment.	*RCT (between subjects)* Participants were randomly assigned to either the experimental group (trained in slow DB) or the control group (briefed on attention control manipulation).	• Perceived motion sickness (*Motion Sickness Assessment Questionnaire*) • Perceived motion sickness during VR (*ad-hoc items*) • Self-efficacy (*ad-hoc items*)	• HR • HRV • RR	The results showed that subjects trained in slow DB exhibited lower respiration rates and higher respiratory sinus arrhythmia (RSA) values compared to the control group. They also reported fewer motion sickness symptoms. The slow DB intervention was effective in reducing motion sickness severity.
Tinga (2019)	The aim of this study was to assess the effectiveness of respiratory biofeedback during VR meditation in reducing subjective tension and objective arousal after stress.	*RCT (between subjects)* Participants were randomly assigned to a respiratory biofeedback condition (visual feedback paired to breathing), a control feedback placebo condition (visual	• Subjective arousal (*ad-hoc VAS scale*)	• HR • HRV • RMSSD • EEG	The results showed that subjective and objective arousal decreased during meditation in all conditions, indicating the overall effectiveness of VR in relaxation exercises. However, respiratory biofeedback was not the most effective in reducing arousal. The reduction in arousal (on all outcome measures combined and HR specifically) was largest in the control feedback placebo condition, suggesting that respiratory biofeedback had no

		feedback not paired to breathing), or a control no-feedback condition (no visual feedback).			additional value and was even less effective than control feedback placebo.
Weerdmeester (2021)	The primary aim of this study was to assess the effectiveness of a VR biofeedback video game called DEEP in reducing anxiety symptoms. The study also examined changes in cognitive appraisals such as self-efficacy, locus of control, and threat-challenge appraisals, and their relationship to anxiety regulation.	*RCT (between subjects)* Participants were randomly assigned to DEEP (experimental condition) or a phone-based guided breathing application (control condition)	• State-trait anxiety (*State Trait Anxiety Inventory*) • Self-efficacy (*competence subscale of the Player Experience of Need Satisfaction*) • Locus of control (*self-agency subscale of the Appraisal Questionnaire*) • Threat challenge (*ad-hoc items*)	-	The results showed that all participants experienced a decrease in trait anxiety symptoms after using the applications, and this reduction was maintained at a 3-month follow-up. However, DEEP did not outperform the control application, suggesting that the additional elements in DEEP did not provide additional benefits beyond the guided breathing exercise provided by the control application. Changes in self-efficacy, locus of control, and threat-challenge appraisals were related to anxiety regulation. DEEP players showed an increase in self-efficacy over the course of the training, while their locus of control became more external. Participants in both conditions appraised the training as challenging rather than threatening, and these challenge appraisals were related to stronger decreases in anxiety.
Weerdmeester (2022)	The study aimed to investigate the effectiveness of including visualizations that mirror changes in breathing in a biofeedback video game intervention (DEEP) for anxiety regulation.	*RCT (between subjects)* Participants were randomly assigned to the experimental (DEEP with breathing mirroring) or control condition (DEEP without breathing mirroring).	• State-trait anxiety (*State Trait Anxiety Inventory*) • Physiological arousal (*competence subscale of the Player Experience of Need Satisfaction*) • Locus of control (*self-agency subscale from the Appraisal Questionnaire*)	-	The presence of these visualizations did not result in stronger decreases in anxiety and arousal compared to participants who did not receive this additional visual feedback. The reinforcement technique tied to players' movement and the focus on deep diaphragmatic breathing may have been sufficient for anxiety regulation. The study also examined the relationship between cognitive appraisals (self-efficacy and locus of control) and anxiety. Participants who experienced higher self-efficacy had lower anxiety levels, and internal locus of control was related to lower post-play anxiety. However, these relationships were less pronounced for self-reported physiological arousal.

Weibel (2023)	The aim of this study was to identify the optimal approach and technology to reduce stress and increase relaxation in a 30-minute session.	*RCT (between subjects)* Participants were randomly assigned to one of the four following conditions: a HRV biofeedback condition via HMD (HRV-BF_{HMD}) or via a 2D screen (HRV-BF_{screen}), a paced breathing condition via HMD (sPB_{HMD}) or via a 2D screen (sPB_{screen}).	• Mood (*Multidimensional Mood Questionnaire*) • Relaxation (*ad-hoc VAS scale*) • Stress (*ad-hoc VAS scale*)	• HR • HRV • SDNN • LF • Cardiac coherence	Results showed that HRV-BF improved the low frequency band of HRV and cardiac coherence more than sPB and using an HMD resulted in higher cardiac coherence than using a screen. No significant differences were found in mood, relaxation and stress as self-reported measures between HRV-BF and sPB, and between HMDs and screens.

VR = virtual reality; RCT = randomized controlled trial; RR = respiratory rate; RRV = respiratory rate variability; HR = heart rate; HRV = heart rate variability; RMSSD = root mean square of successive differences between normal heartbeats; LF = low-frequency power; HF = high-frequency power; EEG = electroencephalogram; SCL = skin conductance level; SBP = systolic blood pressure; DBP = diastolic blood pressure; fNIRS = functional near-infrared spectroscopy; SDNN = standard deviation of normal-to-normal heartbeat intervals; HMD =head mounted display.

2.4.1 Study design and participants

Fifteen out of the 18 included studies were randomized controlled trials, and 3 were controlled studies. Moreover, all studies had pre- and post-intervention measurements, and a follow-up measurement was conducted only by Weerdmeester et al. (2021) after three months and by Shiban et al. (2017) after one year. Across all 18 studies, a total of 1006 participants were studied. Eleven studies included young adult participants with a mean age between 18 and 29 years old, while 4 studies included participants with a mean age ranging from 33 to 55 (Barton et al., 2024; Blanke et al., 2022; Blum et al., 2019; Shiban et al., 2017). One study included participants with a mean age ranging from 6 to 12 (Savas et al., 2024), another one included participants with a mean age ranging from 55 to 64 (Schrempf et al., 2022) and another one did not report the sample's age (Stromberg et al., 2015).

Ten out of 18 studies had more female participants, while two studies had the same number of male and female participants (Lan et al., 2021; Shiban et al., 2017). Moreover, 5 studies had more male participants (Barton et al., 2024; Blanke et al., 2022; Savas et al., 2024; Schrempf et al., 2022; Weibel et al., 2023), and another one had only female participants (Kniffin et al., 2014). Ten out of 18 studies involved healthy participants. Fifteen studies were conducted in a non-hospital setting. One study involved patients recovering from COVID-19 pneumonia with persistent dyspnea (Blanke et al., 2022), another one involved pediatric oncology patients (Savas et al., 2024), and another involved patients with colorectal cancer or liver metastases from colorectal cancer undergoing surgery (Schrempf et al., 2022). Other research involved participants with insomnia (de Zambotti et al., 2022), motion sickness (Russel et al., 2014; Stromberg et al., 2015), aviophobia (Shiban et al., 2017), and severe anxiety levels (Weerdmeester et al., 2021).

2.4.2 Interventions' length

Regarding the length of the interventions, in most studies participants received a single session (Barton et al., 2024; Blanke et al., 2022; Blum et al., 2019; 2020; Kniffin et al., 2014; Russel et al., 2014; Savas et al., 2024; Soyka et al., 2014; Stromberg et al., 2015; Tinga et al., 2019; Weerdmeester et al., 2022; Weibel et al., 2023), while in other studies they received two (de Zambotti et al., 2022; Hu et al., 2021); four (Weerdmeester et al., 2021); five (Shiban et al., 2017); eight (Lan et al., 2021) or eleven or twelve sessions (Schrempf et al.. 2022). Furthermore, the VR experience was from 5 to 10 minutes long for the majority of the interventions (Barton et al., 2024; Blanke et al., 2022; Tinga et al., 2019; Blum et al., 2019; 2020; Hu et al., 2020; Kniffin et al., 2014; Russel et al., 2014; Savas et al., 2024; Schrempf et al., 2022; Soyka et al., 2014; Stromberg et al., 2015; Weerdmeester et al., 2022). In four studies, it was 20 minutes long (de Zambotti et al., 2022; Lan et al., 2021; Shiban et al., 2017; Weibel et al., 2023). Moreover, only in Weerdmeester et al. (2021), the VR experience lasted from 30 to 60 minutes.

2.4.3 Measures

We have identified several measures used in the 18 studies: validated questionnaires, ad hoc questionnaires, physiological measures, and user experience measures. Seven studies mainly used validated questionnaires to

measure pre- and post-intervention psychological outcomes such as anxiety (Blum et al., 2019; Savas et al., 2024), depression (Weerdmeester et al., 2021; 2022), negative affect (de Zambotti et al., 2022; Hu et al., 2021; Kniffin et al., 2014), relaxation (Blum et al., 2019), focus on breath (Blum et al., 2020), cognitive arousal (de Zambotti et al., 2022), regulatory skills in high-risk situations (Kniffin et al., 2014), pain (Hu et al., 2021) and fear of port catheter needle insertion (Savas et al., 2024). On the other hand, nine studies mainly used ad hoc questionnaires to measure stress (Soyka et al., 2016; Weibel et al., 2023), subjective arousal (Tinga et al., 2019), current feeling and overall mood (Barton et al., 2024; Schrempf et al., 2022), fear of flying (Shiban et al., 2017), and motion sickness (Russel et al., 2014; Stromberg et al., 2015). Other outcomes such as self-efficacy in managing motion sickness (Russel et al., 2014; Stromberg et al., 2015), breathing awareness (Blanke et al., 2022), breathing control (Lan et al., 2021), and changes in state mindfulness (Barton et al., 2024) were examined.

Several studies also collected pre- and post-intervention physiological measures such as heart rate (HR) (Kniffin et al., 2014; Russel et al., 2014; Schrempf et al., 2022; Soyka et al., 2016; Stromberg et al., 2015; Tinga et al., 2019; Weibel et al., 2023), heart rate variability (HRV) (Blum et al., 2019; 2020; de Zambotti et al., 2022; Kniffin et al., 2014; Russel et al., 2014; Shiban et al., 2017; Soyka et al., 2016; Tinga et al., 2019; Weibel et al., 2023), root mean square of successive differences between normal heartbeats (RMSSD) (Blum et al., 2019; 2020; Tinga et al., 2019), standard deviation of normal-to-normal heartbeat intervals (SDNN) (Weibel et al., 2023), respiratory sinus arrhythmia (RSA) (Stromberg et al., 2015), blood pressure (de Zambotti et al., 2022; Schrempf et al., 2022), tidal volume (Blanke et al., 2022), skin conductance level (SCL) (Shiban et al., 2017), and brain activity (de Zambotti et al., 2022; Tinga et al., 2019). Furthermore, 8 out of 18 studies also used respiration rate (RR) as a pre- and post-intervention physiological measure to test the efficacy of the technique itself (Blanke et al., 2022; Blum et al., 2020; Kniffin et al., 2014; Lan et al., 2021; Russel et al., 2014; Savas et al., 2024; Schrempf et al., 2022; Stromberg et al., 2015).

A few studies (n=9) further analyzed the impact of the interventions proposed on users' experiences and perceptions in relation to the interventions using various types of measures. Most studies used self-reported measures to gauge users' perceptions of the interventions. Barton et al. (2024) used a modified version of the Perceived Restoration of Activities Scale (PRAS) to investigate the perceived restoration of each VR intervention. Blanke et al. (2022) used an ad hoc questionnaire to evaluate patients' acceptance and feasibility of intervention. Blum et al. (2019) measured participants' liking, effort to comply, and perceived discomfort using Likert scales. De Zambotti et al. (2022) employed a Likert scale to measure participants' discomfort and difficulties. Lan et al. (2021) administered a questionnaire to assess user satisfaction and willingness to continue using the system. Savas et al. (2024) used a Visual Analogue Scale (VAS) to evaluate participants' satisfaction with the port catheter needle insertion procedure. Soyka et al. (2016) utilized ad hoc items to measure fun, task difficulty, time perception, and willingness to use the interventions in the future. Blum et al. (2020) administered a validated questionnaire to measure attractiveness, perspicuity, novelty, and stimulation. Weibel et al. (2023) utilized validated questionnaires to assess the degree of autonomy, control and competence in using the technology, the sense of presence in the virtual environment, the experience of flow, the ease of

use and perceived usability of the system. They also used some of the Unified Theory of Acceptance and Use of Technology (UTAUT) subscales (Venkatesh et al., 2003) to evaluate the effort expectancy, the facilitating conditions, the behavioral intention, and the hedonic motivation related to the technology.

Some studies measured the perceived realism of the environments, including Kniffin et al. (2014), who utilized a 7-point scale to measure the perceived realism of the interaction; Russell et al. (2014), who employed a 7-point Likert scale to rate the realism of a virtual video; and Stromberg et al. (2015), who used a 7-point scale to rate the perceived realism of the environment.

These diverse measurement approaches allowed researchers to capture participants' experiences and perceptions across a range of factors, including acceptance, satisfaction, liking, discomfort, realism, and future usage intentions.

2.4.4 Mapping the use of virtual reality

VR technology offers a wealth of opportunities for creating virtual environments that can be combined with breathing techniques for various purposes, as will be discussed in the following sections (see Table 3).

For instance, VR has been used to simulate real-world scenarios to train people on managing their breathing in different settings (n=4). By practicing breathing exercises in a safe and controlled virtual environment that replicates uncomfortable conditions they may encounter in real life, individuals can improve their skills and confidence. Shiban et al. (2017) used VR to help people with aviophobia by simulating the experience of flying. Kniffin et al. (2014) used VR to teach female participants how to manage respiration and internal state in a situation where a male avatar was making aggressive advances. Similarly, Russel et al. (2014) and Stromberg et al. (2015) used VR to reproduce real-world scenarios, such as a stormy ocean and a boat in rough seas, respectively, to help people cope with motion sickness through diaphragmatic breathing.

Another advantage of using VR is the ability to create gamified tasks that make practicing breathing techniques fun and enjoyable (n=3). Weerdmeester et al. (2021, 2022) and Savas et al. (2024) incorporated game-like elements to make participants practice breathing techniques in response to changes in the virtual environment. These elements could include interactive elements (e.g., expanding and contracting circles) within the virtual environment that prompt participants to regulate their breathing in specific ways.

VR further allows users to escape from their real-life stressors and immerse themselves in controlled, calming environments (n=5). This typically involves being in a calming environment (Schrempf et al., 2022) or calming natural environment, such as a forest, beach, or mountain setting, where visual and auditory cues can help to promote a sense of calm and reduce distractions from the outside world, such as a virtual forest environment with birds and crickets (de Zambotti et al., 2022; Weibel et al., 2023), a virtual beach at sunset (Blum et al., 2019), or a stylized natural landscape with rocks and flowers, displaying hills and swaying trees in the background (Blum et al., 2020). In these environments, participants can practice slow diaphragmatic breathing through either a guided meditation (de Zambotti et al., 2022) or by controlling environmental elements' changes with their breath (Blum et al., 2019; Blum et al., 2020; Weibel et al., 2023).

VR also provides the possibility of creating symbolic scenarios (n=3). Tinga et al. (2019), for example, used a white cloud to symbolically represent their breathing, in particular by approaching it when they were inhaling and distancing itself when exhaling. Similarly, Soyka et al. (2016) used an animation of a jellyfish so that participants could follow its rhythmic movements to control their breath and Barton et al. (2024) used a sphere representing participants' breathing which gradually increase its visual features.

Finally, VR can provide synchronous or asynchronous bodily visual feedback (n=3), using either full virtual bodies (Blanke et al., 2022; Lan et al., 2021) or specific body parts, such as 3D lungs (Hu et al., 2021). The use of bodily visual feedback in VR can help users to better understand and control their own movements and bodily sensations, which can be useful for practicing breathing techniques.

These environments are integrated with various breathing techniques to achieve different goals, such as controlling internal status and reducing clinical symptoms. Interestingly, in all 18 studies identified, immersive VR was used through tethered VR headsets such as Meta Quest 2 (Barton et al., 2024), Oculus CV1 (Blum et al., 2019; Blum et al., 2020), Oculus Rift (de Zambotti et al., 2022; Hu et al., 2021), Oculus Rift DK2 (Tinga et al., 2019), Oculus Go for Business (Schrempf et al., 2022), Oculus Quest (Weibel et al., 2023), eMagin 2800 3D visor (Kniffin et al., 2014), HTC Vive (Lan et al., 2021; Weerdmeester et al., 2021, 2022), and HMD V6 (Shiban et al., 2017). One study used a smartphone-based VR headset (Zeiss VR ONEPLUS and Samsung Galaxy s8) (Blanke et al., 2022), and Russel et al. (2014) employed a 3D head mounted goggle set with over the ear headphones. Three studies did not specify the headset used (Savas et al., 2024; Soyka et al., 2016; Stromberg et al., 2015).

Table 3. VR device, VR setting, integration with breathing techniques, and biofeedback.

First author (year)	VR device	Biofeedback	*VR experience* Description	*Type of breathing* Intervention
Barton (2024)	Tethered VR headset (Meta Quest 2, Meta Quest 1, HTC Vive)	no	*Calming and symbolic scenario* Participants experienced a virtual environment with a narrow field of view to sustain focus and reduce fatigue. They could see fractal-like symmetrical shapes and, in the center of the virtual scenario, the breathing sphere surrounded by a breathing pacer (a circle).	*Slow paced breathing* In this 6-minute virtual scenario, participants were asked to synchronize the movement of a sphere connected to their breathing with the movement of the visual pacer that had a rate of 6 breaths per minute. The environment around the sphere gradually increased its visual complexity with different shapes and colors to promote interest and engagement. Participants were asked to spread the arms outwards during the inhale phase and to bring the arms back together during the exhale phase. Movements were tracked thank to the controllers in both hands.
Blanke (2022)	Smartphone-based VR headset (Zeiss VR ONEPLUS + Samsung Galaxy s8)	no	*Virtual body* Participants were instructed to look at a virtual body of the same gender lying next to them in a similar position during the virtual environment experience.	*Normal breathing* Participants received synchronous or asynchronous feedback of their breathing via a gender-matched virtual body. The visuo-respiratory stimulation lasted 5 minutes. In the synchronous condition, the virtual body illuminated with maximal radiance at the end of inspiration and minimal at the end of expiration. In the asynchronous condition, the visual stimulation was randomly generated with a phase-shift and frequency modulation.
Blum (2019)	Tethered VR headset (Oculus CV1)	yes	*Natural environment* Participants experienced a virtual beach scenery at sunset, including various elements such as palms, rocks, and a campfire, accompanied by ambient instrumental background music and sounds of the ocean and campfire.	*Diaphragmatic breathing* Participants performed diaphragmatic breathing at a rate of 6 breaths per minute with auditory guidance while receiving either standard graphical feedback (control group) or VR feedback (experimental group) during a single 10-minute heart rate variability biofeedback session.
Blum (2020)	Tethered VR headset (Oculus CV1)	yes	*Natural environment* Both experimental and control groups experienced a virtual environment of a stylized natural landscape with hills, rocks, flowers, and swaying trees.	*Diaphragmatic breathing* Certain elements, such as flowers, parts of trees, and rocks, were designed to change color either randomly (control group) or according to participant's respiration (experimental group). Participants completed a single session practicing slow diaphragmatic breathing for 7 minutes in VR while either performing breathing exercise or receiving a respiratory biofeedback
de Zambotti (2022)	Tethered VR headset (Oculus Rift)	yes	*Natural environment* The study utilized the Nature Treks VR app Version 1.71 to provide a virtual	*Diaphragmatic breathing* Participants either practiced slow diaphragmatic breathing in a VR-guided meditation or engaged in quiet activities for 20 minutes in two non-consecutive evening sessions before bedtime.

			environment of a forest during an orange sunset with birds and crickets.	
Hu (2021)	Tethered VR headset (Oculus Rift)	no	*Virtual body* Participants were shown 3D virtual lungs.	*Diaphragmatic breathing* Participants were randomly assigned to either interoceptive breathing focusing sessions using VR technology (VRB group), watching a VR display of a 3D lungs image that synchronized with their inhaling and exhaling cycles or traditional mindful breathing (TMB group), imagining their breathing inflating and deflating in an abstract manner. During the experimental week, on the first and seventh days, both groups had a 10-minute breathing practice and 20 trials of the thermal quantitative sensory test (tQST) in-person in the lab. From the second to the sixth day, participants practiced home self-guided exercises. In the VRB group, participants watched a 3D VR display of synchronized inhaling and exhaling cycles for 10 minutes and listened to their breathing sounds using headphones. In the TMB group, participants imagined their breathing inflating and deflating abstractly. Both groups were instructed to perform diaphragmatic breathing.
Kniffin (2014)	Tethered VR headset (eMagin 2800 3D visor)	no	*Real-world setting* The study involved participants having an interaction with a male avatar controlled by a male experimenter in an adjacent room within a virtual reality setting. The virtual scene featured an automobile interior with bucket seats and an exterior view simulating a rainy evening with the automobile parked near a lake. The interaction began with small talk, and the actor made sexual advances, which escalated into more aggressive behavior and anger towards the participant.	*Diaphragmatic breathing* Participants were randomly assigned to either a breathing or attention control condition and listened to instructions before an 8–12-minute VR interaction with a male avatar. Participants in the breathing condition received audio instructions on diaphragmatic breathing and were instructed to use the technique throughout the experiment at a pace of 3-7 breaths per minute.

Lan (2021)	Tethered VR headset (HTC Vive)	yes	*Virtual body* A 3D human body model and a realistic facial model based on a fontal face photo supplied by the participant.	*Diaphragmatic breathing* During the virtual reality experiment, participants were asked to use abdominal breathing and focus on slowing down their breathing rate. The experimental group was given a 3D human body model that simulated the changing of body temperature with a virtual line that changed thickness and color based on their breathing rate, while the control group received no feedback. They had 8 training sessions, 4 times a week for 2 weeks, each lasting 20 minutes. In each training session, they were encouraged to slow down their breathing as much as possible.
Russel (2014)	3D head mounted goggle set with over the ear headphones	no	*Real-world setting* The virtual experience consisted of a 10-min color video of ocean swelled in a stormy sea. The participants experienced a fluctuating view of a stormy dark blue horizon and that then followed the wave downwards until only water was visible	*Diaphragmatic breathing* Depending on their assigned condition, participants were either briefed on diaphragmatic breathing techniques or received an attention control manipulation involving instructions on being aware of their surroundings. Both groups then experienced a 10-minute VR simulation of an ocean swelled in a stormy sea and were asked to use the given instructions
Savas (2024)	VR headset	yes	*Gamified task (BioVirtualPed)* The VR environments consisted of a submarine environment and a garden environment.	*Not specified* Patients could choose one of the two 5-minute virtual environments available (a submarine scenario and a garden scenario) and interact with it using slow and regular breathing during the port catheter needle insertion procedure. Specifically, new sea creatures were added to the submarine environment and flowers and trees were added to the garden environment as the participant breathed slowly and regularly.
Schrempf (2022)	Tethered VR headset (Oculus Go for Business)	no	*Calming environment* The VR experience was designed to produce a calming effect.	*Not specified* Participants received around 11 and 12 sessions over the 6 days spent in the hospital, with 2 sessions per day (one in the morning and one in the evening), each lasting 8–10 minutes. One or two sessions were administered before surgery, depending on the admission hour in the hospital, and the others after surgery until discharge from the hospital. In each session, participants were guided by a narrator and were invited to perform guided reflections and breathing exercises with breath visualization.

Shiban (2017)	VR headset (HMD V6)	no	*Real-world scenario* The VR environment simulated a passenger compartment of a Boeing 73.	*Diaphragmatic breathing* Participants received either virtual reality exposure therapy or virtual reality exposure therapy with diaphragmatic breathing. The latter group received breathing instructions during the exposure session and were instructed to inhale through the nose for 4 seconds, exhale through the mouth for 6 seconds, and maintain a respiration frequency of 6 cycles per minute.
Soyka (2016)	Not specified	no	*Symbolic scenario* Participants saw a jellyfish moving in an underwater environment.	*Normal breathing* Participants were randomly assigned to either an Under Water Environment (UWE) condition or a control group (JELLY condition) and received a single 10-minute virtual reality session. In the virtual underwater environment, participants saw a jellyfish moving up and down in the 6 seconds paced breathing rhythm.
Stromberg (2015)	Not specified	no	*Real-world scenario* The VR experience showed a boat in rough seas	*Diaphragmatic breathing* Participants were assigned to an experimental or control group and received a single 50-minute session including instructions, a breathing practice session, and a VR experience of a boat in rough seas. The experimental group received training in slow diaphragmatic breathing (DB) techniques, while the control group received attention control manipulation.
Tinga (2019)	Tethered VR headset (Oculus Rift DK2)	yes	*Symbolic scenario* The VR experience showed a white cloud moving towards and away from participants.	*Mindful breathing* Participants were randomly assigned to a respiratory biofeedback condition, a control feedback placebo condition, or a control no-feedback condition. All groups received a single session including arousal induction and a 6-minute VR audio guided meditation focused on mindful breathing. The respiratory biofeedback group controlled a cloud in the virtual environment with their respiration, while the control feedback placebo group saw the cloud moving automatically, and the control no-feedback group only saw a blue background.

Weerdmeester (2021)	Thetered VR headset (HTC Vive)	yes	*Gamified task (DEEP)* The VR environment consisted of a virtual underwater world.	*Diaphragmatic breathing* Participants with high scores on anxiety, stress, or depression were randomly assigned to the DEEP or phone-based guided breathing conditions. Both conditions received multiple sessions, including a 1-hour session and a 30-minute session in a relaxing environment (training phase 1), followed by a 30-minute session and a 1-hour session in an exposure environment (training phase 2). In the DEEP condition, participants experienced a virtual underwater world with biofeedback during diaphragmatic breathing. In the control condition, participants were asked to breathe through their diaphragm and match their breathing to instructions.
Weerdmeester (2022)	Tethered VR headset (HTC Vive)	yes	*Gamified task (DEEP)* The VR environment consisted of a virtual underwater world.	*Diaphragmatic breathing* Participants played a 10-minute single session of DEEP, a virtual biofeedback video game. They were instructed to use deep and calm diaphragmatic breathing during the game, allowing them to move through the virtual underwater world. In the experimental condition, participants were shown visualizations that mirrored their breathing.
Weibel (2023)	Tethered VR headset (Oculus Quest)	yes	*Natural environment* Participants experienced a mountainous virtual environment as if they were sitting on a tree trunk overlooking a beautiful field with flowers. It was bordered by trees, plants, stones, and distant mountain peaks. They could also see the sun and hear birds' songs and hear running water.	*Slow paced breathing* In the biofeedback conditions (both with HMD and screen), HRV changes related to the paced breathing exercise led to changes in the virtual environment (e.g., flower growth, sun rising on the horizon, increased brightness). In the slow paced breathing conditions (both with HMD and screen), the changes in the environment were not related to participants' HRV. Participants had two 10-minute training sessions.

VR = virtual reality; HRV = heart rate variability; HMD = head mounted display.

2.4.5 Mapping the use of breathing

2.4.5.1 Types of breathing

Regarding breathing, several studies used diaphragmatic breathing at a frequency of 6 breaths per minute (Barton et al., 2024; Blum et al., 2019; de Zambotti et al., 2022; Shiban et al., 2017; Stromberg et al., 2015; Weerdmeester et al., 2021, 2022) or at a frequency of 3-7 breaths per minute (Kniffin et al., 2014) or at a frequency of 4.5-6.5 breaths per minute defined by the authors as slow paced breathing (Weibel et al., 2023). Tinga et al. (2019) employed mindful breathing, whereas Blanke et al. (2022) asked participants to breathe normally while receiving synchronous (intervention) and asynchronous (control) feedback of their breathing. Only three studies have not specified the type of breathing used (Savas et al., 2024; Soyka et al., 2016; Schrempf et al., 2022).

2.4.5.2 Breathing techniques and their integration with VR

Two methods can be distinguished for helping participants breathe properly. The first method consists of giving breathing instructions before the VR experience, and the second one consists of giving breathing instructions during the VR experience. The latter method, in turn, includes using pacers that participants listen to or watch to breathe properly during the VR experience or using biofeedback during the VR experience, through which participants can interact with the virtual environment and change it according to their breath.

For example, regarding the first method, participants were asked to listen to a short set of audio instructions training in diaphragmatic breathing before the VR exposure. Then, they were instructed to use these skills throughout their remaining time in the experiment (Kniffin et al., 2014; Russel et al., 2014; Stromberg et al., 2015; Tinga et al., 2019; Weibel et al., 2023). Interestingly, in one study, participants were asked to practice breathing at home for four days following the given instructions (Hu et al., 2021).

Concerning the second method, pacers were introduced to guide participants' breathing during the VR experience (Schrempf et al., 2022). For example, de Zambotti et al. (2022) provided pre-recorded breathing audio files for inhaling (a person breathing in through the nose) and exhaling (a person breathing out through the mouth). In other studies, participants were asked to follow the rhythmic motion of a jellyfish with their breathing (Soyka et al., 2016), or an oval or a circle that expanded (inhale) and retracted (exhale) during the VR experience (Barton et al., 2024; Stromberg et al., 2015), or a semi-transparent white cylinder with a small disc going up and down inside it (Weibel et al., 2023). Furthermore, audible cues to breathe appropriately during the virtual scenario were introduced by Stromberg et al. (2015) and Shiban et al. (2017). In Hu et al. (2021), researchers gave orientation on the breathing pattern beforehand, and the participants could visualize the 3D lungs reproducing their breathing cycles.

Biofeedback was also employed to help participants breathe during the VR experience. For instance, in Blum et al. (2019), the cloud coverage in the sky was associated with breathing and heart rate variability: the better the latter parameter, the clearer the sky became. In Weibel et al. (2023), a higher increase in heart rate variability

led to the flowers growing, the sun rising on the horizon, and the natural soundscape intensifying, creating a brighter and more colorful environment.

In another study, the cloud moved towards the participant while breathing in and away from the participant while breathing out (Tinga et al., 2019). In Blum et al. (2020), elements of the VR environment, such as flowers, parts of trees, and rocks, were able to change their color whenever the participant was exhaling. The color change lasted as long as the respective exhalation. In Savas et al. (2024), new sea creatures were added to the submarine environment and flowers and trees were added to the garden environment as the participant breathed slowly and regularly. In one study, to simulate the changing of body temperature, a virtual line in the center of the virtual body was created. The thickness and colors of this line changed according to the breathing rates. When the participant breathed slower, this central line became thicker, and its color changed from yellow to red (Lan et al., 2021). In two studies using an underwater virtual environment, up- and forward-forces were applied with each inhale, and a speed boost was applied with each exhale. Moreover, the plants changed in size and illumination according to inhalation or exhalation. During deep and calm exhalations, participants could also use a flashlight to illuminate a dark cave. Another visual feedback was provided by an expanding and contracting circle (i.e., getting bigger with the inhale and smaller with the exhale) in the players' field of vision (Weerdmeester et al., 2021; Weerdmeester et al., 2022).

2.4.6 Outcomes

Breathing has been used to promote different goals. For example, it was employed to promote relaxation, decrease arousal levels, improve breathing control and focus on breath, and decrease clinical and perceived physical symptoms.

2.4.6.1 Relaxation

Four studies used breathing to promote relaxation, and specifically 3 involved healthy participants (Barton et al., 2024; Blum et al., 2019; Soyka et al., 2016) while one involved cancer patients (Schrempf et al., 2022). In Barton et al. (2024), breathing has been used to promote relaxation, calmness, positive mood and to reduce mental fatigue. The healthy participants were randomized in three groups. The Interactive VR group experience a 6-minute scenery in which participants were asked to synchronize the movement of a sphere connected to their breathing with the movement of a visual pacer. The Passive VR group had no control over the 6-minute virtual scenery and participants were asked to breathe normally. The Nature VR group watched a 360° nature video on YouTube VR. Results showed no significant differences between groups, but mental fatigue and anxiety decreased and calmness and relaxation increased in all conditions. Moreover, the Interactive VR group reported increased focus and decreased sadness, while there were no changes in the other groups. In Blum et al. (2019), breathing, in combination with heart-rate variability biofeedback, has been used to promote relaxation, relaxation self-efficacy, focus on the present and attentional resources, and reduce mind wandering after a cognitive stressor task. Specifically, the healthy participants were randomized into two groups. The VR-based heart rate variability biofeedback group (VR-BF) experienced a 10-minute virtual beach scenery with

accompanying sounds and music while performing slow diaphragmatic breathing. The standard heart rate variability biofeedback group (Standard-BF) received abstract feedback in the form of graphical geometrical indicators. Physiological measures such as HRV, RMSSD, and heart coherence were measured using a Polar H7 chest strap, while relaxation self-efficacy, mind wandering, focus on the present, and attentional resources were assessed using questionnaires and computerized tasks. Results showed that the VR-BF intervention increased self-efficacy, relaxation and focus on the present over time and promoted a reduction in reaction times and in mind-wondering compared to the Standard-BF intervention. In other research, breathing has been used to enhance relaxation and reduce stress after a stressful task in healthy participants. For example, Soyka et al. (2016) randomly assigned healthy participants to either the Under Water Environment (UWE) condition or the control group (JELLY condition). Both groups received a single 10-minute session of VR, but only the UWE group was immersed in an underwater environment and instructed to follow the rhythmic motion of a jellyfish with their breathing. The control group only saw the jellyfish without any surrounding environment. Both groups heard the same underwater sounds, and a piezo-electric crystal respiration effort sensor was placed around participants' chests to detect breathing. HR and HRV were also measured with a blood pulse sensor on the left index finger (Brain Products). Participants were asked to rate their level of relaxation and enjoyment after the VR session. Results showed no significant differences in relaxation between the two groups, but the UWE condition was rated as more fun and more likely to be used at home than a traditional breathing technique. In clinical settings, Schrempf et al. (2022) focused on promoting quality of life, relaxation and positive mood in cancer patients undergoing surgery. They randomly assigned participants to the VR-breathing condition, or the classical music condition or the control group receiving standard treatment. The study involved around 11 and 12 sessions over the 6 days spent in the hospital, with 2 sessions per day, each lasting 8-10 minutes. Results showed no significant differences in quality of life, HR, RR, and blood pressure between the three groups, but the VR-breathing group appeared significantly less bored after the intervention compared to the music group and showed high adherence to the sessions.

2.4.6.2 Arousal reduction

Three studies employed breathing to promote arousal reduction in healthy participants. For example, Tinga et al. (2019) aimed to examine the effectiveness of respiratory biofeedback during VR meditation in lowering subjective and objective arousal after stress. The healthy participants were randomly assigned to one of the following conditions: (a) a respiratory biofeedback condition in which visual feedback was paired to breathing (i.e., clouds moving towards the participant while breathing in and away from the participant while breathing out); (b) a control feedback placebo condition in which visual feedback was not paired to breathing; (c) control no-feedback condition in which no visual feedback was used. Participants were instructed to follow the audio-guided meditation instructions while keeping their eyes open and then experienced a 6-minute meditation task in VR. Breathing, HR, HRV, and RMSSD were detected using a BioNomadix wireless system, and the researchers found a greater reduction in arousal in the control feedback placebo condition. Breathing in combination with biofeedback was also employed by Weibel et al. (2023) who aimed to identify the optimal

approach and technology to reduce stress in a single session. The healthy participants were randomly assigned to one of the following conditions: (a) a HRV biofeedback condition via HMD (HRV-BF_{HMD}) and (b) a HRV biofeedback condition via a two-dimensional desktop screen (HRV-BF_{screen}) in which HRV changes related to the paced breathing exercise led to changes in the virtual environment (e.g., flowers growth, increased brightness); (c) a paced breathing condition via HMD (sPB_{HMD}) and (d) a paced breathing condition via a two-dimensional desktop screen (sPB_{screen}) in which the changes in the environment were not related to participants' HRV. Physiological measures such as HRV, SDNN and cardiac coherence were measured using a Polar H10 chest strap, while relaxation, stress, and mood were assessed using questionnaires. Results showed that HRV-BF improved the low frequency band of HRV and cardiac coherence more than sPB and using an HMD resulted in higher cardiac coherence rather than using a screen. In other research, breathing has also been employed as a self-regulation strategy during interactions with an aggressive male. For instance, Kniffin et al. (2014) investigated whether diaphragmatic breathing (measured through a strain gauge sensor placed around the participant's abdomen) could be used to improve healthy women's regulatory skills in high-risk situations. Researchers randomly assigned participants to either a breathing or attention control condition and underwent an 8–12-minute VR interaction with a male avatar in an automobile interior with bucket seats and an exterior view simulating a rainy evening. The breathing group received brief audio instructions training them in diaphragmatic breathing, while the control group listened to a short audio recording and was instructed to pay careful attention. HR, HRV, and RR were measured. The breathing group had a decrease in HRV over the course of the trial and slowed its respiration rate following the VR experience. These results suggest that training in diaphragmatic breathing may improve physiological outcomes after this type of VR exposure.

2.4.6.3 Breathing awareness and focus on breath

Breathing has also been used to promote breathing awareness: specifically, 2 studies involved healthy participants (Lan et al., 2021; Blum et al., 2020) and one study involved patients recovering from COVID-19 pneumonia (Blanke et al., 2022). For instance, Lan et al. (2021) aimed to improve participants' breathing control and sleepiness. They assigned healthy participants to either the feedback group or the control group with no feedback. During the eight VR experiences, they were asked to use abdominal breathing, and a pressure sensor attached to the abdomen was used to detect it. For each participant in the feedback group, a realistic 3D human body model was created with a central virtual line that changed its thickness and color according to the participant's breathing. A heating pad was sewn into the clothes of the participants to simulate the rising body temperature experienced by well-trained mediators when they enter a deep state of meditation. The study involved 8 training sessions over 2 weeks, with 4 sessions per week, each lasting 20 minutes. Results showed that the feedback group was able to control breathing in a more uniform way during the training and reported fewer eye-blinking events compared to the control group. Another example can be the study of Blum et al. (2020) in which they investigated the efficacy of a developed biofeedback algorithm on fostering focus on breath. Participants were randomized to a control or feedback group. They received a single session of VR breathing exercises in a virtual environment depicting a stylized natural landscape and were instructed to

practice slow diaphragmatic breathing. For the feedback group, the simulation was further integrated with a respiratory biofeedback system in VR that made elements change color in response to the participant's exhalation, serving as respiratory feedback. On the other hand, the control group did not receive feedback. Physiological parameters such as HRV, RMSSD, LF, and HF were measured using a Polar H10 chest strap, and the VR-controller on the abdomen was used to detect inhalations and exhalations. Following this intervention, the feedback group increased the use and duration of diaphragmatic movements, reported an easier focus on the breath, a lower respiration rate, and higher RMSSD and LF compared to the control group. In addition, Blanke et al. (2022) focused on alleviating dyspnea in patients recovering from COVID-19 pneumonia and improving their breathing comfort, awareness, and agency. They detected breathing with the Go Direct® Respiration belt and used VR to embody participants in a gender-matched virtual body and to then manipulate the breathing feedback (synchronous or asynchronous with respect to the patient's chest movements). Participants received both synchronous (intervention) and asynchronous (control) feedback of their breathing. While no significant differences were found between the intervention and control groups, breathing comfort improved after the synchronous feedback intervention compared to baseline, and 91.2% of patients were satisfied with the intervention, with 66.7% perceiving it as beneficial for their breathing.

2.4.6.4 Clinical symptoms reduction

Breathing has been used to reduce clinical symptoms in 5 studies. Specifically, Savas et al. (2024) aimed to reduce psychophysiological symptoms such as anxiety and fear associated with a port catheter needle insertion in pediatric oncology patients and their mothers. They investigated the effects of a VR intervention called BioVirtualPed which consisted of two scenarios (a submarine environment and a garden environment) that patients could choose and interact with using slow and regular breathing during the port catheter needle insertion procedure. Respiration rate was measured using the ADXL354 sensor. Results showed that patients in the intervention group reported significantly lower fear and anxiety levels compared to patients in the control group who did not experience VR, as well as their mothers. Weerdmeester et al. (2021, 2022) also aimed to reduce anxiety. They investigated the effects of a VR intervention called DEEP, which consisted of a virtual underwater world where clinical participants used slow-paced breathing techniques to influence their movement. A controller belt measured the expansion of participants' diaphragms. In Weerdmeester et al. (2021), participants trained in a relaxing environment during the first phase (1 hour and 30 minutes) and in an exposure environment (a dark cave with only a dim flashlight that illuminates during deep and calm exhalations) during the second phase (1 hour and 30 minutes) a significant reduction in trait anxiety symptoms from pre- to post-test was found both in the DEEP condition and in the control condition that used a phone-based guided breathing application. Furthermore, DEEP players reported lower self-efficacy and perceived resources in session one, felt less internal control in the third session, and had lower threat-challenge ratios compared to the control group. However, DEEP players showed an increase in self-efficacy over the course of the training, and they were more engaged in the first session compared to those in the control group. Moreover, Weerdmeester et al. (2022) aimed to investigate the extent to which the mirroring visualizations in DEEP

increase healthy players' ability to regulate their anxiety and whether the presence of these visualizations would result in higher levels of internal locus of control and self-efficacy. In this study, participants were randomly assigned to either an experimental condition where they played DEEP with visualizations that mirrored their breathing, or a control condition without the mirroring visualizations. After a brief instruction and preparation phase of the Trier Social Stress Test (TSST), participants in both conditions played DEEP for 10 minutes. The results showed that participants in the experimental condition did not show greater reductions in anxiety and arousal and increases in self-efficacy and locus of control compared to the control group. However, the more self-efficacy participants experienced while playing DEEP, the lower their anxiety was immediately after playing, and the stronger their pre- to post-play decrease in anxiety was. Shiban et al. (2017) focused instead on fear of flying reduction. They created a safe and controlled environment to simulate the experience of flying and used this stimulation to examine the effects of diaphragmatic breathing as a coping strategy for aviophobia. The respiration rate was measured with a strap placed around the waist in the three VR flights, each lasting 22.5 minutes. HR and SCL were also measured. The researchers found a greater tendency to overcome the fear of flying in the diaphragmatic breathing group compared to the non-diaphragmatic breathing group. On the other hand, de Zambotti et al. (2022) investigated the effects of a VR-based mind-body approach on reducing bedtime arousal in adolescents with insomnia. The Nature Treks VR app was used to provide a virtual forest environment with birds and crickets, and thoracic and abdominal piezoelectric breathing bands were employed to detect breathing movements. Other physiological parameters such as ECG, HRV, LF, HF, EEG, and systolic and diastolic blood pressure were measured using various sensors. Participants in the experimental group engaged in VR-guided meditation for two non-consecutive evening sessions, with each session lasting 20 minutes. Within the environments, they practiced slow diaphragmatic breathing following a prerecorded breathing audio file for inhaling and exhaling while interacting with the environment by grabbing spheres with symbols to activate a rain sound and a dark mode to further rest their breathing. On the other hand, participants in the control group were asked to engage in a quiet activity. Results showed lower physiological arousal in the experimental condition compared to the control group. Results also showed that the intervention resulted in acute autonomic and cortical modulation, leading to lower physiological arousal, heart rate, and cortisol compared to the control condition. Resting-state HR was also significantly lower after the VR-guided meditation and paced breathing intervention session compared to pre-intervention levels and compared to levels preceding and following quiet activities.

2.4.6.5 Perceived physical symptoms reduction

In reviewing the literature, it has emerged that 3 studies have not only emphasized the psychological outcomes but have also investigated the impact of combining VR with breathing techniques on different perceived physical symptoms.

For instance, some research employed breathing as a perceived physical symptoms reduction strategy such as pain. Hu et al. (2021) aimed to compare the effectiveness of two methods in modulating healthy participants' pain thresholds. To do this, they randomly assigned participants to one of two conditions: (a) interoceptive

breathing focusing sessions using VR 3D lungs that synchronized with the participants' breathing cycles in real time (VRB) or (b) traditional mindful breathing (TMB). A Braebon plethysmography belt was used to synchronize the 3D lungs with participants' inhalation and exhalation cycles during their diaphragmatic breathing. Results showed that, after a week of practice, both breathing interventions resulted in a significant increase in pain thresholds, with no significant between-group differences. TMB modulated the prefrontal cortex to facilitate sensory-interoceptive processing of breathing but inhibit sensory-discriminative pain processing. VRB, on the other hand, augmented cortical visual-auditory activations to override pain processing and raise the pain threshold. On the other hand, Russell et al. (2014) and Stromberg et al. (2015) aimed to examine the effect of diaphragmatic breathing strategies on motion sickness. In both studies, the experimental group was debriefed on diaphragmatic breathing and then invited to use it during the 10-minute VR experience (a stormy ocean and a boat in rough sea, respectively). On the other hand, the control group received only attention control manipulation before the VR exposure. A respiration sensor was placed around the abdomen, and a respiratory effort transducer was used to detect breathing. HR and HRV were also measured with three electrodes connected to a BioPac ECG100C electrocardiogram amplifier module. In Russel et al. (2014), results showed that the diaphragmatic breathing protocol increased parasympathetic nervous system tone, slowed RR, and decreased the development of motion sickness symptoms as compared to the control condition. The study also found a significant positive correlation between an increased RR and more motion sickness symptoms in the diaphragmatic breathing condition. Furthermore, in Stromberg et al. (2015), the diaphragmatic breathing group reported lower breathing rates, a higher HRV, and reduced motion sickness severity as compared to the control group.

As we can see, breathing techniques can be used to manage relaxation, arousal, and breathing awareness and reduce both psychological and perceived physical symptoms.

2.4.7 User experience

Barton et al. (2024) investigate the perceived restoration of each VR intervention and no differences were found between the three conditions. They also assess the physical and mental effort employed by participants during the VR experience. Results showed that the Interactive VR condition involved significantly greater physical and mental effort than the passive VR condition.

Blanke et al. (2022) assessed patients' acceptance and feasibility of VR intervention through an ad hoc questionnaire. The results showed that a majority of the patients (91.2%) were satisfied with the intervention, and 66.7% reported respiratory benefits. Additionally, a significant proportion expressed a desire to continue using the device during recovery and at home. Some patients also indicated a preference for earlier usage during their hospital stay. Overall, the findings suggest positive acceptance and the feasibility of VR intervention.

Blum et al. (2019) assessed participants' overall experience of the biofeedback treatment by measuring liking, effort to comply, or perceived discomfort. The results revealed no significant differences between the groups in terms of effort to comply and perceived discomfort. However, the VR-BF group reported higher liking ratings compared to the Standard-BF group, with a statistically significant difference observed. Blum et al.

(2020) assessed users' experience using the User Experience Questionnaire (UEQ; Laugwitz et al. 2008) with four subscales: attractiveness, perspicuity, novelty, and stimulation. The overall mean values were high in both conditions (breathing exercise and biofeedback), suggesting a satisfying user experience. A separate one-way ANOVA was conducted for each subscale, and there were no significant differences between the two conditions, indicating that the addition of biofeedback did not significantly alter the user experience.

De Zambotti et al. (2022) assessed the potential discomfort and difficulties experienced by participants during a bedtime intervention session involving VR immersion and slow breathing. Participants were asked to rate discomfort and difficulties the following morning on a Likert scale. Most participants perceived low discomfort associated with VR immersion, while slowing down breathing was challenging for 30-40% of the sample.

After the role-play, Kniffin et al. (2014) asked participants to rate the perceived realism of the interaction on a 7-point scale. The results showed that participants in the VR condition rated the interaction as more real than those in the non-VR condition. Additionally, participants in the VR condition reported higher levels of negative affect both during and after the interaction compared to those in the non-VR condition. These findings suggest that VR increases the realism of such role-plays.

In the study conducted by Lan et al. (2021), a questionnaire was administered to gauge user satisfaction and willingness to continue using the system for long-term meditation practice. The results revealed that subjects in the feedback group exhibited stronger agreement across most of the questions (e.g., "I find this breathing control experiment enjoyable"). Notably, they found the multimodal feedback system for meditation training enjoyable, as indicated by their responses to the first question.

Russell et al. (2014), after the experiment, asked participants to rate the realism of a virtual video on a seven-point Likert scale, including how real it looked and how real the boat motion felt. The study found no significant difference in perceived realism between the diaphragmatic breathing condition and the control condition.

Savas et al. (2024) investigated their participants' satisfaction with the port catheter needle insertion procedure and participants in the intervention group reported significant higher satisfaction levels than those in the control group, as well as their mothers.

Soyka et al. (2016) asked their participants to rate the intervention in terms of fun, task difficulty, time perception, and willingness to use it in the future, using ad hoc items. The results indicated that the underwater world VR experience was perceived as significantly more enjoyable and less monotonous compared to other experiences. On average, participants found it relatively easy to synchronize their breathing with the motion of the jellyfish, although there was considerable variability. As regards time perception, it was observed that the distribution of time perception was skewed towards longer durations in the underwater world experience condition, despite the average perceived time being the same for both groups. Finally, in terms of future usage, individuals in the underwater world experience condition expressed willingness to utilize this tool at home for relaxation, while participants in the jellyfish condition displayed reluctance.

Stromberg et al. (2015) asked subjects to rate the perceived realism of an ocean swells video on a 7-point scale. Participants were asked two questions regarding the video's perceived realism: "During the video, how real

did it look?" and "During the video, how real did the motion of the boat feel?" The responses were summed to create a perceived realism scale. The scale aimed to measure how real the video looked and felt to the subjects, but results were not reported.

Weibel et al. (2023) asked their participants to rate their degree of autonomy, control, and competence, their sense of presence and flow, the ease of use and effort expectancy, facilitating conditions, behavioral intention, and hedonic motivation related to the technologies used, as well as the sickness experienced during the virtual environment experience. Interestingly, adopting slow paced breathing was associated with considerably higher perceived competence than adopting HRV biofeedback. Moreover, immersive VR was considered significantly more fun than non-immersive VR.

2.5 Discussion

The goal of the present scoping review was twofold: firstly, to map the existing literature regarding the integration of breathing techniques and the VR experience (RQ1), and secondly, to examine which health-related outcomes these VR and breathing interventions have addressed and what are their effects on these outcomes (RQ2).

Concerning the first research question, the review revealed that different breathing techniques can be employed during a VR experience to guide and synchronize the users' breath. Examples include diaphragmatic breathing, slow paced breathing and mindful breathing. These techniques usually involve slow, controlled breaths that lead to relaxation and improve breath awareness. Users may receive instructions on breathing before entering the VR environment or during the VR experience. In the first case, the instructions may be in the form of audio recordings or written instructions that teach participants how to perform specific breathing techniques. This pre-training allows participants to become familiar with the desired breathing patterns and transfer them to the VR experience. Alternatively, the VR environment may include visual cues, such as watching the movement of an object expand and contract in synchrony with inhaling and exhaling or tracking the rhythmic movement of an avatar. VR can further provide real-time biofeedback, allowing users to observe and interact with their breathing patterns in the virtual environment. In most cases, this input takes the form of visual cues, such as shifting colors, forms, or surrounding aspects in reaction to breathing. Biofeedback provides a direct link between the user's breathing and the virtual environment, improving awareness and control over breathing.

Concerning RQ1, the review further revealed that all the controlled studies meeting our criteria integrated breathing exercises in immersive, rather than non-immersive, VR experiences. Specifically, immersive VR provides highly engaging experiences that can increase the effectiveness of breathing techniques in different ways. First, while traditional breathing exercises can sometimes feel repetitive and boring, leading to a lack of motivation (Soyka et al., 2016), VR may overcome this limitation adding a new level of engagement and making breathing exercises more enjoyable. This can help users stay motivated and committed to the task at hand. Indeed, VR can turn breathing exercises into an interactive experience that feels more like a fun activity than a tedious task. This is possible thanks to VR interactivity, which refers to the exchange between the user and the virtual environment, with users being able to interact with the virtual world and eventually receive

real-time feedback. Interactivity may work at different levels. Users can interact directly with virtual items by engaging with virtual representations of their breath, for example, or controlling objects in their environment that respond to their breathing. VR's technology can further provide immediate and personalized feedback on breathing patterns. Users can receive visual and/or audio cues to indicate if they are breathing correctly or if they need to adjust their breathing. This real-time feedback helps users develop a better awareness of their breathing and allows them to make necessary corrections to improve their technique (Lüddecke & Felnhofer, 2022). However, VR's interactivity extends beyond direct physical engagement. The results of the present scoping review reveal an additional dimension of interactivity within the VR experience. Interactivity can occur even through observation, where users modify their behavior based on what they see and experience within the virtual environment without controlling or manipulating objects. This form of interactivity can involve observing and responding to ambient changes within the virtual environment. For example, it may include monitoring modifications to objects, such as clouds changing in size (Tinga et al., 2019), or following animations within a virtual environment, like tracking a moving jellyfish (Soyka et al., 2016). This allows users to adapt their responses, decision-making, or emotional reactions based on the information and stimuli presented in the virtual scenario.

Second, VR environments can be designed to create a sense of calm, providing an ideal environment for relaxation and focused breathing (Barton et al., 2024). Overall, VR is a unique and effective technology for practicing and improving breathing techniques. The interactivity, and the possibility of providing real-time feedback contribute to an engaging and positive breathing experience. This affordance can be boosted by immersive VR that may help block out distractions from the outside world, allowing users to fully engage in breathing exercises and achieve a deeper state of relaxation. Therefore, users can transport themselves in breathtaking natural scenery, serene beaches, or even gardens, evoking a feeling of peace and serenity and feel themselves completely immersed in these scenarios. Today, people are often bombarded with hundreds of stimuli and sources of stress, making it challenging to find moments of true calm and relaxation. In this sense, the restorative effects of virtual nature settings have been widely demonstrated (Valtchanov et al., 2010; Chirico & Gaggioli, 2019; Litleskare et al., 2020), and VR has the potential to make breathing exercises more effective in promoting well-being by fostering a sense of calmness. Thanks to immersive scenarios, users can achieve a high level of presence that enhances the acquisition of breathing skills to be applied to real-world situations (Riva et al., 2020). This transfer of skills can improve overall well-being and resilience in daily life. Thus, the combination of breath and VR provides a unique and immersive experience that promotes relaxation, mindfulness, and focus, potentially leading to various psychological and physiological benefits.

As for RQ2, the present scoping review found that breathing integrated with VR can be an effective and transversal way to improve the mental health continuum. For example, immersive VR systems can be applied to people who have low levels of well-being in a specific situation because of the fear of flight, insomnia, or difficulties during an interaction with an aggressive male. In these cases, breathing integrated with immersive VR has proven to be an effective tool for reducing arousal and increasing regulatory skills (Shiban et al., 2017; de Zambotti et al., 2022; Kniffin et al., 2014). Also, with patients recovering from COVID-19 pneumonia,

synchronous feedback of breathing integrated with immersive VR improved patients' breathing comfort and breathing awareness (Blanke et al., 2022). As far as anxiety is concerned, breathing integrated with VR has proven to be effective (Savas et al., 2024) but without substantial differences from other interventions such as a phone-based guided breathing application (Weerdmeester et al., 2021, 2022). Moreover, breathing integrated with immersive VR can be effective in promoting relaxation, breathing awareness, focus on breath, and reducing arousal in people with good levels of well-being. In these situations, breathing biofeedback proved to be effective compared with not providing any feedback (Lan et al., 2021; Blum et al., 2019, 2020). On the other hand, the regular movement of a symbolic element (e.g., a cloud) guiding breathing without any feedback can have the same, or better, positive effects (Tinga et al., 2019), suggesting that biofeedback is not always fundamental. Furthermore, positive effects on relaxation can be obtained regardless of the context in which the symbolic element guiding breathing is inserted (Soyka et al., 2016).

This scoping review also revealed the positive effects of breathing integrated with immersive VR on perceived physical health together with mental health, showing the indissoluble relationship between mind and body. Several studies included in this review indeed analyzed, together with mental health-related outcomes but also physical outcomes such as pain and motion sickness. In these interventions, diaphragmatic breathing integrated with VR was effective in slowing respiration rate, increasing the parasympathetic nervous system (Russell et al., 2014; Stromberg et al., 2015), and weakening the pain processing function (Hu et al., 2021).

The breathing integrated with VR approach can be applied to the mental health continuum as it allows both clinical and healthy participants to be reached. It can also be applied to reduce clinical symptoms and increase well-being outcomes such as relaxation and breathing awareness. Furthermore, it can have positive effects on both mental and perceived physical health, highlighting the strong connection between them. In this regard, the possibility of integrating breathing exercises with VR can enrich the therapeutic options available to clinicians. In fact, this integration can be adopted by different therapeutic approaches, such as cognitive-behavioral therapy or integrative therapy, to facilitate gradual exposure to phobias (Shiban et al., 2017) or particularly stressful situations (Kniffin et al., 2014) and to encourage the construction of resources to deal with such events. In addition, breathing exercises integrated with VR can be particularly useful for clinical practitioners working in hospital settings and interested in helping patients who have to undergo surgery, or a specific procedure such as a port catheter needle insertion (Savas et al., 2024), and to cope with the post-operative phase (Schrempf et al., 2022). In this way, incorporating VR with breathing techniques can foster greater patients' involvement and adherence in the therapeutic process. Furthermore, the results emerged from this scoping review can give suggestions for VR developers aimed at creating virtual environments for improving mental health. They can design VR experiences allowing clinicians to choose the virtual environment (e.g., relaxing scenario, metaphorical scenario, real-world environment), breathing mode (e.g., diaphragmatic breathing, slow-paced breathing, mindful breathing) according to their patients' characteristics and the objective of the therapeutic session. VR developers can also implement real-time feedback within VR environments to help patients monitor and adjust their breathing patterns during guided breathing therapeutic sessions. Indeed, direct interaction with the virtual environment can improve the patients' sense of presence

making the experience more engaging. VR developers may also design self-help virtual experiences that increase adherence and engagement, by allowing users to tailor them to their specific preferences and goals, choosing between different environments and breathing modes, breathing pacers (e.g., following the rhythmic motion of an element or audible cues to breathe appropriately), and difficulty levels.

2.6 Conclusions

Despite the encouraging findings, this review has some limitations, especially concerning the heterogeneity in the methods and protocols of the included studies. Different types of immersive VR systems, different breathing techniques, and various feedback methods were used in the studies reviewed, making it difficult to draw definitive conclusions about the best practices in this field. Moreover, the wide range of outcomes measured also added to the complexity of the analysis. Understanding these varied effects and offering more specific recommendations to practitioners would require more in-depth research.

Despite these limitations, this scoping review presents an encouraging view of the potential benefits of integrating breathing techniques with VR experiences. Based on the current evidence, this approach appears to have positive effects on mental health, including reducing anxiety, promoting relaxation, and enhancing breathing awareness. The potential of these techniques to create an engaging, immersive, and therapeutic environment cannot be underestimated. However, more research is needed to understand the impact and the long-term effects of these techniques. In particular, future research in this area should focus on several aspects. Firstly, there is a need for standardized methods and protocols to allow for better comparison and synthesis of the results. These protocols should include specifics about the type of VR systems, the design of the VR environments, and the type of breathing techniques. Secondly, future studies should investigate the long-term effects of these interventions. This would involve tracking participants' progress over time and assessing whether the benefits of the interventions persist in time. While the current results provide insights on user experience, including acceptability, usability, and perceived usefulness of these interventions, further investigation would not only enhance our understanding of the current user experience but also inform the development of future interventions. Such efforts are essential for the successful implementation and long-term sustainability of VR interventions in real-world settings, ensuring they remain effective and relevant to the needs of users. This user-centered approach would increase the likelihood of successful implementation and use of these interventions in different contexts. Furthermore, a comprehensive understanding of user experience could guide the development of guidelines for designing and implementing VR-based breathing interventions. This, in turn, would help standardize practices across different settings, enhancing the comparability of study results and the overall effectiveness of these interventions.

Lastly, the potential of VR-based breathing interventions should be explored further by targeting specific mental health outcomes and making a direct comparison with all possible non-VR interventions targeting these diverse outcomes. This approach could embrace a broader range of populations and conditions (Pancini et al., 2023). At the moment, only a few studies focus on specific outcomes such as stress and anxiety. For example, a recent meta-analysis conducted on 5 studies showed that there were no significant changes between VR and

non-VR breathing interventions in terms of stress, anxiety, mood, HR, and HRV (Cortez-Vázquez et al., 2024). While this scoping review found promising effects in both healthy and clinical populations, it is unclear whether certain techniques are more beneficial for certain populations or conditions. Therefore, research is needed to extend these findings and offer more customized interventions for diverse clinical and well-being contexts. For example, VR breathing techniques could be utilized in the treatment of various mental health disorders, as a complementary therapy in physical rehabilitation, or as a tool for promoting general well-being. These areas are ripe for exploration and could significantly contribute to our understanding of the full potential of the breathing integrated with VR approach.

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Authors' contributions

All authors contributed to the scoping review conception and design. EP and DV individually screened the title and abstract of the retrieved records before analyzing the full papers that met the inclusion criteria. All authors (EP, AFDN, DV) reviewed the included articles, created the tables, and filled them in with relevant information. The first draft of the manuscript was written by EP and AFDN and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Statements on open data, ethics, and competing interests

This paper is a scoping review of published studies, and since it does not involve primary data collection, there is no data to make available for public access. Similarly, as this paper is a review paper, no ethics approval was necessary. The authors declare no competing interests.

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CHAPTER 3

Savoring Life During Pandemic: An Online Intervention to Promote Well-Being in Emerging Adults

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Introduction

Due to the accumulation of pandemic risk factors associated with their age-specific developmental tasks, such as the need for autonomy and identity construction, emerging adults reported decreased psychological well-being and quality of life (Varma et al., 2021; Zhen & Zhou, 2022; Parello et al., 2024). Specifically, the pandemic had a negative impact on various elements of emerging adults' lives. For example, lockdown restrictions reduced their demand for extrafamilial social contacts, and negatively affected their daily routines (Boursier et al., 2023; Parrello et al., 2024). Indeed, time was frequently viewed as too slow, too rapid, or ambiguous, no longer marked by the regular daily rhythms and commitments, such as sleep-wake, university, work, or leisure activities, frequently causing disorientation (Cravo et al., 2022; Parrello et al., 2024). Moreover, because lockdown constraints forced them to learn remotely, students had to deal with substantial changes in their educational experiences and lost the chance to share their academic journey with friends and coworkers. Specifically, university students' mental health was particularly affected, indeed many university students reported high levels of stress, anxiety, and depression, with females reporting significantly higher levels than males (Gómez-García et al., 2022; Chen & Lucock, 2022). Along with feeling lost and powerless, emerging adults also had to give up professional experiences and deal with more uncertainty about their career goals and expectations (Chen and Lucock, 2022; Parrello et al., 2024). When combined, these factors caused emerging adults' mental health to deteriorate over time, resulting in a decline in emotional and psychological well-being after the pandemic and an increase in feelings of sadness, anxiety, negative affect, and loneliness that still have an effect in the present (Kauhanen et al., 2023; Busetta et al., 2023).

In particular, taking the Italian context into consideration, according to the 2023 Annual Report of the Istituto Nazionale di Statistica (ISTAT), emerging adults are confirmed as the age group that most often declares good or very good physical health conditions, although in recent years a worrying worsening of mental health indicators is being observed, particularly in girls. As a result of the pandemic in 2021, a more pronounced deterioration in psychological well-being had been observed in girls, and this is also confirmed by the most recent data, as the psychological well-being index, investigated through the 36-Item Short Form Survey (SF36), falls further, from 68.2 in 2022 to 66.5 in 2023.

Therefore, in this context, it becomes essential to design and implement digital solutions aimed at promoting well-being of emerging adults as stated by the Mental Health Continuum Model (Keyes, 2002), with the advantage of being remotely accessible solutions and also paying attention to the environmental impact. Thus, savoring, that is the ability to generate and amplify positive emotions, appears to be a valuable approach to enhance well-being in emerging adults as highlighted by the literature (Smith et al., 2014) and to be delivered through digital solutions. Consequently, considering that, to the best of our knowledge, there are no Italian studies focusing exclusively on online savoring, we aimed to test the impact of an online savoring intervention on emerging adults. Accordingly, this chapter highlights the potential of savoring as a concrete, sustainable and practical tool to counteract the negative psychological effects caused by the pandemic in this age group and to be integrated into a DTx focused on fostering well-being.

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Savoring Life During Pandemic:

An Online Intervention To Promote Well-Being In Emerging Adults

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3.1 Abstract

Background. Savoring, that, is the ability to create and increase positive emotions, represents a promising approach to enhancing subjective well-being (SWB) in emerging adults. This controlled study aims to investigate the preliminary effects of a self-help e-savoring intervention on increasing savoring beliefs and strategies and SWB in times of the COVID-19 pandemic.

Methods. Forty-nine emerging adult participants were recruited using the snowball sampling method. The experimental group (n = 23) completed six online exercises (two exercises per week for three weeks) while the control group (n = 26) did not receive the intervention. Both groups filled out online questionnaires before and after the intervention. User experience and perceived usefulness of the intervention were assessed for the experimental group.

Results. A repeated measures analysis of variance (ANOVA) revealed a significant increase for the experimental group in savoring beliefs (especially toward the present and the future) and in positive emotions compared to the control group. The perspicuity, attractiveness, and efficiency of the online platform were very positively evaluated, and most participants rated the intervention as useful.

Conclusions. The results of this preliminary study together with the high level of adherence and the appreciation for the intervention indicate the potential of promoting online savoring and positive emotions in emerging adults. Future research could evaluate its long-term effects and verify its results with other age groups.

Keywords: Savoring, Emerging Adults, Subjective Well-Being, Positive Emotions, Online Interventions, COVID-19 Pandemic.

3.2 Background

The lives of people across the world have been severely impacted by the COVID-19 pandemic. Not only major health risks and economic uncertainty but also mental health challenges have been extensively documented (Vindegaard et al., 2020). Among the different populations that have been psychologically impacted by the

COVID-19 crisis, emerging adults, such as individuals aged 18-30 years (Arnett et al., 2014), who are already called on to face complex and uncertain challenges (Arnett, 2000) (e.g., completing their education, leaving the parental home, finding a job, having a stable romantic relationship, and eventually having children), need to be seriously taken into consideration (Gryber et al., 2021; Hawes et al., 2022). COVID-19 containment measures such as social distancing, lockdowns, the closure of borders, businesses, and universities have been effective in slowing the spread of the virus and protecting physical health, but they have also limited emerging adults' opportunities for independence, personal and professional growth, as well as interactions with family members, friends, and co-workers (Nussbaumer-Streit et al., 2020; Sibley et al., 2020). In particular, all of these unexpected changes together with the impact of COVID itself (e.g., oneself or family members becoming seriously ill, or worries about it) have caused a burden of mental health conditions including anxiety, depression, irritability, reduced sleep quality, psychological distress over the uncertainty of the future, frustration, and loneliness (Asmundson et al., 2020; Graziano et al., 2021; Sheroun et al., 2020; Aslan & Pekince, 2021; Genç & Arslan, 2021; Zammitti et al., 2021), and have significantly decreased emerging adults' subjective well-being (SWB) (Diener et al., 2002). In fact, according to the ISTAT (Istituto Nazionale di Statistica) report of 2021, in Italy, both adolescents and emerging adults with ages ranging between 19 and 24 reported a decrease in SWB (Moksnes et al., 2019; Zheng et al., 2019; ISTAT, 2021).SWB is a combination of people's overall evaluation of how satisfied they are with their lives and their affective responses to everyday events (Diener et al., 2011). Several studies have shown that SWB, especially in the form of positive affect, is associated with protective psychological and behavioral factors such as greater social connection, greater perceived social support, more optimism, and a greater likelihood of engaging in healthy behaviors and correlates (Diener et al., 2011). Indeed, SWB can foster better psychological health, and it is recognized as a critical factor in the prevention of depression (Genç & Arslan, 2021; Kansky & Diener, 2017; Arslan et al., 2022). Some uncontrollable life events and major unexpected changes, such as those associated with a pandemic, can undermine people's SWB, and for this reason developing interventions to support the subjective well-being of young adults in uncertain times is of relevant interest.

3.2.1 Savoring and subjective well-being

Among positive psychology interventions (PPIs), one promising approach that already demonstrated its positive impact on SWB is savoring. Savoring is the ability to generate, prolong, or intensify positive emotions, and it can increase awareness and recognition of the latter (Bryant, 2003; Bryant et al, 2011; Croft et al., 2014; Bryant & Veroff, 2007). Therefore, the essence of savoring lies in the "conscious awareness of ongoing positive feelings" related to the experience (Smith & Bryant, 2017). While savoring, people become aware of ongoing positive feelings, and the intensity and duration of these feelings change.

Theoretically, savoring has been identified as a mechanism strictly connected to the well-known theories of positive psychology, namely the broaden and build theory of positive emotions and the undoing hypothesis

(Fredrickson, 1998, 2003; Quoidbach et al., 2010; Smith et al., 2020). Indeed, savoring allows the generation, maintenance, and amplification of positive feelings and buffers against adverse health outcomes and negative emotions (Smith et al, 2020; van Steenbergen et al., 2021). Savoring can involve a form of mental journey through time through which individuals can generate positive emotional states in the present thanks the focus on the here and now (present moment), the imagination of past (positive reminiscence) or future positive (positive anticipation) events (Bryant et al., 2011; Quoidbach et al., 2010). Research has shown that people may or may not be aware of their savoring skills (savoring beliefs). According to Bryant (2021), "savoring beliefs involve a conscious awareness of one's ability or inability to experience and manage positive experience." On the one hand, the evidence suggests the presence of individual differences in savoring beliefs that are associated with personal traits such as extraversion, optimism, and emotional stability (Bryant & Veroff, 2007; Palmer et al., 2014; Smith & Hollinger-Smith, 2015). On the other hand, Bryant and Veroff (2007) identified several savoring strategies that can amplify the intensity and duration of positive emotions. They are, for example, sharing with others, such as experiencing a positive event with a close friend; memory building, which is taking mental photographs of an event to remember it; self-congratulation, such as focusing on personal life achievements; sensory-perceptual sharpening, which is grasping every sensory aspect of a positive event; feeling absorbed in the moment; and using behavioral expressions such as laughing or jumping. Finally, other strategies include having a temporal awareness of the experience (for example, remembering that events end and must be fully experienced when they occur), and counting blessings such as thinking of small positive things of the day.

A meta-analytical review conducted by Smith et al. (2014) found a substantial positive impact of savoring interventions on the intensity and duration of positive emotions and on well-being. Savoring outperforms other interventions such as optimism in terms of increasing positive affect, happiness, and life satisfaction while decreasing negative affect (Salces-Cubero et al., 2019). Savoring has been positively associated with well-being and negatively associated with depressive and anhedonia symptoms in both youth and adults (Bryant, 2003; Quoidbach et al., 2010). Until now, only a few savoring interventions for emerging adults have been proposed, and they have shown promising results. Bryant and Veroff (2007) asked college students to notice as many pleasant aspects as possible of the environment around them (e.g. the flowers, the sun) during a 20-minute walk. A week later, these students reported higher levels of happiness than those belonging to the neutral condition and the negative focus condition. Other researchers trained 94 college students to exercise the savoring strategies through recorded or written instructions, and, after 2 weeks, they found a significant reduction in depression and negative affect (Hurley & Kwon, 2012).

3.2.2 Online savoring

Recently, the broad approach of positive technology has recognized the positive role that technologies can have in promoting well-being by taking advantage of different strategies (Riva et al., 2012; Riva et al., 2016). Within this perspective, online positive psychology interventions (OPPIs) show several potentialities: they are accessible from different devices, they can reach different populations, and they are cost-effective (Boiler & Abello, 2014; Stibon et al., 2019; Krifa et al., 2022; Datu et al., 2022). Furthermore, OPPIs provide several advantages for

emerging adults, as they are “digital natives” and use the Internet and apps daily for many activities and are favorable toward using self-help content (Krifa et al., 2022; Davies et al., 2014). Digital psychological self-help interventions can be accessed from any location, thus overcoming logistical and geographical barriers to treatment delivery, and often resulting in more affordable and less time-consuming interventions in comparison to traditional interventions, with a subsequent significant improvement in self-monitoring processes (Fleming et al., 2018; Riva et al., 2021; Villani et al, 2013).

Up to now, savoring has been integrated with other strategies in online interventions. This is the case with Heintzelman et al.’s (Heintzelman et al., 2020; Diener & Biswas-Diener, 2019) 12-week in-person and online program for promoting SWB called "ENHANCE.". Participants, aged between 25 and 75, were asked to perform certain actions, including complimenting others, actively listening to other people, identifying and focusing on positive events, savoring, practicing mindfulness, and expressing gratitude. At the end of the intervention, participants belonging to both the in-person and online experimental groups reported higher levels of life satisfaction and positive affect and a reduction of negative affect, depressive symptoms, and perceived stress compared to the waiting list control group. In other recent research, savoring interventions alone have been delivered and tested online. The pilot study by Park (2019) aimed to teach the components of savoring through a website by providing several psychoeducational resources (articles, videos, and books) to promote the daily practice of savoring. The intervention lasted 21 days and showed the potential for an online self-managed savoring intervention to increase savoring and subjective well-being. However, only 22% of the initial participants (128) completed the intervention. Yu et al. (2020) asked Taiwanese college students to perform a pleasant activity by paying attention to the positive emotions they felt for 20 minutes a day three times a week. Afterwards participants were asked to describe and post these emotions on a social network (e.g., Facebook) by using a photo and/or a text. The study found a significant increase in positive affect and decrease in depression in the experimental group in the post-test compared to the control condition. However, the decreased level of depression was not maintained in the follow-up.

3.2.3 The present study

When people are overwhelmed by negative events, they may be unable to notice or appreciate positive things; in fact, threats, distress, or distraction can inhibit people’s ability to savor positive experiences (Smith & Bryant, 2017). Being able to recognize and appreciate positive moments during challenging events can be a source of strength (Smith et al., 2020; Bryant & Smith, 2015; Borelli et al., 2015; Jiao et al, 2021). Thus, savoring can represent a favorable approach in dealing with challenges such as the COVID-19 pandemic. Starting from these premises and taking advantage of the potential of a self-help approach (Fu et al., 2021), we developed a self-help e-savoring intervention (Savor Project) and conducted a preliminary test of its benefits for emerging adult participants. We hypothesized that (1) people in the experimental group would more strongly believe in their ability to enjoy positive events (savoring beliefs) compared to the control group. Concerning SWB, we hypothesized that (2) participants in the experimental group would have a higher level of life satisfaction and positive affect and a lower level of negative affect than participants in the control group. We also explored whether

the intervention would increase the likelihood of behaviors and/or thoughts that can amplify the intensity and duration of positive emotions (savoring strategies). In addition, we categorized the qualitative experiences written as comments by participants in terms of elicited emotions, bodily awareness, and content of the visualized experiences. Finally, we evaluated the user experience and the perceived usefulness of the intervention.

3.3 Methods

3.3.1 Participants

The participants were recruited using the snowball method thanks to posters published on social media and through word of mouth. The sample size of the feasibility study was calculated with G Power [55], and it was found that 46 participants would be needed to achieve 90% power with an average effect size ($f = 0.25$) with a repeated measurement design within/between interaction (number of groups 2; number of measurements: 2; correlation between repeated measurements: 0.5). In the current study, 55 emerging Italian adults were randomly assigned to the experimental and the control groups using block randomization. A label of A or B (A = intervention, B = control) was assigned to each group (block size = 4). Free online software (Research Randomizer 4.0) was used to generate the randomization list. Six people belonging to the experimental condition were excluded from the final sample because they did not complete all the activities, resulting in final sample sizes of 23 in the experimental condition and 26 in the control condition. The only inclusion criteria were age between 18 and 30 years, fluency in the Italian language, and having Internet access. All participants who met the above criteria and provided electronic informed consent were included in the sample.

Demographic characteristics, including age, gender, educational level, employment status, and marital status, were collected at baseline and reported in Table 1. Participants come from different regions of Northern Italy, such as Lombardy, Emilia-Romagna, Piemonte, and Veneto. The continuous variable (age) is reported as mean (M) and standard deviation (SD), whereas categorical variables (gender, education level, marital status, and employment status) are reported as frequencies and percentages. Differences between groups at baseline were analyzed with a Student *t*-test for age and a chi-square test for categorical data (Jamovi, Version 1.6.23.0) and no significant differences emerged between groups (see Table 1).

Table 1. Participants' characteristics.

		Experimental group (N = 23)	**Control group (N = 26)**	***p***
Age, Mean (SD)		25.09 (2.31)	24.50 (2.27)	.375[a]
Gender, N (%)	Male	10 (43)	10 (38)	.721[b]
	Female	13 (57)	16 (62)	

Education level (%)	Senior high school	9 (39)	9 (35)	.221[b]
	Bachelor's degree	4 (17)	10 (38)	
	Master's degree or higher	10 (44)	7 (27)	
Marital status (%)	Single	13 (57)	12 (46)	.733[b]
	Partner	9 (39)	12 (46)	
	Cohabiting partner	1 (4)	2 (8)	
Employment status (%)	Unemployed	3 (13)	0	.166[b]
	Worker	13 (56)	13 (50)	
	Student	5 (22)	11 (42)	
	Student-worker or trainee	2 (9)	2 (8)	

[a] Based on independent sample Student *t*-test

[b] Based on chi-square test

3.3.2 The study measures

Savoring beliefs and strategies were assessed both before and after the savoring intervention.

The Savoring Beliefs Inventory (SBI) was used to assess savoring beliefs (Bryant, 2003). Items from the original SBI were translated into Italian and then back translated by two independent translators. The outcome was discussed until all the translators agreed on reaching a consensus on cross-language equivalence. The SBI consists of 24 items that can be answered via a 7-point Likert scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*. The SBI is composed of three subscales that, when added together, yield the total score (α = .89 for this study). The *anticipation* subscale (α = .74 for this study) measures how much a person believes he or she can savor through anticipation (e.g., "I feel a joy of anticipation when I think about upcoming good things"). The *present* subscale (α = .89 for this study) assesses how much the participant believes he or she can savor the present moment (e.g., "I know how to make the most of a good time"). The *reminiscence* subscale (α = .78 for this study) assesses how much the participant is perceived to be able to savor a memory (e.g., "I enjoy looking back on happy times from my past"). High scores on these subscales and the total scale indicate a greater perceived ability to savor positive events.

An adapted short version of the Ways of Savoring Checklist (WOSC) was used to assess savoring strategies (Bryant, 2003). The original WOSC was translated into Italian and then back translated by two independent translators. The outcome was discussed until all the translators agreed on reaching a consensus on cross-language

equivalence. The original version is made up of ten sub-scales and a total of 60 items that can be responded to using a 7-point Likert scale from 1 = *strongly disagree* to 7 = *strongly agree*. We used an adapted short version of 14 items in this study, focusing only on a few amplifying strategies (α = .62 for this study), such as sharing with others (e.g., "I looked for people to share it with"), self-congratulation (e.g., "I told myself why I deserved this good thing"), absorption (e.g., "I thought only about the present—got absorbed in the moment"), and counting blessings (e.g., "I thought about what a lucky person I am that so many good things have happened to me"). Both before and after the intervention, we assessed both dimensions of subjective well-being: life satisfaction and negative and positive affect.

The Italian version of the Satisfaction With Life Scale (SWLS) was used to assess the cognitive dimension of subjective well-being and global life satisfaction (five items with responses on a 7-point Likert scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*, (e.g., "In most ways my life is close to my ideal") (Diener et al., 1999; Fabio & Busoni, 2009). The sum of all items is used to calculate the score, and high scores indicate high levels of life satisfaction (α = .84 for this study).

The Italian version of the Scale of Positive and Negative Experiences (SPANE) was used to measure positive and negative affect (Diener et al., 2010; Corno et al., 2016). This self-report scale consists of 12 items and is composed of two subscales: the positive affect subscale (6 items: positive, good, pleasant, happy, joyful, contented) (SPANE-P, α = .85 for this study) and the second negative affect subscale (6 items: negative, bad, unpleasant, sad, afraid, angry) (SPANE-N, α = .76 for this study). For all items, the response scale was a 5-point Likert scale (1 = *very rarely or never* and 5 = *very often or always*). The sum of positive and negative emotions can be used to calculate the score.

Furthermore, at the end of the first five activities, we asked participants to write down their thoughts about the exercise they had just performed. This was done after the fifth rather than the last activity because, at this point, participants were told that they would be sent a certificate of participation and access to the website for a full year as a gift for their participation. In this case, self-report measures would not have been appropriate: delivering gifts and then asking participants how they felt could in fact make them suspicious of the researchers' intentions to manipulate their mood, and this, in turn, could dissipate the positive emotion induced (Isen, 2008; Yant et al., 2013).

Finally, at the end of the intervention, the User Experience Questionnaire (UEQ) was used to investigate the participants' experiences in using the online platform and doing the savoring exercises (Laugwitz et al., 2008). It contains six scales and is made up of 26 total items: *attractiveness* (α = .83 for this study) refers to the general impression with respect to the product (e.g., annoying - enjoyable), *efficiency* (α = .58 for this study) focuses instead on the organization and practicality of the website (e.g., impractical - practical), and *perspicuity* (α = .74 for this study) refers to the perceived ease of use (e.g., not understandable - understandable). Furthermore, *stimulation* (α = .85 for this study) refers to the interest and enthusiasm generated by its use (e.g., boring - exciting), and *novelty* (α = .81 for this study) focuses on its innovation and creativity (e.g., conservative - innovative). We have not included *dependability*, which focuses on how secure and predictable the interaction with the site was, because the internal consistency of the items in the scale appeared unacceptable (α < .5). The

UEQ response modality is characterized by semantic differentials, and each item can be assigned a score between -3 and +3, where -3 represents the most negative answer, 0 a neutral answer, and +3 the most positive answer. For each scale, values between -0.8 and 0.8 represent a neutral evaluation, scores greater than 0.8 indicate a positive evaluation, and scores lower than -0.8 indicate a negative evaluation, while values near +2 represent a very positive, near-optimal impression of participants (Rauschenberger et al., 2013).

A final item, with responses made on a 5-step Likert scale (1 = *very little* and 5 = *very much*), was used to assess the perceived usefulness of the intervention ("Referring to the entire intervention, how much do you think it was useful for you?"). Finally, participants made comments about the whole intervention, as previously mentioned.

3.3.3 E-savoring intervention

The entire intervention was designed and developed exclusively online to reach emerging adults in total safety during the COVID-19 pandemic. An ad hoc website was therefore designed and created via the WordPress platform (at the domain *www.progettosavor.it*), accessible from any device (smartphone, tablet, or computer) with an Android, iOS, Windows, or macOS operating system. The goal was to create a website with simple graphics that was intuitive and usable. Participants accessed the site with a username and password, and, once participants entered the website, they could access the online questionnaires (through a link to Qualtrics) and the intervention exercises (Table 2). Specifically, participants had to complete 2 exercises a week for this 3-week intervention, for a total of 6 exercises. Participants were emailed a reminder when each exercise was published on the website. Each exercise took about 10 minutes to complete, and participants were given the opportunity to access the exercise in either recorded audio or written text format, to give participants the chance to choose their favorite modality (Fig. 1).

Table 2. Savoring activities.

Temporal orientation	Exercise	Description
Past	Recall three positive past moments	Participants were invited to draw up a list of 3 happy moments that could also include important goals achieved in their life. This activity was inspired by a study by Lyubomirsky et al. (2006).
Past	Recall and amplify a positive past experience	Participants were asked to relive a positive experience.
Present	Three good daily things to be thankful for	Participants were invited to identify, over the course of the day, 3 good things which they were grateful for. This activity was inspired by a study by Eamons and Mc Cullough (2003).
Present	Absorption during an activity	Participants were asked to perform an activity that they particularly enjoyed and to pay attention to the perceptual experience related to positive emotions.

Future	Anticipation of positive events	Participants were asked to imagine 3 positive events that could happen in the next few days and to pay attention to the emotions they felt while doing so. This activity was inspired by a study by Quoidbach et al. (2009).
Future and conclusion	Boosting savoring activities and waiting for a gift	Participants watched a 5-minute relaxation video in which music and natural scenarios were integrated. A narrative voice guided throughout the completed exercises to boost their effects.

Fig. 1. Online intervention: home page and example of activity.

3.3.4 Procedure

The study was conducted from October 2021 to February 2022, during the fourth wave of the COVID-19 pandemic in Italy. This pilot randomized controlled study used a between-subjects design and included two assessment moments. An email was sent to each participant interested in participating that provided information regarding the intervention. Personal credentials for accessing the website were sent to the experimental group participants. Participants were then invited to fill out informed consent forms and online baseline questionnaires—the SBI, WOSC Amplifying, SWLS, and SPANE (T0). The e-savoring intervention took place during the following 3 weeks. At the end of the intervention (T1), participants completed the same questionnaires—SBI, WOSC Amplifying, SWLS, and SPANE—with the integration of the UEQ and usefulness ad hoc questions only for the experimental group. The control group didn't carry out any activity and completed only the pre- and post-

intervention questionnaires in the same time frame as the experimental group. At T1, the control group received by email the credentials for accessing the e-savoring intervention for one year.

3.3.5 Data Analyses

All statistical analyses were conducted using Jamovi (Version 1.6.23.0). Group differences regarding psychological dimensions (savoring beliefs and strategies and subjective well-being) were examined at baseline using the Student *t*-test for independent samples. The intervention's effect was examined through a repeated measures ANOVA with time as a within-subjects factor and group as a between-subjects factor. We were interested in the time x group interaction, which would indicate a differential change due to the intervention.

Qualitative data were analyzed thematically (Braun & Clarke, 2006). A thematic analysis identifies, analyses and reports patterns of meaning (themes) across the dataset, in order to answer the research question. This approach enabled concise analysis of a large amount of textual data by using a deductive approach in which unexpected themes could arise "bottom-up" from the data. Relevant parts of the data were systematically identified, before being coded into potential themes that were refined, defined, and named. Finally, a narrative analysis of the themes was conducted.

3.4 Results

Before analyzing effects related to the e-savoring intervention, we compared the psychological dimensions at baseline and no differences emerged between groups (Table 3).

Table 3. Psychological dimensions at baseline.

		Range (min-max)	**Experimental group (N = 23)**	**Control group (N = 26)**	***p***
SBI, mean (SD)	Anticipation	8-56	38.48 (7.35)	38.31 (6.65)	.932[a]
	Present	8-56	33.26 (8.19)	33.65 (9.19)	.181[a]
	Reminiscence	8-56	41.83 (5.23)	38.58 (7.54)	.090[a]
	SBI total	24-168	113.57 (16.43)	113.54 (19.88)	.996[a]
SWLS, mean (SD)		5-35	20.87 (6.31)	21.23 (6.05)	.839[a]
SPANE, mean (SD)	SPANE-P	6-30	18.65 (4.41)	19.69 (4.15)	.400[a]
	SPANE-N	6-30	15.04 (5.27)	14.92 (3.69)	.926[a]

WOSC, mean (SD)	Amplifying	14-98	61.74 (8.35)	60.23 (9.27)	.555[a]

[a] Based on independent sample Student *t*-test

Note. SBI: Savoring Belief Inventory; SWLS: Satisfaction With Life Scale; SPANE-P: Scale of Positive and Negative Experience – Positive; SPANE-N: Scale of Positive and Negative Experience – Negative; WOSC: Ways Of Savoring Checklist

3.4.1 Effectiveness of the e-savoring intervention: preliminary results

A repeated measures ANOVA with time as a within-subjects factor and group as a between-subjects factor was performed for all variables (Table 4). We were interested in the time x group interaction, which would indicate a differential change due to the intervention. Descriptive data are shown as mean (M) and standard deviation (SD).

Table 4. Comparison between groups: repeated measures ANOVA interactions effects.

		Experimental group M (SD)	**Control group M (SD)**	**Time x group, interaction effect**		
				f	***p***	η^2
SBI Anticipation	Baseline	38.48 (7.35)	38.31 (6.65)	8.26	.006[a]	.02
	Post	41.78 (5.13)	37.81 (8.51)			
SBI Present	Baseline	33.26 (8.19)	36.65 (9.19)	4.59	.037[a]	.01
	Post	36.57 (7.09)	36.42 (10.16)			
SBI Reminiscence	Baseline	41.83 (5.23)	38.58 (5.74)	1.71	.197	.01
	Post	44.57 (5.29)	39.31 (7.64)			
SBI Total	Baseline	113.57 (16.43)	113.54 (19.88)	6.84	.012[a]	.02
	Post	122.91 (14.27)	113.54 (22.38)			
SWLS	Baseline	20.87 (6.31)	21.23 (6.05)	3.10	.085	.01
	Post	23.04 (5.86)	20.81 (7.14)			
SPANE-P	Baseline	19.65 (4.41)	19.69 (4.15)	6.40	.015[a]	.02
	Post	21.83 (4.28)	20.15 (4.92)			
SPANE-N	Baseline	15.04 (5.27)	14.92 (3.69)	0.51	.478	.00
	Post	13.96 (4.61)	14.58 (3.96)			
WOSC Amplifying	Baseline	61.74 (8.35)	60.23 (9.27)	3.68	.061	.01
	Post	66.35 (9.49)	61.12 (10.75)			

[a]Significant ($p < 0.05$).

Note. M: mean; SD: standard deviation; SBI: Savoring Belief Inventory; SWLS: Satisfaction With Life Scale; SPANE-P:

Scale of Positive and Negative Experience – Positive; SPANE-N: Scale of Positive and Negative Experience – Negative; WOSC Amplifying: Ways Of Savoring Checklist Amplifying

Concerning the effects of the intervention on savoring beliefs (SBI), a significant group x time interaction was found. For the experimental group, there was a significant greater increase in savoring beliefs (total score) compared to baseline, and in particular in savoring the present ($p < .05$) and the future ($p < .01$), than in the control group, while no significant effect related to reminiscence emerged. Concerning the subjective well-being assessment, we did not find a significant change related to its cognitive dimension, such as life satisfaction (SWLS), but we found a significant change related to its affective dimension ($p < .05$), in particular for the positive emotions (SPANE-P): the experimental group showed a significantly greater increase in the positive emotions compared to the control group, while no significant changes about the negative emotions (SPANE-N) were found. Moreover, the analysis of scores obtained by the participants in the adoption of savoring strategies (WOSC Amplifying), including sharing with others, self-congratulation, absorption, and counting blessings, showed a tendency toward a significant increase ($p = .061$) in the experimental group compared to the control group.

3.4.2 Qualitative analysis of visualized experiences

Qualitative data were thematically analyzed in order to explore the research question: What were participants' emotional experiences activated by the savoring exercises? There was no missing data, because the online questionnaire required participants to provide qualitative comments about each activity performed. Two principal themes were identified: a) activated positive emotions (Shiota et al., 2011; Fredrickson, 2013) and experienced bodily awareness, and b) the content of the visualized experience. As far as the content is concerned, we considered the social dimension (*shared experiences,* related to activities performed together with others such as friends, relatives, partner, etc. vs. *individual activities* that take place alone), the scenario (*natural environments* referred to outdoor natural places vs *artificial environments* referred to indoor places such as offices, homes, gyms, etc.), and the performed activity (*occupational activities,* such as work and/or study, vs. *recreational activities,* such as reading, walking, and other leisure activities). Details are reported in Table 5.

Table 5. Qualitative evaluation of the visualized experiences: principal themes (number of participants).

		Recall three positive past moments	**Recall and amplify a positive past experience**	**Three good daily things to be thankful for**	**Absorption during an activity**	**Anticipation of positive events**
POSITIVE EMOTIONS	Happiness	7	5	8	2	10
	Joy	2	12	2	2	12

	Enthusiasm	1	2	1	0	8
	Gratitude	5	4	13	3	7
	Pride	9	2	4	7	6
	Love	2	1	2	0	1
	Hope	0	1	1	1	6
	Serenity	5	6	5	12	8
BODILY AWARENESS	Bodily Awareness	0	10	0	5	3
EXPERIENCE CONTENT	Shared Experiences	15	8	19	4	21
	Individual Experiences	11	8	9	22	13
	Natural Environments	4	4	6	8	7
	Artificial Environments	1	2	4	4	4
	Occupational Activities	10	5	3	0	5
	Recreational Activities	9	6	12	22	21

The first activity, consisting of asking participants to list three happy moments, led participants to recall both shared (65%) and individual experiences (48%), and mostly related to occupational activities (43%). These memories elicited positive emotions, and in particular pride and satisfaction (39%) and happiness (30%). The second activity, consisting of recalling and amplifying one positive moment, led participants to recall both shared and individual experiences (both 35%) and related to both occupational and recreational activities (22% and 26%, respectively). This activity mostly elicited joy (52%) and boosted bodily awareness (43%). The third activity, asking participants to identify three daily things to be grateful for, led them to visualize mostly shared experiences (83%) related to recreational activities (52%) and also elicited gratitude (56%) and happiness (35%). The fourth activity, which asked participants to be fully involved in the enjoyable activity they were doing, led participants to visualize mostly individual experiences (96%) performed in a natural environment (35%) during recreational time (96%). This activity elicited serenity (52%) and pride and satisfaction (30%). The fifth activity, asking participants to imagine at least two positive events that could happen in the next few days and pay attention to the

emotions aroused by the imagined events, led participants to anticipate both shared (91%) and individual experiences (56%), mainly related to natural environments (30%) and recreational activities (91%), which mostly elicited happiness (43%), enthusiasm (35%), and gratitude (30%).

3.4.3. User experience and perceived usefulness

Furthermore, at the end of the e-savoring intervention, participants filled out the User Experience Questionnaire. Participants reported a very positive evaluation of the system in terms of *perspicuity, attractiveness,* and *efficiency*; *stimulation* and *novelty* were also positively evaluated. Furthermore, participants evaluated the intervention as useful (the average rating is between "quite useful" and "very useful," median = 4). Details are reported in Table 6.

Table 6. E-savoring intervention evaluation: user experience.

	M	**SD**	**Positive cut-off**	**Range**
Attractiveness	1.88	0.73	>0.8	-3/+3
Perspicuity	2.41	0.76	>0.8	-3/+3
Efficiency	1.90	0.65	>0.8	-3/+3
Stimulation	1.54	1.05	>0.8	-3/+3
Novelty	1.04	1.07	>0.8	-3/+3
Perceived usefulness	3.61	0.78	n.a.	1-5

Note. M: mean; SD: standard deviation.

Regarding perceived usefulness, a qualitative analysis was also conducted. A descriptive analysis of the participants' comments about the overall evaluation of the intervention revealed some key areas: 15 out of 23 participants left a written comment; 5 out of 15 participants (33%) reported increased awareness of positive experiences and associated feelings. For example, a 24-year-old woman stated, "This path has been a path of inner reflection that helps you reflect on your reactions to the moments of your life. […] For me, it was interesting and enjoyable to take this type of path. It was useful to stop and think and to understand yourself a little more." Furthermore, 7 out of 15 participants (47%) reported that they had learned strategies to boost positive emotions. For instance, a 26-year-old woman asserted, "I found this to be a very clear method of learning a simple but sometimes difficult concept without input. It gave me the opportunity to reflect, and stop, and think about the good things, which exist and are considerably more common than the bad ones. I will treasure these exercises, especially in times when everything seems difficult. Thank you." Moreover, 8 out of 15 participants (53%)

expressed their intention to put into practice the strategies they learned in the future. For example, a 23-year-old woman reported, “It helped me especially in reliving the positive emotions of past events. I was really savoring all the emotions I felt. In the second activity, I relived the happy moment in my mind, and it really felt like I was there, and I felt a lot of the happiness I felt in that event. I had never tried to do such a thing; I had never been able to savor so well the feelings from a past event. […] I've found that I can relive those emotions whenever I want thanks to this activity! I think I will take all the activities of this project with me for the rest of my life. This project […] has been a great practical help! Thank you!"

3.5 Discussion

The COVID-19 pandemic has proven to be a challenging time for emerging adults who reported a worrying decline in mental health and subjective well-being (Hawes et al., 2022; Graupensperger et al., 2022). Starting from these premises, the present study developed and investigated the effects of a self-help e-savoring intervention in improving savoring beliefs and strategies and the subjective well-being of emerging adults.

Findings partially confirmed our hypotheses. Concerning the effectiveness of the intervention on increasing savoring beliefs (H1), participants reported significant improvements and this result is in line with other studies reporting an increase in total SBI levels (Park, 2019). Participants felt more able to savor both upcoming positive events and the present moment. Participants showed a slight but not significant improvement in reminiscence beliefs. These results are in line with Bryant’s (2003) statement that people typically consider themselves better at savoring through reminiscence. Furthermore, before the intervention (baseline), reminiscence levels were higher than at the other times; thus, participants already felt competent to savor memories and positive past experiences.

Concerning the intervention’s effect on SWB, the second hypothesis (H2) was partially confirmed. On the one hand, there was not a significant increase in life satisfaction, probably due to the short duration of the intervention. The brevity of this intervention (6 activities in 3 weeks) allowed us to achieve a very good adherence rate but did not sustain a change in the global cognitive assessment of one's life. More time is needed to achieve a sustained change—which was reported in other studies that had longer-lasting interventions (e.g., 12 weeks) (Salces-Cubero et al., 2019; Diener et al., 1999). In addition, other studies that integrated different positive psychology strategies (e.g., mindfulness, gratitude, optimism, strengths, etc.) or more savoring strategies found increases in life satisfaction as well as other positive psychological outcomes (Heintzelman et al., 2020; Brouzos et al., 2022; Smith & Bryant, 2019). On the other hand, the intervention was effective in increasing positive emotions. The opportunity to write comments about the performed savoring activities may have stimulated participants' reflection. Indeed, writing about positive experiences can promote the building of a logical narrative, which in turn fosters the maintenance of positive emotions (Yu et al., 2020). In line with the study carried out by Yu et al. (2020), we did not find a change in negative emotions. It is important to highlight that savoring does not exclusively include focusing on the positive aspects of life while ignoring the negative ones. Indeed, the benefits of savoring are visible in the ability to notice and appreciate positive moments despite and during life difficulties

(Smith & Bryant, 2017, 2019). Thus, in our study, we cannot exclude the possibility that some negative emotions related to the challenging situation of the pandemic affected participants' emotional states.

Regarding the effectiveness of the intervention in increasing savoring strategies as a research question, participants reported a tendency toward a significant improvement. Interestingly, after a 3-week intervention, a change in participants' savoring behaviors was triggered. Nevertheless, it is not possible to compare this result with those of previous studies because, to our knowledge, no savoring interventions have investigated the effects on savoring strategies (Smith & Bryant, 2013; Chadwick et al, 2021). Future studies that assess this dimension are needed.

Qualitative analyses revealed that participants experienced several positive emotions during the visualized events, such as happiness, joy, pride, gratitude, and serenity. While they were more absorbed by individual activities in savoring the present moment, they were oriented toward savoring relational activities in the future. This finding highlights the importance of encouraging positive moments with family, friends, and partners after social distancing ends. Recreational visualizations prevailed over work activities. Due to the importance and need of promoting well-being and positive emotions in the workplace, savoring interventions could be adapted to this context (Fritz & Taylor, 2022).

Regarding the user experience, the website was perceived as easy to use. Indeed, it was designed and created specifically for this intervention, and all functions were intuitive. In addition, most participants perceived the whole intervention as useful, as the savoring activities elicited positive emotions and reflections.

Taking into account the present study's findings as a whole, it seems that the online savoring intervention represents an effective protocol to sustain emerging adults' subjective perception of being able to intensify positive emotions related to the present and the future and to boost positive affect during the COVID-19 pandemic. The present findings are consistent with the positive outcomes reported by other previous online savoring interventions based on psychoeducational resources or proposing different strategies (Park, 2019; Yu et al., 2020).

3.5.1 Limitations and strengths

The current study focuses on the development, implementation, and preliminary evaluation of a new online savoring intervention with emerging adults during the COVID-19 pandemic, leaving the door open for future research to address its limitations and refine its findings.

First, we included a control group that did not engage in any activity other than completing the assessments at the two times, and, according to Kraiss et al. (2022), this issue could have an impact on the evaluation of intervention effectiveness. This limitation requires us to view the results with caution and encourage future studies to test the intervention with active control groups. Second, because we used convenience and snowball sampling methods, we have to recognize that this choice could have an influence on the results' generalizability. Third, we used savoring scales not validated in Italian. On one hand, the *ad hoc* version of the WOSC was not fully reliable; on the other hand, even if the SBI had not previously been validated in Italian, the reliability of the subscales was good. Furthermore, these results can be considered preliminary and only partially generalizable, as they involve a small sample of emerging adults from Northern Italy.

Despite these limitations, we can recognize some strengths of this study. One is the implementation of a self-help savoring intervention, solidly anchored in some of the amplification strategies proposed by Bryant and Veroff (2007). Furthermore, the online implementation of the intervention can be viewed as one of its strengths, as it allowed participation of emerging adults from different regions during a time when fear of contagion was still high and young people struggled to resume the normal activities they practiced before the pandemic. The ability to amplify positive emotional experiences anchored in one's personal history allows one to feel highly engaged in the activities, and the ease of the exercises fits well with the self-help approach.
Finally, the high adherence rate represents another strength of the current study, probably sustained by engaging activities proposed in a short intervention. In other cases, extended online savoring interventions had a high dropout rate due to the significant effort and time required (Park, 2019).

3.6 Conclusions and implications

The online self-help e-savoring intervention showed great potential for promoting well-being and savoring in the emerging adult population during the COVID-19 pandemic. The high level of adherence and the appreciation for the intervention led us to speculate that it could be adapted and tested with a large sample of participants of various ages. Furthermore, future studies are encouraged in assessing the maintenance of achieved results with a follow-up evaluation. Finally, given the increase in mental disorders such as anxiety and depression in emerging adults as a result of the COVID-19 pandemic, as well as recent research on the role of savoring in reducing depression, it might be worthwhile to apply this intervention to this population as well as others affected by these mental health conditions (Irvin et al., 2022).

Abbreviations

SWB: Subjective Well-Being

ANOVA: Analysis of Variance

ISTAT: Istituto Nazionale di Statistica

PPIs: Positive Psychology Interventions

OPPIs: Online Positive Psychology Interventions

M: Mean

SD: Standard Deviation

SBI: Savoring Beliefs Inventory

WOSC: Ways of Savoring Checklist

SWLS: Satisfaction With Life Scale

SPANE: Scale of Positive and Negative Experiences

UEQ: User Experience Questionnaire

Declarations

Ethics approval and consent to participate

This study has been conducted in compliance with the Declaration of Helsinki and approved by the Ethics Committee of Psychology Department of Università Cattolica del Sacro Cuore of Milan (protocol 21-22). All participants signed an informed consent form before beginning the research about the research protocol, data protection and privacy according to the General Data Protection Regulation (GDPR; EU 2016/679). The study's objectives, confidentiality, and anonymity were described, and volunteers were given full authority to complete the study. All methods were performed in accordance with the relevant guidelines and regulations in the declaration - Ethics approval and consent to participate section.

Consent for publication

Not applicable.

Availability of data and materials

The dataset used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors conceptualized the study. EP, FP, LS designed the questionnaires, website, and activities, collected study data, and created the first draft of the manuscript. DV supervised EP, FP, LS throughout all phases of the study, conducted statistical analyses and took part in revising drafts of the manuscript. All authors read and approved the submitted, revised, and final manuscript.

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CHAPTER 4

Integrating Virtual Reality with Savoring to Promote Well-Being of Patients with Chronic Respiratory Diseases: A Pilot Randomized Controlled Trial

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Introduction

As previously mentioned, the pandemic had a strong negative impact on both physical and mental health, impairing respiratory functions on the one hand and undermining psychological well-being on the other, and this was particularly evident for patients with chronic respiratory diseases (CRDs), which are pathologies that cause non-reversible airflow restrictions as well as several extrapulmonary adverse consequences, and include for example chronic obstructive pulmonary disease (COPD), interstitial lung diseases (ILD), bronchiectasis, idiopathic pulmonary fibrosis, and chronic asthma. Indeed, the treatment of patients with these diseases has been negatively influenced by the COVID-19 pandemic because rescheduled or canceled appointments as a result of an increased influx of patients with COVID-19, and COVID-19 management strategies like social distancing (Lazzerini et al., 2020; Gruiskens et al., 2023). Furthermore, CRDs patients experienced high levels of fear of contagion, especially from care providers and, because of all these factors, CRDs patients have been particularly affected by the pandemic, thus reporting high levels of psychological distress, including anxiety and depression and a lower psychosocial well-being (Lazzerini et al., 2020; Pouwels et al., 2021; Gruiskens et al., 2023).

Related to this, together with Luca Bernardelli, the CEO of the Become-Hub, the Italian VR company we collaborated with for the Programma Operativo Nazionale (PON) doctoral program, we started a partnership with the Pulmonary Rehabilitation Unit of IRCCS INRCA Casatenovo (Italian National Research Center on Aging). Thanks to the meetings with the doctors in charge of the Pulmonary Rehabilitation Unit, it was possible to understand the strong negative impact that the COVID-19 pandemic had on their patients with CRDs on both their physical and mental health and the effects it still had in the present, together with the effects it still had in the organization and protocols of the hospital. For example, as a result of the pandemic, patients admitted to the hospital for 3 weeks for pulmonary rehabilitation were still not allowed to leave the hospital ward on the third floor for the entire duration of their stay or go to the garden outside. In addition, the requirement to wear a mask when leaving one's room or being in contact with other patients or medical staff was still in effect. In addition, every three days each patient had to repeat the swab to check for the presence or absence of COVID-19 and the entry of relatives to visit hospitalized patients was restricted, in fact, relatives could only come twice a week by reservation only, wearing a mask and alternating with the relatives of other hospitalized patients.

As a result of the information gathered, it was decided to develop a first draft of a digital therapeutics having the goal of improving mental health and respiratory outcomes of patients with chronic respiratory diseases in the post-pandemic period. Accordingly, the literature was reviewed to identify existing DTx created for CRDs patients and some DTx aimed at promoting and managing physical health, but not mental health, were found. For example, Snyder et al. (2020) created a digital inhaler with built-in sensors (ProAir Digihaler) that connects to a companion mobile app and aimed at better management of COPD (Hong et al., 2021). Furthermore, Chen et al. (2019) have employed a web platform to help COPD patients control their medications and symptoms. Patients are given electronic medication monitors to passively monitor their usage of short-acting beta-agonists, as well as a smartphone app to track use patterns and receive feedback. Providers can also access

data collected through a website and send notifications if a patient's recommended inhaler use changes significantly. Moreover, Kim et al. (2024) have developed the EASYBREATH app as a pulmonary rehabilitation program that includes aerobic exercise training, breathing training, and an educational program. Thank to this app, CRDs patients can perform pulmonary rehabilitation at home for a total of 24 exercises three times weekly for eight weeks. As mentioned earlier, existing DTx in the literature thus focus on physical health management, but, to our knowledge, there are no DTx aimed at promoting mental health in CRDs patients. In this context, it therefore becomes essential to create and implement a suitable and sustainable DTx aimed at enhancing the well-being of these patients, especially in the post-pandemic time period. Hence, taking advantage of the potential of savoring also in the Italian context and of the well-established literature on VR (Chapter 1, 2, 3), this chapter highlights the potential of a VR-based DTx integrated with savoring in promoting emotional and psychological well-being in CRDs patients.

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Integrating Virtual Reality with Savoring to Promote Well-being of Patients With Chronic Respiratory Diseases: a Pilot Randomized Controlled Trial

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4.1 Abstract

Background. Chronic respiratory diseases (CRDs) are widespread pathologies that cause non-reversible airflow limitations as well as a variety of extrapulmonary adverse effects. For these reasons, these pathologies are related to frequent hospitalizations and, consequently, high levels of anxiety, depression, and stress. In this respect, relaxation in Virtual Reality (VR) integrated with savoring, which is the ability to generate and amplify positive emotions, can be used to increase well-being and relaxation in CRDs patients.

Objective. This pilot randomized controlled trial aimed to investigate the effectiveness of a two-week VR-based relaxation intervention integrated with savoring in CRDs patients in increasing emotional and psychological well-being, positive emotions, relaxation, oxygen saturation levels (SpO2) and decreasing negative emotions.

Methods. This study involved 45 hospitalized CRDs patients from the Pulmonary Rehabilitation Unit of IRCCS INRCA Casatenovo. Alongside traditional pulmonary rehabilitation, the experimental group (N = 23) took part in the four-session VR-based intervention, while the active control group (N = 22) listened to relaxing music. In each session, the experimental group experienced a relaxing virtual scenario followed by a savoring exercise. Both groups filled out the self-reported questionnaires before the intervention (T0), after (T1), and in the one-month follow-up (T2), and before and after each session. The experimental group's VR acceptance and sense of presence were also measured.

Results. Regarding the primary outcomes, taking T0 and T1 into account, repeated measures ANCOVAs revealed a significant increase for the experimental group in emotional and psychological well-being, positive emotions, relaxation, and a significant decrease in negative emotions compared to the control group. The psychological changes were maintained at T2. Concerning secondary outcomes, patients reported high VR acceptance and sense of presence.

Conclusions. These results suggest that relaxation VR integrated with savoring can promote well-being and reduce clinical symptoms not only in the post-intervention, but also in the long term. Indeed, savoring can

amplify the positive effects of relaxing VR and help patients to focus and amplify their positive experiences, thus counteracting the negative psychological consequences of CRDs.

Trial registration: anzctr.org, ACTRN12624000435583; https://www.anzctr.org.au/ACTRN12624000435583.aspx (retrospectively registered). This study was approved by the Ethics Committee of the IRCCS INRCA Casatenovo but for administrative issues the trial registration was no completed prospectively. The registration was therefore completed retrospectively before data analysis and paper writing.

Keywords: chronic respiratory diseases, psychological well-being, virtual reality, savoring, positive emotions, relaxation.

4.2 Introduction

4.2.1 Background

Chronic respiratory diseases (CRDs) are conditions that negatively impact the lungs and airways (Byrne et al., 2015). They include, for example, chronic obstructive pulmonary disease (COPD), interstitial lung diseases (ILD), bronchiectasis, idiopathic pulmonary fibrosis, and chronic asthma (Cox et al., 2021; Raveendran et al., 2021). CRDs were the third greatest cause of mortality in 2019, accounting for 4.0 million deaths and a global prevalence of 454.6 million cases (Momtazmanesh et al., 2023). These disorders result in frequent and chronic respiratory inflammations and infections (Bousquet et al., 2007) and can be caused by continual exposure to environmental stimuli such as smoke from cigarettes, air pollution, or job-related risks (Cox et al., 2021). People with CRDs experience cough, dyspnea, breathlessness, limiting functional capacity, decline in lung function, reduced exercise tolerance, and frequent hospitalizations (Cox et al., 2021; Celli et al., 2004; Rutkowski et al., 2021). As a result, several CRDs patients can suffer restrictions in their daily activities due to the need to do daily home therapies such as oxygen therapy (Doi, 2003). To improve the physiological conditions and physical activity of people with chronic respiratory diseases, pulmonary rehabilitation can be delivered through exercise training accompanied by education and behavior change (Cox et al., 2021; Spruit et al., 2013). Pulmonary rehabilitation can be delivered in an inpatient setting (McCarthy et al., 2015) by providing daily exercise training during cyclical hospitalizations.

Because of all these factors, CRDs patients' quality of life is adversely affected, and patients frequently report high levels of anxiety and stress, as well as high levels of depression and low levels of emotional and psychological well-being (Lolak et al., 2008; Yohannes, 2020). Anxiety and stress, in particular, can have a severe impact on patients' quality of life and functional capacity (Lee et al., 2017; Nicola et al., 2023), thus increasing dyspnea and impairing compliance with home therapies (Lolak et al., 2008). In this context, promoting relaxation can be an effective way to decrease anxiety and stress levels in CRDs patients. In fact, several studies have shown that listening to relaxing music is effective in relieving anxiety, stress, and dyspnea,

improving lung capacity, and promoting greater exercise tolerance (McBride et al., 1999; Panigrahi et al., 2014; Huang et al., 2021; Philip et al., 2021).

4.2.2 Promoting relaxation with virtual reality

Another promising tool to promote relaxation in CRDs patients is immersive virtual reality (VR). This technology enables the creation of interactive worlds generated by computers that replace real-world sensory experiences with digitally created ones, generating the sensation of being in digital settings (Freeman et al., 2017). VR involves several key processes, including the sense of presence, which is the feeling of being there in the digital experience (Villani et al., 2007; Riva et al., 2016; Di Natale et al., 2020). Virtual reality has been successfully employed in promoting relaxation and reducing stress, anxiety (Villani et al., 2007; Maples-Keller et al., 2017; Pancini et al., 2023), and depression (Zeng et al., 2018; Riva et al., 2021; Valmaggia et al., 2016). It has also shown relevant potential in improving and regulating emotional well-being and mood and promoting positive emotions (Herrero et al., 2014; Pizzoli et al., 2019; Riches et al., 2021; Malighetti et al., 2023) also in patient populations (Veling et al., 2021; Schrempf et al., 2022). Thanks to VR, the user can immerse himself in various digital environments, such as restorative natural scenarios, and this can be particularly suitable for hospitalized patients who cannot move to natural outside environments (Riches et al., 2021). Specifically, virtual restorative scenarios usually show pleasant and peaceful natural environments such as islands, the sea, parks, and gardens, and they can be integrated with nature-related auditory elements with relaxation properties and have been shown to be effective in different contexts (Pizzoli et al., 2019). To date, however, with CRDs patients, immersive VR has been mainly used to facilitate pulmonary rehabilitation, as immersive scenarios enable “attention shifting” and distract patients from negative feelings (e.g., fatigue, dyspnea, and monotony) and motivate them during exercise training (Jung et al., 2020; Rutkowski, 2021; Pittara et al., 2023). To our knowledge, only a recent RCT evaluated the effectiveness of a 2-week intervention based on 10 sessions of immersive VR-therapy on the intensity of depressive, anxiety, and stress symptoms in hospitalized COPD patients (Rutkowski et al., 2021). A virtual garden based on the Ericksonian psychotherapy approach, representing symbolically the patient’s health and its improvement during the hospitalization through changes in the coloring of the scenario, was used. By comparing this VR intervention with the control group experiencing 10 sessions of Schultz autogenic training, the within-subjects analysis showed significant changes in depression, anxiety, and stress levels in the experimental group.

4.2.3 Amplification of positive emotions

To enhance the positive effect of VR, an additional tool related to the amplification of positive emotions can be employed (Pancini et al., 2023). Indeed, positive emotions can play an important role in counteracting the negative effects of anxiety and stress in CRDs patients. In this respect, according to the broaden and build theory of positive emotions, positive emotions broaden habitual ways of thinking and acting (Fredrickson, 2013). Furthermore, according to the undoing hypothesis, positive emotions can neutralize the harmful effects of negative emotions, as a consequence, they allow the increase of intellectual resources and build a pool of resources from which to draw in future difficult situations (Fredrickson, 2013; Fredrickson & Joiner, 2002;

Tugade & Fredrickson, 2004). A positive psychology technique strictly related to this approach is savoring, which refers to the ability to recognize, appreciate, and amplify positive experiences and emotions in one's life (Bryant & Veroff). Interestingly, people can savor a positive past event and relive in the present the same positive emotions experienced in the past and experience new ones (positive reminiscence) (Bryant & Veroff, 2007), but they can also savor the present moment or a future positive experience (positive anticipation). Literature has shown the consistent impact of savoring interventions on increasing positive emotions and well-being, as well as decreasing negative emotions and reducing depression (Bryant & Veroff, 2007; Irvin et al., 2020; Bryant, 2021; Villani et al., 2023). Up to now, savoring has not yet been applied to CRDs patients, and its possible integration with VR could promote patients' awareness of the positive states experienced during the virtual experience and enable them to create a connection with their personal experiences.

4.2.4 The present study

Starting from these premises and taking advantage of the potential of virtual reality and savoring, we conducted a pilot RCT aimed at investigating the effectiveness of an innovative two-week VR-based relaxation integrated with savoring intervention in CRDs patients. This RCT was conducted in collaboration with the Italian VR company Become-Hub that provided the software and the VR equipment and the Pulmonary Rehabilitation Unit of IRCCS INRCA Casatenovo. Specifically, taking the primary outcomes into consideration from the baseline (T0) to the post-intervention (T1), we hypothesized that (1) emotional and psychological well-being would increase more in the experimental group compared to the active control group who listened to relaxing music. In addition, we hypothesized that (2) patients of the experimental group would achieve higher levels of positive affect and lower levels of negative affect, and (3) higher levels of relaxation compared to the active control group. We also hypothesized that (4) the experimental group would maintain the psychological changes at the one-month follow-up (T2) compared to the active control group.

As secondary outcomes, taking pre- and post-sessions into consideration, we also hypothesized that (5) self-report relaxation and peripheral oxygen saturation (SpO_2) would increase more in the experimental group compared to the active control group. Through self-report, we also evaluated VR acceptance, the sense of presence experienced in VR, and the perceived usefulness of the intervention. Finally, we qualitatively explored patients' experiences with VR and the savoring exercises. G*Power 3.1.9.7 software (Kang, 2021) was used to calculate the sample size. Calculation was based on repeated-measures ANOVA: the within–between interaction type I error rate was set at 5% (= 0.05), the effect size of the main outcomes was 0.25, and the type II error rate gave 90% power for the two groups and two repeated sets of measurements (Rutkowski et al., 2021). Correlation among the repeated measures was 0.5 gave 90% power for the two groups and two repeated sets of measurements; correlation among the repeated measures was 0.5 and non-sphericity correction ε was 1.0 and it was found that 46 participants would be needed. The anticipated attrition was estimated around 15% (Hart et al., 2023) and, for this reason, 54 participants were involved.

4.3 Methods

4.3.1 Design and participants

This RCT used a between-subjects design. It included three assessment moments, i.e., baseline (T0), post-intervention (T1), and one-month follow-up (T2), and was carried out from January 2023 to September 2023. 54 patients from the IRCCS INRCA Casatenovo Pulmonary Rehabilitation Unit who met the inclusion and exclusion criteria were recruited by the doctors together with the researchers. Age over 18 years and a diagnosis of chronic respiratory disease according to ERS/ATS criteria were the inclusion criteria. The exclusion criteria included pre-existing medical disorders that prevent the use of the Oculus Quest 2 headset, such as (1) the existence of binocular vision anomalies, (2) a history of seizures or epileptic conditions, (3) the presence of cardiac pacemakers, defibrillators, or implanted devices, and (4) the use of hearing aids. A diagnosis of dementia or cognitive impairment documented in the medical records, as well as a Mini Mental State Examination score of < 26, were other exclusion criteria. These patients were hospitalized for about 3 weeks to undergo pulmonary rehabilitation and were not allowed to leave the ward (directives issued by the hospital as a result of the COVID-19 pandemic). Two patients refused to participate due to personal reasons, thus, 52 patients were randomly assigned by the researchers to the experimental and control groups using block randomization. A label of A or B (A=intervention, B=control) was assigned to each group (block size = 4). Free online software (Research Randomizer 4.0) was used to generate the randomization list. Data were screened for outliers and no outliers were found. Three patients of the experimental group and 2 patients of the active control group were excluded from the analysis because they did not complete the T1 questionnaires due to an early hospitalization discharge. Moreover, 2 patients of the active control group were excluded from the analysis because of severe physical issues during the weeks of hospitalization that greatly impacted their psychological health thus requiring a psychotherapeutic consultation. Consequently, the final sample size resulted in 23 patients in the experimental condition (M_{age} = 71.70, SD = 7.14) and 22 patients in the control condition (M_{age} = 68.18, SD = 8.66) (Figure 1). The IRCCS INRCA Casatenovo Ethics Committee approved this study (protocol number: 3739_2023) and the study was retrospectively registered in anzctr.org (ACTRN12624000435583).

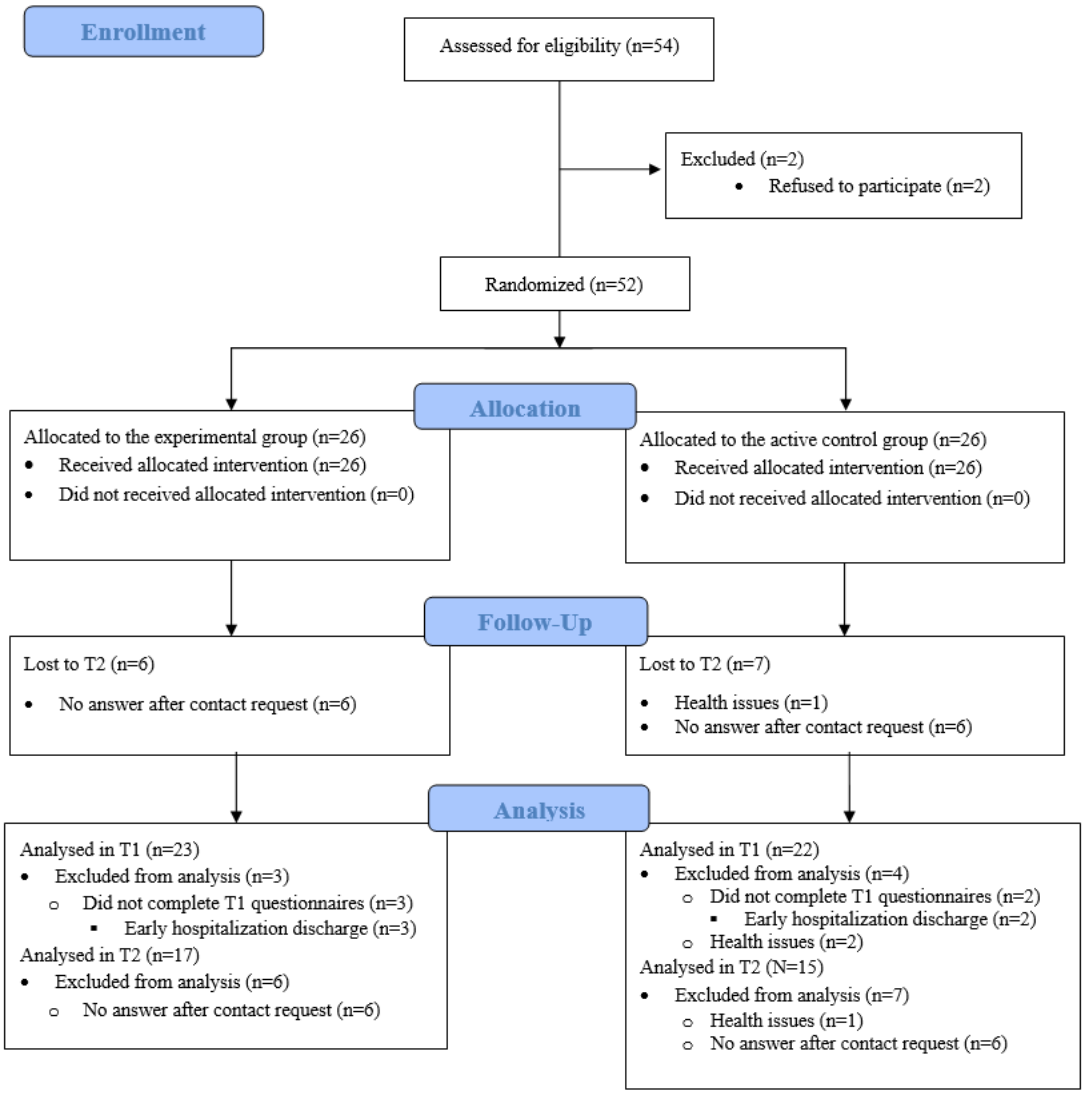

Fig. 1. CONSORT flow diagram.

At baseline, demographic information such as age, gender, educational level, employment status, marital status, and type of chronic respiratory disease were collected. The characteristics of the final sample (after the screening for outliers and missing data) are shown in Table 1.

Table 1. Participants' characteristics of the final sample.

		Experimental group (N = 23)	**Control group (N = 22)**
Age, Mean (SD)		71.70 (7.14)	69.18 (8.66)
Gender, N (%)	Male	11 (48%)	11 (50%)
	Female	12 (52%)	11 (50%)
Education level, N (%)	Elementary school	4 (17%)	6 (27%)
	Middle school	11 (48%)	9 (41%)
	Senior high school	8 (35%)	4 (18%)
	Bachelor's degree	-	2 (9%)
	Master's degree	-	1 (5%)
Marital status, N (%)	Single	2 (9%)	1 (5%)
	Cohabitant	1 (4%)	1 (5%)

	Married	13 (56%)	15 (67%)
	Divorced	2 (9%)	1 (5%)
	Widowed	5 (22%)	4 (18%)
Employment status, N (%)	Worker	1 (4%)	1 (5%)
	Unemployed	-	1 (5%)
	Retired	20 (87%)	19 (85%)
	Other	2 (9%)	1 (5%)
Smoke	Non-smoker	4 (17%)	9 (41%)
	Active smoker	3 (13%)	4 (18%)
	Ex smoker	15 (66%)	9 (41%)
	Other	1 (4%)	-
Respiratory disease, N (%)	COPD mild (FEV1≥80%)	2 (9%)	-
	COPD moderate (79%>FEV1≥50%)	4 (17%)	5 (23%)
	COPD severe (49%>FEV1≥ 30%)	7 (30%)	7 (31%)
	COPD very severe (FEV1≤ 29%)	2 (9%)	-
	Idiopathic pulmonary fibrosis	3 (13%)	-
	Chronic asthma	2 (9%)	1 (5%)
	Bronchiectasis	1 (4%)	3 (14%)
	Interstitial lung disease	-	2 (9%)
	Other	2 (9%)	4 (18%)

4.3.2 Measures

To assess cognitive impairment prior to the intervention, the Italian version of the Mini Mental State Examination (MMSE), consisting of 11 items, was used to evaluate patients' cognitive functions (Folstein et al., 1983; Measso et al., 1993; Magni et al., 1986). The maximum score achievable was 30 and the cut-off was set at 26 and no patients were excluded (Ruggeri, 1993; Monsch et al., 1995; Cockrell & Folstein, 2002).
To assess psychological changes before (T0) and after the intervention (T1) and the maintenance of these changes in the one-month follow-up (T2), both groups completed several questionnaires.

Primary outcomes

Emotional well-being (defined as enjoyment and absence of unpleasant feelings) and psychological well-being (defined as taking steps toward one's goals and having a life purpose) (Delle Fave et al., 2011) were measured using the emotional well-being subscale (EWB, ω = .76, α = .65) (3 items) and the psychological well-being subscale (PWB, ω = .81, α = .80) (6 items) of the Italian Mental Health Continuum Short Form (MHC-SF) (Keyes, 2002; Petrillo et al., 2015). A 6-point Likert scale can be used to answer (0 = *never* and 5 = *every day*). Positive and negative affect were measured using the Italian version of the Scale of Positive and Negative Experiences (SPANE) (Diener et al., 2010; Corno et al., 2016). This self-report scale consists of 12 items and is divided into two subscales: positive affect (SPANE-P, ω = .83, α = .83) and negative affect (SPANE-N, ω = .85, α = .84). The response scale for all items was a 5-point Likert scale (1 = *very rarely or never* and 5 = *very often or always*).

Furthermore, changes in relaxation within each session were assessed both subjectively through a 10-point Visual Analogue Scale (relaxation VAS) (Aitken, 1969) (in T0, T1, T2, and before and after each session), and objectively through the NONIN Palm Saturimeter that measures peripheral oxygen saturation (SpO_2, the proportion of oxygen-saturated hemoglobin to total hemoglobin in the blood; it was assessed before and after each session).

Secondary outcomes

To assess the VR acceptance and the sense of presence experienced in VR by the experimental groups, two questionnaires were proposed after each session. The Slater Usoh Steed Presence Questionnaire (SUS) (Usoh et al., 2000) was used to examine the patients' sense of presence in the virtual environment (ω = .84, α = .82). This questionnaire consists of 6 items that can be answered via a 7-point Likert scale (1 = *not at all* and 7 = *very much*).

VR acceptance was also assessed through an ad hoc questionnaire based on the Unified Theory of Acceptance and Use of Technology (UTAUT) model (Philippi et al., 2021) and measuring behavioral intention (ω = .88, α = .88), performance expectancy (ω = .94, α = .93), effort expectancy (ω = .95, α = .94), and anxiety (ω = .94, α = .86). The response scale for all the 10 items was a 7-point Likert scale (1 = *strongly disagree* and 7 = *strongly agree*).

At the end of each session, patients in the experimental group were asked to freely share their impressions about the virtual experience and to describe the positive events they thought about during the savoring exercise. They were also asked to rate the intensity of 5 emotions felt during the session (love, awe, enjoyment, gratitude, and hope) on a 10-point VAS ranging from 1 (*not at all*) to 10 (*very much*).

A final item was used to assess the perceived usefulness of the intervention on a 5-step Likert scale (1 = *not useful at all* and 5 = *completely useful*) ("Referring to the entire intervention, how much do you think it was useful for you?"). Finally, patients were invited to share their opinions and suggestions about the intervention.

4.3.3 Procedure

After giving informed consent, patients of both groups completed the pre-intervention questionnaires (T0 - MMSE, MHC-SF, SPANE, relaxation VAS). Then, together with the traditional pulmonary rehabilitation, the experimental group (N = 23) participated in the VR-based relaxation and savoring intervention, while the active control group (N = 22) listened to relaxing music on the headphones, as already done in previous studies with this population (Rutkowski et al., 2021). The music was selected from previous studies that have already used it (Knight & Rickard, 2001; Hill & Frederick, 2016) also with chronic respiratory diseases patients (McBride et al., 1999) and the songs used can be found in Appendix A, section 1.

The intervention lasted two weeks and included four 25-minute sessions in the afternoon after the pulmonary rehabilitation physical exercises (Figure 2). The baseline assessment was done in a separate session earlier to

avoid overloading the patients. In each session, the experimental group experienced an immersive 10-minute relaxing virtual scenario (provided by the Italian VR company Become-Hub) using the Oculus Quest 2 headset integrated with a narrative voice. It was a pre-recorded virtual scenario and patients could explore the virtual environment seated and without using the hand controllers (Figure 3). These scenarios were already used in other relaxation protocols (Riva et al., 2021; Malighetti et al., 2023; Riva et al., 2022; Pallavicini et al., 2022; Farahimanesh et al., 2023). In addition, these scenarios have recently become medical CE (*Conformité Européenne*, a medical device that meets all applicable health, and safety regulations in the European Union). Moreover, patients completed a savoring exercise proposed through pre-recorded audio after each virtual scenario to consolidate and amplify the positive emotions generated by the VR experience. The sessions were administered by the researchers and occurred one-on-one with each participant. Furthermore, 4 patients in the experimental group and 3 patients in the control group did not complete the fourth session due to early hospitalization discharge. At the end of the intervention (T1) and at one-month follow-up (T2), both groups completed the questionnaires again (MHC-SF, SPANE, relaxation VAS). At the one-month follow-up, depending on patients' preferences, they were contacted by phone to fill out the questionnaires, while those who wanted could fill them out online on Qualtrics.

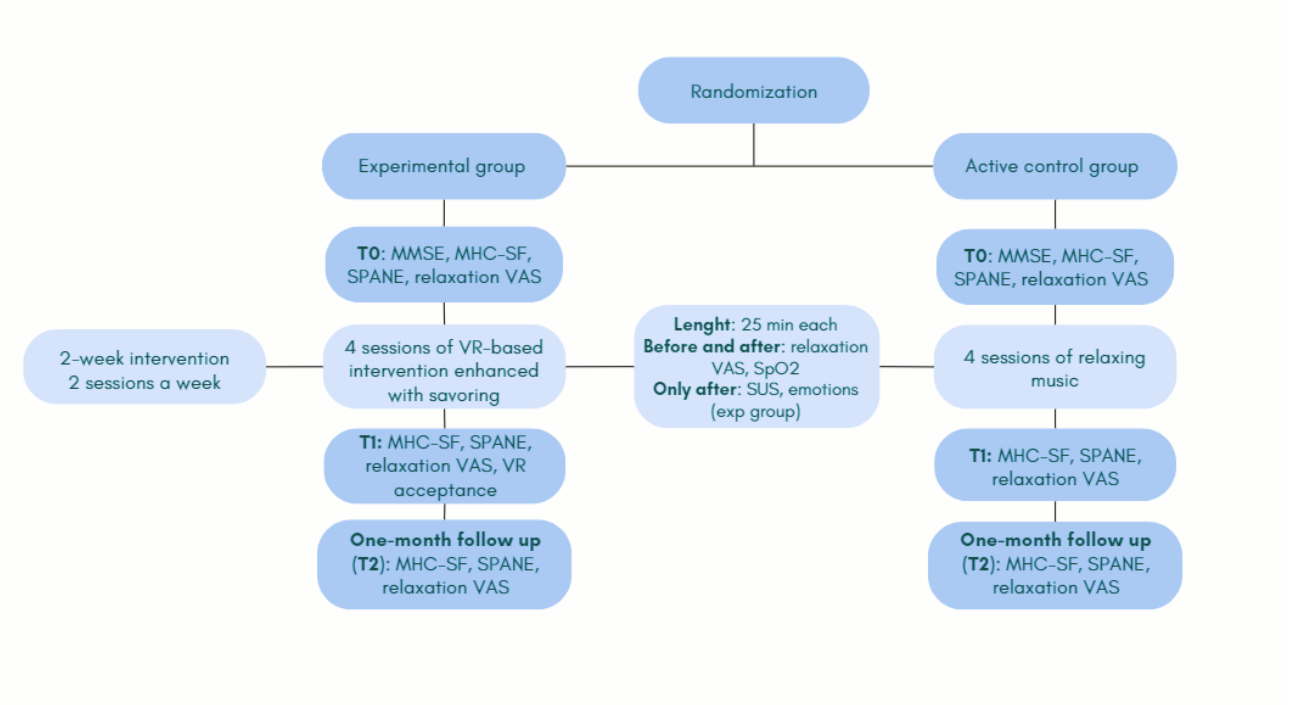

Fig. 2. Study procedure.

Fig. 3. A participant during the VR experience.

4.3.4 VR and savoring protocol

The protocol included four VR-based relaxation integrated with savoring sessions. Specifically, in the first session, patients watched *The Secret Garden*, where they were guided through a quiet and peaceful environment. Throughout the virtual scenario, a relaxing narrative voice guided the participant on a walk inside a Japanese garden on a sunny day. Moving forward, it was also possible to cross a calm pond thanks to a small wooden bridge and pass through cherry blossom trees (Riva et al., 2021; Riva et al., 2020; Pallavicini et al., 2022; Farahimanesh et al., 2023). After that, patients were guided through a savoring exercise (an example of the savoring exercises script can be found in Appendix A, section 2). In particular, they were invited to remember the positive emotions and sensations felt during the VR experience. Afterwards, they were asked to recall and savor a positive memory where they felt similar emotions (Figure 4).

In the second session, the patients watched *The Waterfall in The Prairie* (Malighetti et al., 2023). The relaxing narrative voice made them notice the colorful flowers, the quiet lakes, and the waterfalls during a walk in the prairie. In this environment, the patients could also listen to the sounds of water, the chirping of birds, and the quiet voices in the distance from a small, distant village. Later, they were invited to recall the positive emotions felt during the virtual experience and were asked to savor a positive past event shared with a loved one.

In the third session, the patients watched *The Beach at Sunset*, where the narrative voice guided them on a walk along the beach until sunset. In this scenario, they could see the colors of the sand and the sea, the relaxing, soothing hues of the sunset, and the beauty of the starry sky. They could also pay attention to the sound of the waves on the shore and notice the light wind moving the palms. Afterwards, the patients were

invited to recall the positive emotions felt during the VR experience and to mentally create and savor a personal nice place connected to these emotions (Louie, 2004; Hyland et al., 2016).

In the fourth session, the patients selected the scenario they liked the most among those experienced in the previous sessions. After that, they were guided through the exercises completed in the previous sessions to consolidate them.

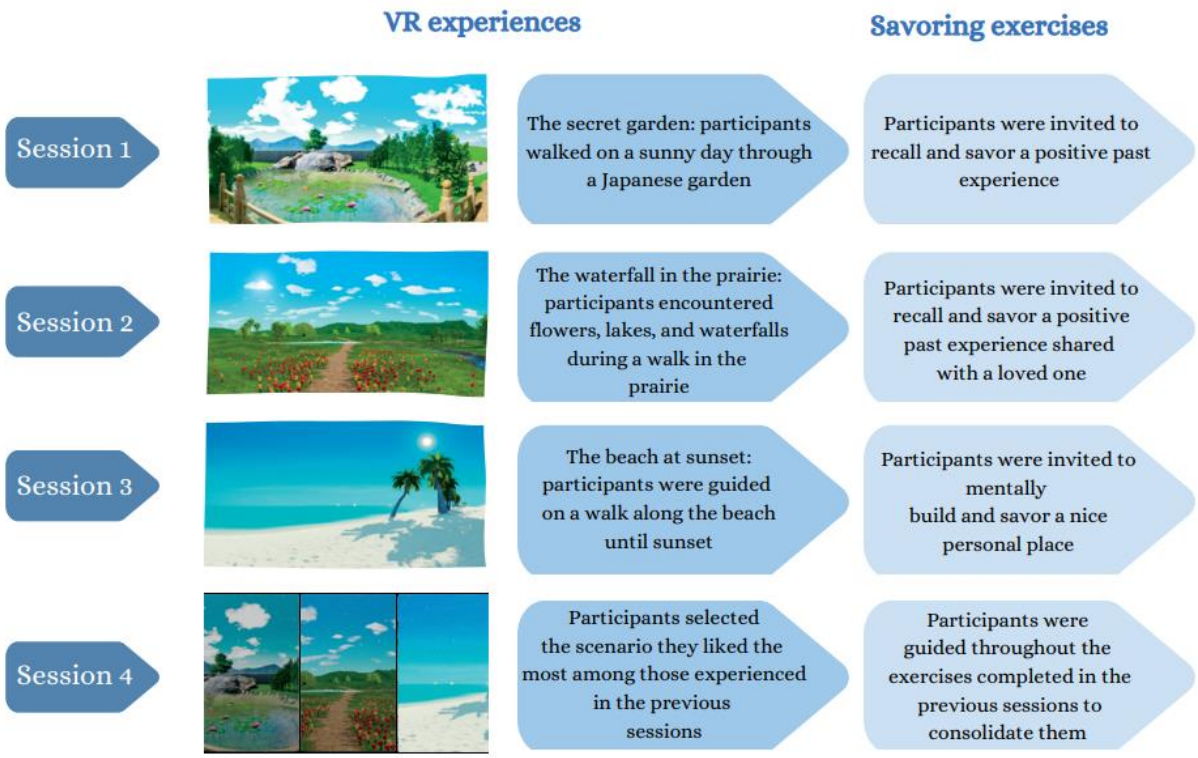

Fig. 4. Sessions of the VR-based integrated with savoring intervention.

4.3.5 Data analysis

Data analysis was conducted using IBM SPSS Statistics 29.0.1.0. and the data were screened for outliers and missing data. Group differences regarding emotional and psychological well-being, positive emotions, negative emotions, and relaxation were examined at baseline using the Student t-test for independent samples. The intervention primary outcomes for the experimental group (N = 23) and for the active control group (N = 22) were investigated by considering MHC-SF EWB, MHC-SF PWB, SPANE-P, SPANE-N, and relaxation VAS scores at pre- (T0) and post-intervention (T1). A repeated measures ANCOVA was used with group condition (experimental group and active control group) as the between-subjects factor and time (T0 and T1) as the within-subjects factor to investigate the time x group interactions as they would indicate a significant change due to the intervention. To assess the maintenance of the changes at the one-month follow-up, another repeated measures ANCOVA was performed on a subsample at the one-month follow-up (T2) of the experimental group (N = 17) and active control group (N = 15) who also completed the T2 questionnaires. Group condition (experimental group and active control group) was used as the between-subjects factor, and

time (T1 and T2) was used as the within-subjects factor. For both ANCOVAs, the centered variables (MHC-SF EWB, MHC-SF PWB, SPANE-P, SPANE-N, and relaxation VAS scores at baseline) were created and used as a covariate to adjust the baseline differences between groups. The covariates were centered by subtracting the mean covariates score from each covariate score. Repeated contrasts were used to test the differences between groups. Furthermore, group differences regarding relaxation and SpO_2 in each of the four sessions were investigated by creating the delta scores (by subtracting the pre-session scores to the post-session scores) and then using the Student t-test for independent samples.

Thematic analysis was used to assess qualitative data (Braun, 2006). To address the research question, a thematic analysis detects, analyses, and provides patterns of meaning (themes) across the dataset. This method allowed for the concise analysis of a huge amount of textual material using a deductive approach in which unexpected themes could emerge "bottom-up" from the data. Relevant data points were found methodically before being classified into prospective themes that were refined, defined, and labelled by two judges. Finally, the themes were subjected to a narrative analysis and they are reported in Appendix A.

4.4 Results

To investigate differences between groups regarding the psychological dimensions at baseline, the Student t-test for independent samples was used. Significant differences in emotional (MHC-SF EWB) ($t(43) = -4.01$, $P<.001$) and psychological well-being (MHC-SF PWB) ($t(43) = -2.62$, $P = .012$), and in positive emotions ($t(43) = -4.51$, $P<.001$) were found. No significant differences between groups in negative emotions (SPANE-N) and relaxation (relaxation VAS) were found.

4.4.1 Effectiveness of the VR-based relaxation integrated with savoring intervention

A repeated measures ANCOVA with group condition as a between-subjects factor (experimental group N = 23, active control group N = 22) and time (T0 and T1) as a within-subjects factor was performed for all variables with centered MHC-SF EWB, MHC-SF PWB, SPANE-P, SPANE-N, and relaxation VAS baseline scores as covariates and each of them was used for each analysis. The time x group interactions were examined as they would indicate a significant change due to the intervention. Descriptive data are shown as mean (M) and standard deviation (SD) (Table 2). The repeated measures ANCOVA indicated a significant greater increase in the experimental group in emotional (MHC-SF EWB, $P<.001$; repeated contrast: $P<.001$) and psychological well-being (MHC-SF PWB $P<.001$; repeated contrast: $P<.001$), positive emotions (SPANE-P, $P<.001$; repeated contrast: $P<.001$), and relaxation (relaxation VAS, $P<.001$; repeated contrast: $P<.001$) compared to the control group. Furthermore, the repeated measures ANCOVA revealed a significant decrease in the experimental group in negative emotions (SPANE-N, $P<.001$; repeated contrast: $P<.001$) compared to the control group. See Figure 5 for emotional and psychological well-being, positive and negative emotions, and relaxation scores in T0 and T1 for both groups.

Table 2. Comparison between groups in T0-T1: repeated measures ANCOVA interactions effects.

	Experimental group M (SD)		**Active control group M (SD)**		**Time x group, interaction effect**		
	T0	**T1**	**T0**	**T1**	***F***	***P***	***Partial η²***
MHC-SF EWB	3.05 (1.38)	3.92 (0.85)	5.84 (3.02)	4.18 (1.01)	165.85	<.001[a]	.888
MHC-SF PWB	3.31 (1.15)	4.02 (0.70)	4.09 (0.80)	4.31 (0.71)	26.61	<.001[a]	.559
SPANE-P	17.87 (4.84)	23.30 (4.38)	23.86 (4.00)	24.64 (4.88)	14.38	<.001[a]	.407
SPANE-N	11.91 (6.05)	9.48 (5.12)	11.09 (5.01)	10.00 (3.61)	17.60	<.001[a]	.456
Relaxation VAS	7.13 (2.91)	8.65 (2.12)	7.73 (2.52)	8.95 (1.52)	31.22	<.001[a]	.598

[a]Significant ($p < 0.05$).

Note. M: mean; SD: standard deviation.

MHC-SF EWB: Mental Health Continuum Short Form - Emotional Well-Being; MHC-SF PWB: Mental Health Continuum Short Form - Psychological Well-Being; SPANE-P: Scale of Positive and Negative Experiences – Positive affect; SPANE-N: Scale of Positive and Negative Experiences – Negative affect; Relaxation VAS: Relaxation Visual Analogue Scale.

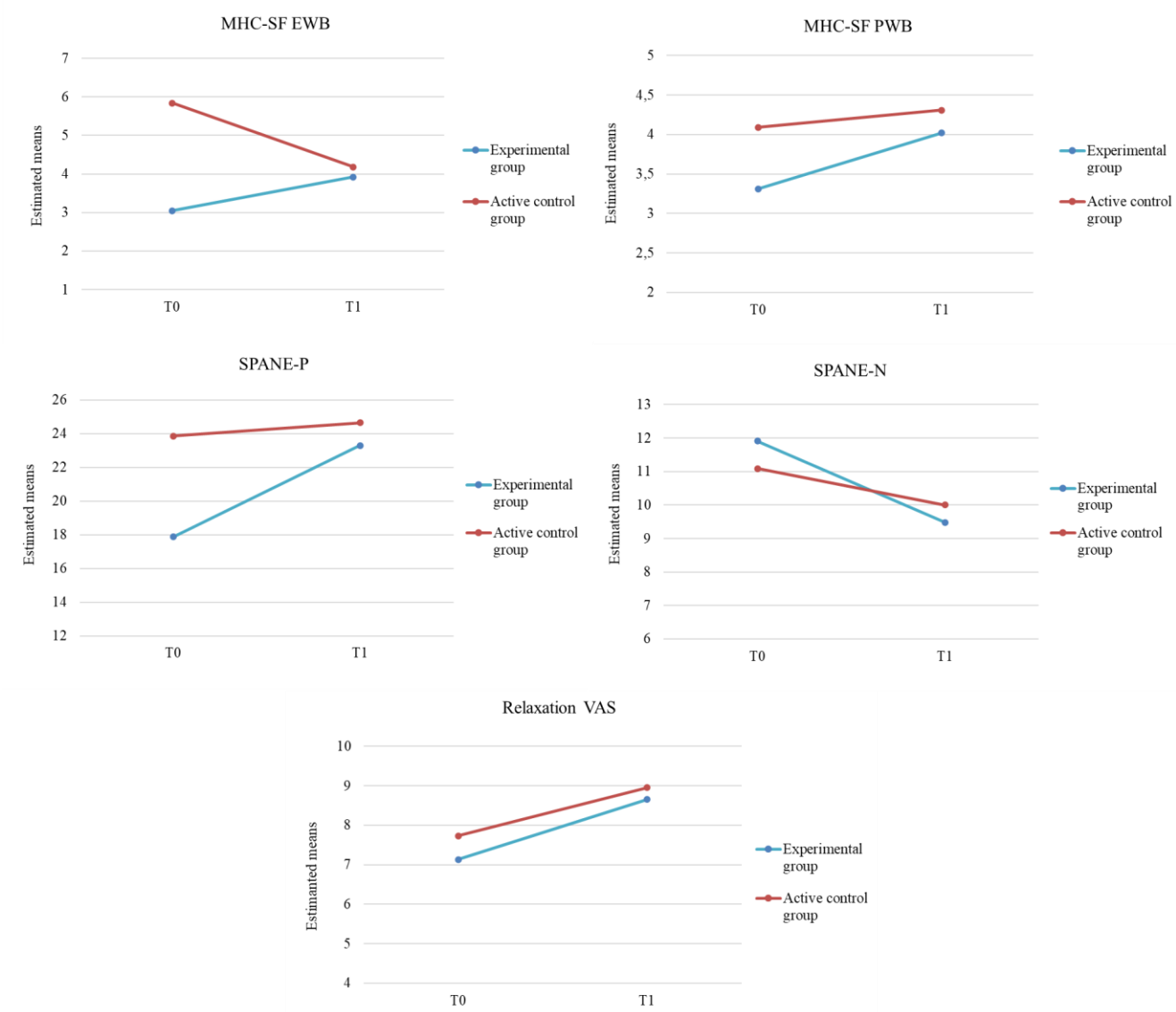

Fig. 5. Emotional and psychological well-being, positive and negative emotions, and relaxation scores in T0 and T1 in both groups.

4.4.2 Maintenance of the psychological changes at the one-month follow-up

To assess the maintenance of psychological changes achieved post-intervention (T1) after one month (T2), a repeated measures ANCOVA with group condition as a between-subjects factor (experimental group N = 17, active control group N = 15) and time (T1 and T2) as a within-subjects factor was performed for all variables with centered MHC-SF EWB, MHC-SF PWB, SPANE-P, SPANE-N, and relaxation VAS baseline scores as covariates and each of them was used for each analysis. No significant differences between groups were found in emotional (repeated contrast: P = .299) and psychological well-being (repeated contrast: P = .173), in positive (repeated contrast: P = .071) and negative emotions (repeated contrast: P = .329), and in relaxation (repeated contrast: P = .473) (Table 3).

Table 3. Comparison between groups in T1-T2: repeated measures ANCOVA interactions effects.

	Experimental group M (SD)		Active control group M (SD)		Time x group, interaction effect		
	T1	**T2**	**T1**	**T2**	***F***	***P***	***Partial η²***
MHC-SF EWB	4.00 (0.92)	3.52 (1.25)	3.97 (1.16)	3.53 (1.11)	1.25	.299	.080
MHC-SF PWB	4.02 (0.70)	3.90 (0.66)	4.08 (0.71)	4.05 (0.67)	1.86	.173	.114
SPANE-P	23.65 (4.62)	22.65 (5.24)	24.40 (5.36)	24.07 (4.14)	2.90	.071	.167
SPANE-N	9.53 (5.42)	11.00 (4.69)	10.13 (3.73)	11.13 (4.50)	1.15	.329	.074
Relaxation VAS	9.00 (1.36)	7.53 (2.15)	8.80 (1.74)	7.80 (2.33)	0.76	.473	.052

[a]Significant ($p < 0.05$).

Note. M: mean; SD: standard deviation.

MHC-SF EWB: Mental Health Continuum Short Form - Emotional Well-Being; MHC-SF PWB: Mental Health Continuum Short Form - Psychological Well-Being; SPANE-P: Scale of Positive and Negative Experiences – Positive affect; SPANE-N: Scale of Positive and Negative Experiences – Negative affect; Relaxation VAS: Relaxation Visual Analogue Scale.

4.4.3 Relaxation changes within sessions

To investigate differences between groups in each session, delta scores for self-reported relaxation and SpO_2 were created by subtracting the pre-session scores from the post-session scores. The Student t-test for independent samples was performed on delta scores. Both relaxation and SpO_2 increased in all sessions in both groups and no significant differences were found between groups (Table 4).

Table 4. Relaxation and oxygen saturation levels (SpO_2) before and after each session.

		Experimental group M (SD)	Active control group M (SD)	Independent sample t-tests	
				t	***P***
Relaxation 1	Pre-session 1	6.78 (2.58)	7.64 (2.28)		
	Post-session 1	8.83 (1.11)	9.32 (1.04)		
	Delta score	2.04 (2.10)	1.68 (1.84)	0.61	.542
Relaxation 2	Pre-session 2	6.74 (2.16)	6.86 (2.78)		
	Post-session 2	8.84 (1.50)	9.14 (1.78)		
	Delta score	1.74 (2.03)	2.27 (2.29)	-0.83	.412
Relaxation 3	Pre-session 3	7.43 (2.17)	7.32 (2.66)		
	Post-session 3	8.57 (1.41)	9.14 (1.39)		
	Delta score	1.13 (1.77)	1.82 (1.97)	-1.24	.223
Relaxation 4	Pre-session 4	8.21 (1.78)	8.00 (2.03)		
	Post-session 4	9.21 (1.03)	9.47 (1.12)		
	Delta score	1.00 (1.33)	1.47 (1.50)	-1.03	.311
SpO_2 1	Pre-session 1	92.04 (3.57)	92.50 (3.49)		
	Post-session 1	94.26 (2.12)	95.55 (1.71)		
	Delta score	2.22 (2.71)	3.05 (2.89)	-0.99	.327
SpO_2 2	Pre-session 2	92.26 (3.63)	93.09 (2.2)		
	Post-session 2	94.87 (2.28)	95.73 (2.16)		
	Delta score	2.61 (3.14)	2.64 (2.26)	-0.03	.973
SpO_2 3	Pre-session 3	91.39 (3.09)	93.68 (2.57)		
	Post-session 3	93.91 (3.13)	95.41 (2.20)		
	Delta score	2.52 (2.31)	1.73 (2.90)	1.02	.314

SpO_2 4	Pre-session 4	93.42 (1.80)	94.21 (2.23)		
	Post-session 4	95.21 (1.47)	95.74 (1.94)		
	Delta score	1.79 (1.93)	1.53 (1.74)	0.44	.662

[a]Significant ($p < 0.05$).

Note. M: mean; SD: standard deviation.

4.4.4 VR acceptance and sense of presence

Regarding VR acceptance, patients reported high levels of behavioral intention (range: 1-7 for each subscale; M = 5.55, SD = 1.91). They also showed high levels of performance expectancy (M = 5.21, SD = 1.91) and effort expectancy (M = 5.64, SD = 1.54) for this intervention. In addition, patients reported very low levels of VR anxiety when experiencing the intervention (M = 1.16, SD = 0.64). Furthermore, patients experienced a high sense of presence (range: 1-7; session 1: M = 5.25, SD = 1.45; session 2: M = 5.20, SD = 1.77) especially during the last 2 sessions (session 3: M = 5.73, SD = 1.32; session 4: M = 5.77, SD = 1.69).

4.4.5 Qualitative analysis of the virtual reality experiences and the savoring exercises

After each session, we asked patients to freely describe how they had felt during the VR experience, and we categorized their impressions into some thematic areas. These thematic areas and the in-depth analysis of the contents of the narrated experiences is in Appendix A, section 3.

Regarding savoring exercises, they have stimulated the memory of several positive experiences related to childhood, adolescence, births of children and grandchildren, marriages, travel, day-trips, illnesses, and retirement. Some memories were related to specific elements of virtual scenarios they had seen before, whereas others were not. A qualitative evaluation of the emotions and positive bodily sensations experienced by the patients during the savoring exercises can be found in Appendix A, section 4.

4.4.6 Perceived usefulness of the intervention

Regarding perceived usefulness, 8 patients in the experimental group evaluated the intervention as completely useful, 4 patients rated it as very useful, 8 as quite useful and 2 as little useful. Two patients of the active control group evaluated listening to relaxing music as completely useful, 13 patients rated it as very useful, 5 as quite useful, and one as not useful at all. A qualitative analysis of patients' explicit opinions and suggestions about the intervention was also conducted. It is possible to identify 6 main categories from the patients' comments, 4 of which are common to both groups (Table 5).

Table 5. Qualitative analysis of perceived usefulness of the intervention.

	Experimental group (number of patients)	**Active control group (number of patients)**
Organization and procedures of the intervention	Sessions and timing were adequate (23) Times between sessions were helpful in reflecting on and appreciating the positive memories that came to mind during the sessions (1) Desire to have more sessions and to view longer VR scenarios (3)	Sessions and timing were appropriate (21)

Expectations about the intervention	Initial hesitation to begin the intervention, but later reconsidered (2)	-
Intervention strengths	Opportunity to relive very good past moments (2) Opportunity to learn something new (1) Break the monotony of hospitalization (2) Breathing better as a result of the intervention (4)	Listening to music was very relaxing (9) Appreciation for the sessions even though they preferred other music genres (3) Disconnect from daily hospitalization routine (1) Breathing better after listening to music (1)
Intervention weaknesses	Preference for more realistic scenarios (2)	-
Future expectations	Desire to follow the intervention again in future hospitalizations (6) Desire to financially support the intervention (1)	Request to receive additional relaxing music to listen to even after the conclusion of the intervention (2) Suggestions of other relaxing music to use for future sessions (1)

4.5 Discussion

Emotional and psychological well-being

People with CRDs often face significant challenges due to their conditions, which go beyond the physical aspect and extend to emotional and psychological impacts. Therefore, it is crucial to develop innovative approaches to promote CRDs patients' well-being. Taking into account all these elements, this RCT investigated the effectiveness of an innovative VR-based relaxation integrated with savoring intervention in promoting emotional and psychological well-being, positive emotions, relaxation, and reducing negative emotions in CRDs patients. The maintenance of the psychological changes at the one-month follow-up was also investigated.

The findings are very encouraging and partially supported our hypothesis. Regarding the primary outcomes, such as the effectiveness of the intervention on increasing emotional and psychological well-being (H1), patients reported significant improvements, and these results are in line with other studies in which VR scenarios were employed to promote emotional and psychological well-being (Malighetti et al., 2023) and also in patients with chronic diseases (McGhee et al., 2023). Indeed, the 3 virtual experiences took patients on a first-person exploration of natural surroundings, guided by a soothing narrative voice that helped them focus on their positive bodily and emotional sensations (Malighetti et al., 2023). In this regard, savoring may have helped patients amplify the positive states experienced during the virtual experience. This means that the intervention may have helped patients connect with their own thoughts and emotions experienced during the virtual experiences. Furthermore, through the savoring exercises, patients may have had the opportunity to reflect on their own positive memories, savor them, and amplify them deeply.

Positive and negative affect

Regarding the intervention's effect on positive and negative affect, the second hypothesis (H2) was supported. Indeed, the intervention was effective in increasing positive emotions. As highlighted by previous studies, natural environments and nature-related auditory elements included in the VR experiences are effective in promoting positive emotions (Pizzoli et al., 2019). They are also successful in creating effects comparable to restorative natural surroundings (Riches, 2021; Nukarinen et al., 2022) and are particularly suitable for hospitalized patients who cannot move outside the hospital. Furthermore, the savoring exercises can be especially effective for older patients who have several positive memories in which they can immerse themselves (Smith & Hanni, 2019). These findings are also in line with savoring interventions addressed to older people in which participants were able to savor positive past events and experience in the present the positive emotions experienced then (Bryant & Veroff, 2007; Smith & Hollinger-Smith, 2015; Smith & Hanni, 2019). The intervention was also effective in decreasing negative emotions. Previous studies have shown both VR (Montana et al., 2020) and savoring to be effective in reducing negative emotions (Salces-Cubero et al., 2019; Smith et al., 2014). This may be due to the positive emotions experienced both in VR and during savoring exercises, which neutralize the harmful effects of negative emotions related to the pathology and the hospitalization, as stated by the undoing hypothesis (Fredrickson, 2002).

Relaxation

Concerning the effectiveness of the intervention in increasing relaxation (H3), patients reported significant improvements. This result is in line with other studies demonstrating the VR relaxation effect, especially when including natural and peaceful settings and natural auditory elements (Villani et al., 2007; Pizzoli et al., 2019). Indeed, relaxing virtual scenarios were already employed with patients with CRDs showing positive effects on depression, anxiety, and stress (Rutkowski, 2021). This means that Become-Hub's virtual scenarios were effective in promoting relaxation in hospitalized patients with chronic respiratory conditions.

Maintenance of the psychological changes at the one-month follow-up

Concerning the maintenance of the psychological changes at the one-month follow-up, the fourth hypothesis (H4) was supported, suggesting the positive long-term effects of the intervention on emotional and psychological well-being, positive and negative emotions, and relaxation. This means that the intervention provided patients with tools to cope with daily life once hospitalization was over and savoring may have played a role. Thanks to the savoring exercises learned during the intervention, patients were sustained in the formation, maintenance, and amplification of positive feelings, which in turn positively influenced their well-being over time. In particular, savoring practice can motivate patients to be engaged in a broader range of thoughts and behaviors, and it allows for the development of long-term resources (Tugade & Fredrickson, 2004; Smith et al., 2020; Mikkelsen et al., 2004). Because of the psychological burden that CRDs entail, as

highlighted in the literature in several reviews (Mikkelsen et al., 2004; Hynninen et al., 2005; Hurst et al., 2021), having such a tool available to deal with daily life can be a valuable resource.

Relaxation within sessions

Regarding the secondary outcomes, such as the intervention's effect on self-reported relaxation and SpO_2 pre- and post-sessions (H5), the absence of differences between groups can be understood in light of the positive effects of music on relaxation (Huang et al., 2021) already positively tested with COPD patients (Singh et al., 2009; Horuz et al., 2017). It seems that the effects of VR-based integrated with savoring relaxation intervention and relaxing music are similar in the short term (post-session). In contrast, the VR-based intervention was more effective than listening to music after the 2-week intervention and this could be due to its engaging properties, which allow patients to reflect and amplify their positive experiences, while listening to music has immediate positive effects but is less effective considering a 2-week time period.

VR acceptance and sense of presence

Regarding VR acceptance, patients reported a favorable intention to experience the VR-based relaxation integrated with savoring intervention during their future hospitalizations. They also showed a high performance expectancy for this intervention, evaluated it as easy and understandable, and reported very low VR anxiety. These findings are in line with previous studies that employed VR or savoring with people of similar age (Smith & Hanni, 2019; Huygelier et al., 2019; Syed-Abdul et al., 2019). Patients experienced a high sense of presence in all 4 sessions and these results are in line with previous research (Usoh et al., 2000; Birrenbach et al., 2023). Indeed, qualitative analysis revealed that they experienced mainly positive bodily sensations related to VR and the sense of being there in the virtual environments. Moreover, the VR scenarios helped several patients breathe deeper and promote principally positive affective states, including tranquility, peace, and safety. Many patients felt relaxed and were able to connect specific elements of the scenarios to positive past memories, suggesting that virtual experiences can help people in this process through autobiographical recall. Indeed, when the sense of presence and personal importance of VR experiences are considered, they may be experienced in a way that is personally relevant (Kisker et al., 2021), leading to the creation of a connection with the personal experiences.

Qualitative analysis of the savoring exercises also revealed that patients mainly savored positive memories shared with loved ones from the past (e.g., their parents or grandparents) and present (e.g., their sons, daughters, and grandchildren). During the savoring exercises, patients experienced several positive emotions and positive bodily sensations related to these emotions. In addition, most patients in both the experimental and active control groups perceived the respective sessions as useful. Specifically, patients in the experimental group appreciated the organization and procedure, and some of them reported breathing better as a result of the intervention, while others asked to do the intervention again in future hospitalizations. Regarding the active control group, patients found the organization and procedures of the sessions appropriate and found listening to music very relaxing.

4.5.1 Strengths and limitations

Taking into account the findings of this study, it is possible to recognize some strengths of this study. One is that, to the best of our knowledge, this RCT was the first to integrate VR and savoring and to investigate the effectiveness of a VR-based relaxation integrated with savoring intervention in CRDs patients in increasing well-being in terms of emotional and psychological well-being, positive emotions, relaxation, and decreasing negative emotions. In addition, the maintenance of the psychological changes was investigated, highlighting the importance of creating well-being promotion interventions that can help patients even after hospitalization and assess their long-term effects. As underlined by Riches et al. (2021), there is a lack of data in the literature regarding the VR effects on relaxation in the long term, and assessing follow-up is encouraged. The presence of an active control group that listened to relaxing music was another strength of this study because it is a widely used technique that has proven to be effective in enhancing mental and physical well-being in CRDs patients (Huang et al., 2021; Horuz et al., 2017). Moreover, the presence of an active control group contributed to improving the intervention's effectiveness. The fourth strength was the employed methodology which included several approaches, such as quantitative self-report measurements, objective data such as peripheral oxygen saturation, and qualitative data such as patients' memories and opinions, in order to have as complete an overview as possible of the intervention's effects. The session organization and timing were also strengths of this study, probably due to the engaging activities and the two-week duration that was considered appropriate by the patients. Furthermore, some limitations can be identified. First, the sample is heterogeneous, as it includes patients with different chronic respiratory diseases. Investigating the intervention effects on specific CRDs could provide a deeper understanding. Second, these results can be considered only partially generalizable as they involve a sample of CRDs patients from Northern Italy. Third, the sample size decreased considerably at the one-month follow-up, reducing the statistical power. Moreover, given the integrated nature of the protocol that combined VR and savoring, it is not possible with this study to analyze the contribution of the individual components of the protocol (VR-based relaxation and savoring). Future studies are encouraged to investigate the role of both separately. In addition, the occurrence of negative side effects (e.g., cybersickness) of VR was not systematically measured after each session even if the patients' qualitative responses mainly highlighted positive bodily sensations after watching the scenarios.

4.5.2 Conclusions

VR-based relaxation integrated with savoring intervention in CRDs patients is effective in enhancing emotional and psychological well-being, positive emotions and relaxation, and reducing negative emotions and its effectiveness is even higher than widely used techniques such as listening to relaxing music (McBride et al., 1999; Huang et al., 2021). The findings obtained and the appreciation for the intervention showed the potential of VR integrated with savoring, in which savoring can amplify and prolong the positive emotions experienced during VR beyond the virtual scenario, allowing patients to shift their focus and dwell on the positive parts of their lives. Moreover, given the CRDs patients' psychological burden, this intervention

underlines the importance of promoting well-being during the hospitalization weeks and leaving patients with tools they can use in their daily lives and in future difficult situations to recognize and the understanding of long-term effects and to explore the intervention's effects on specific chronic respiratory diseases.

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Not applicable.

Ethics approval and consent to participate

This study has been conducted in compliance with the Declaration of Helsinki and approved by the IRCCS INRCA Casatenovo Ethics Committee (protocol number: 3739_2023). All participants signed an informed consent form before beginning the research about the research protocol, data protection and privacy according to the General Data Protection Regulation (GDPR; EU 2016/679). The study's objectives, confidentiality, and anonymity were described, and volunteers were given full authority to complete the study. All methods were performed in accordance with the relevant guidelines and regulations in the declaration.

Conflicts of interests

The authors declare no conflicts of interests.

4.6 Appendix A

SECTION 1

Music used in the active control group

Session 1

- Debussy *Prelude to the Afternoon of a Faun* (McBride, 1999)
- Bach *Largo from Concerto for Two Violins* (McBride, 1999)

Session 2

- *Chinese Bamboo Flute with Nature Sounds* (Hill & Frederick, 2016)

Session 3

- Mozart *Symphony #40* (2nd movement) (McBride, 1999)
- Pachebel *Canon in D Major* (Knight & Rickard, 2001)

Session 4

- Percy Faith *Theme From a Summer Place, Ebb Tide, Sound of Music* (McBride, 1999)
- Wayne Gratz *Reminiscence, Time Out* (McBride, 1999)
- David Lanz *Cristofori's Dream* (McBride, 1999)

SECTION 2

Example of a savoring exercise after the VR experience

Session 1 – Participants were invited to recall and savor a positive past experience

Good afternoon, to immerse yourself more in this activity I recommend that you close your eyes, but if you prefer you can also keep them open. Now try to think of what positive emotions and feelings this scenario evoked in you, such as tranquility, peace, calmness, relaxation, serenity, harmony, and wonder. I now ask you to think of a positive past episode or event in which you experienced similar emotions. Now take a moment to focus on the chosen positive experience.

If a positive event has come to your mind, we can continue with the exercise. If you need a few more minutes to recall the experience let the researcher know. Now focus on the state of mind you experienced, imagine what thoughts went through you, recall the expression, posture, breath, sensations you experienced in your body on that occasion--as if it were occurring right now. In this image, notice whether you are observing yourself from the outside or whether you are observing yourself firsthand. Observe whether your point of view is from above, from below, from the side, from the front, from behind. Notice at what distance is the scene you visualize; it might be near or far. It might be colored or black and white, still or moving, in focus or blurred, bright or dark. Observe whether details are present or whether the scene is sketchy. There might be sounds or noises, foreground or background. Pay attention now to your breathing, how its rhythm has changed, whether it is slower or faster. Notice where the most intense sensation is in the body (in the shoulders, legs, torso, arms, hands), whether it is diffuse or in specific places, whether it is still or moving.

Now try to slowly reactivate your body starting with the movement of your hands and feet, and if your eyes are closed, gently open them again. Now that you have finished the activity, try to notice the sensations that the exercise has aroused in you and the emotions you have felt and are feeling.

SECTION 3

Qualitative analysis of the virtual reality experiences

After each session, we asked patients to freely describe how they had felt during the VR experience, and we categorized their impressions into some thematic areas (Table 6).

Table 6. Qualitative evaluation of the VR experiences: principal themes and experiences (number of patients).

Themes	Experiences (number of patients)
Bodily sensations	Floating pleasantly within the virtual scenario (3) Being on a chairlift and perceiving peace and tranquillity all around (2) Sensation of flying (1) Little nausea (2) A slight feeling of lurching while viewing the virtual scenario (1)
Immersion	Feeling like touching cherry blossoms in the secret garden (1) Desire to lay on the lawn of the secret garden (1) Desire to lay on the hammock in the beach at sunset (2) Feeling the warmth of the sun and the sea breeze on the skin during the beach at sunset (1)
Deep breathing	Feeling of breathing more deeply and easily (5) A participant rethought about the beach at the sunset during the pulmonary exercise training helped him walk 4 more laps than his daily goal (1)
Affective states	Experiencing tranquillity during the secret garden and the prairie waterfall (1) Feeling peace during the beach at sunset (1) Feeling safety due to the presence of the large tree and village in the distance during the waterfall in the prairie (1) Slight fear of the clear water of the pond due to the inability to swim during the waterfall in the prairie (1)
Relaxation	Experiencing relaxation (9) Feeling a relaxing sensation in the ankles (1) Experiencing feelings of newness and well-being (1) The VR experience was slower than the busy life (1)

Starting from the patients' stories, it can be seen that specific elements of the scenarios, particularly natural elements, elicited memories of positive past events containing similar natural elements.

For example, regarding the "secret garden" VR scenario, the waterfall reminded one patient of waterfalls he had seen in Mexico and Germany. In another patient, the lake recalled a Nile cruise she took a few years earlier, while a patient, seeing the cherry trees, thought of an orchard she saw as a teenager. Some artificial elements encountered during the VR experience were also linked to positive past and future experiences. For example, the garden fence reminded one patient of the fence he wants to build for her daughter's house, while one patient connected the view of the little bridge over the lake to an experience in an oriental museum she had in Scotland. In the "waterfall in the prairie" VR scenario, the sight of tulips reminded one patient of a desire to plan a trip with family members to go see them. The lake and crystal-clear water, on the other hand, reminded one patient of Monet's paintings he saw a few years earlier, while another patient remembered of a vacation spent on a Maldives atoll with his wife, where he was able to see the beautiful colours of the sea and landscape, and when he cried for the beauty of that moment. Furthermore, the meadow in the virtual scenario also prompted many memories related to trips and vacations taken in the mountains as children or adults.

In “the beach at sunset” VR scenario, the sea reminded many patients of vacations where they were able to see a seascape with similar colours, including trips to Santo Domingo and Sri Lanka. Furthermore, for one patient the very light colour of the sand reminded her of snow. Finally, many patients connected the starry sky of the scenario to situations in which they had seen a similar sky: one patient, for example, recalled a vacation when she was young with her friends where one night they saw a beautiful starry sky. Regarding perceived realism of the virtual scenarios, 3 patients considered unrealistic some elements of the secret garden (e.g., the carps and the grass), of the waterfall in the prairie (e.g., the river, the clouds, the wind, and the grass), and two of them of the beach at sunset (e.g., the sun and the starfish).

SECTION 4

Qualitative analysis of the savoring exercises and emotions experienced during each session

In the first savoring exercise, patients were asked to recall and savor a positive memory. For example, one patient narrated about his grandchild’s birth, and another patient thought about the successful outcome of his mother's cancer operation. There were also many narratives pertaining to travel as that of a patient who linked the cherry blossom trees of the virtual experience (the secret garden) to his trip to Kyoto with his daughter during the cherry blossom month.

In the second savoring exercise, patients were asked to savor a positive past event shared with a loved one. Many patients connected the scenario (the waterfall in the prairie) to day trips, such as a patient who recalled in detail a picnic in the mountains with her parents and grandmother when she was 7 years old. After recalling this experience, the patient was moved because she felt all the love from her parents and was amazed that she was able to remember an event from 60 years earlier that she had never thought back to.

In the third savoring exercise, patients were invited to mentally create and savor a personal nice place. Most of the patients linked their memories to the theme of the VR scenario (the beach at sunset) by telling about the experience at the sea and/or in front of starry skies. Moreover, a patient connected the beach sand of the scenario to the desert sand he saw on a trip abroad and stated, "There was a Bedouin tent with rugs and pillows where I could rest and was offered tea. There was also a salt lake with a white bottom and crystal-clear water, fish, dromedaries around the lake and elegant white cranes. I heard the sound of the wind, the verses of the dromedaries, the hubbub of two children with a horse under a tree, and the silence of the desert.”

In the fourth exercise, patients were guided through the exercises completed in the previous sessions to consolidate them. For instance, a patient related the various elements of the scenario she chose to review (the secret garden) to specific moments in her life and reported, "The butterflies reminded me of when I had the net bought as a child to catch butterflies in the garden. The fish reminded me of when I used to go to the amusement park and while playing I won a goldfish. Water lilies reminded me of a lily pad I drew in eighth grade. The stones reminded me of the less good things in his life until retirement, while the green lawn

reminded me of the good things in my life that were more than the bad ones. The bamboo door reminded me of the longed-for retirement that I achieved."

In this framework, the savoring exercises have stimulated the memory of several positive experiences related to childhood, adolescence, births of children and grandchildren, marriages, travel, day-trips, illnesses, and retirement. Some memories were related to specific elements of virtual scenarios they had seen before, whereas others were not. Many patients also freely reported the emotions and positive bodily sensations felt during the savoring exercises (Table 7).

Table 7. Qualitative evaluation of the savoring exercises: emotions and positive bodily sensations (number of patients).

Themes		**Experiences (number of patients)**
Emotions	Positive	Joy (6) Awe (4) Love (3) Commotion and crying (3) Peace (2) Tranquillity and calmness (2) Harmony (1) Gratitude (1)
	Negative	Sadness (2) Melancholy (1)
Positive bodily sensations		An inner tsunami (1) A volcano inside (1) A positive stomach emptiness of relaxation (1) Goosebumps on arms (1) Fluidity (1) A floating sensation (1)

Regarding the emotional experience after the savoring exercises, many patients specified the positive emotions they felt such as joy, awe, love, peace, and gratitude. Some patients also reported the positive bodily sensations associated with the positive emotions felt. Few patients experienced negative emotions such as sadness thinking back to loved ones who are gone or melancholy thinking back to the carefree days of childhood. To learn more about the complexity of the emotional experience reported by the patients, see Appendix A, section 4.

After each session, patients were asked to rate the intensity of 5 emotions felt during the session (love, awe, enjoyment, gratitude, and hope) on a 10-point VAS. Patients in the experimental group experienced high levels of love especially during the second session. Furthermore, they reported high levels of awe, particularly in the first session, gratitude, especially in the fourth session, and hope, particularly in the fourth session. Enjoyment was the emotion patients felt the least (Figure 6).

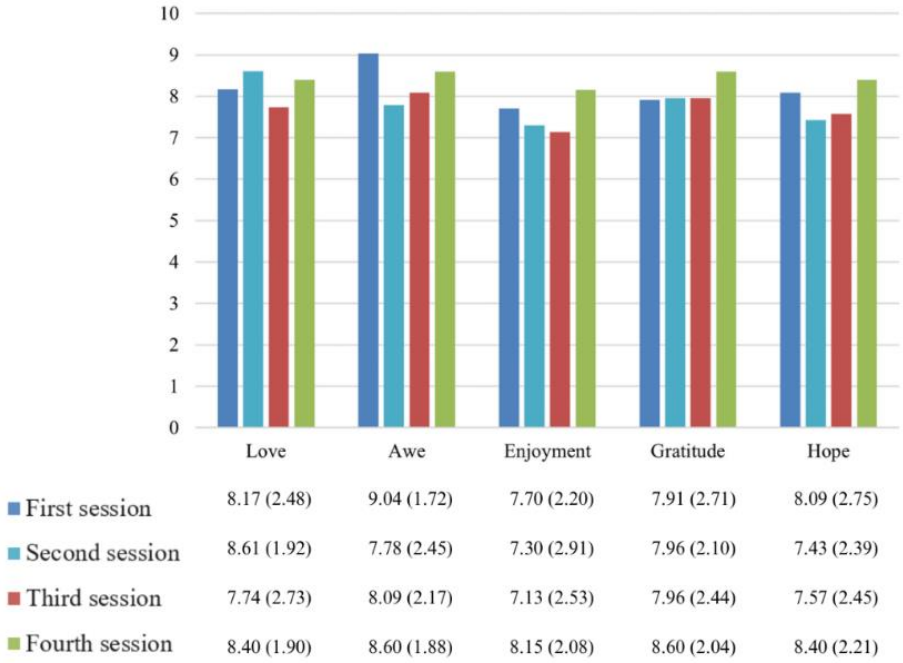

Fig. 6. Emotions experienced after each session in the experimental group, mean (M) and standard deviation (SD).

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CHAPTER 5

The Role of VR-Based Transformative Experience on Emotional and Psychological Well-Being, Positive Emotions and Savoring Practice in Italian And Spanish Emerging Adults: Preliminary Results

Introduction

After evaluating the effectiveness of a first draft of a relaxation VR-based DTx integrated with savoring on CRDs patients, a further step was to explore in more detail the relationship between VR and savoring and, in particular, between virtual transformative experiences and savoring. Indeed, metaphorical language can be applied to VR by creating virtual environments and narratives in which the person can immerse himself or herself, observe and listen to a given scene from other points of view, and consequently acquire new knowledge about himself or herself and others (Gaggioli, 2016). Thanks to metaphorical language, VR emerges as a technology that can promote change through transformative experiences (TEs), i.e., brief experiences that are considered extraordinary and unique, whose consequences are lasting and that influence individuals' self-concept, perception of the world and others, as well as personality and identity (Riva et al., 2016; Chirico et al., 2022; Malighetti et al., 2023). They can therefore provide an opportunity to explore new worlds, challenge oneself, and restructure individuals' cognitive models enhancing the sense of personal self-efficacy and self-reflection (Riva et al., 2016; Malighetti et al., 2023). In this framework, VR can act as a spatial frame of reference, facilitating these transformative experiences and the visualization of positive memories or anticipated future events. Indeed, virtual experiences can play a role in helping people relive specific positive memories and in promoting the vividness and sensory details of these memories. Depending on the associated personal meaning, virtual TEs can therefore be experienced in a personally relevant way, facilitating self-referential recall and processing and thus activating autobiographical memory (Kisker et al., 2021). In this scenario, the retrieval of virtual experiences has been shown to promote autobiographical retrieval mechanisms, allowing past positive experiences to be recalled and associated positive emotions to be consciously relived (Svoboda et al., 2006). Therefore, our goal was to reach a deeper understanding of the effects of VR on the amplification of positive emotions, and in particular, of a virtual TE on savoring practice while creating the basis for the development of an innovative digital solution with a low environmental impact and addressed to emerging adults' well-being promotion. As mentioned in the previous chapters (Chapter 1 and 3), this age group has been particularly affected by the COVID-19 pandemic and nowadays reports decreasing levels of well-being highlighting the need to develop new accessible well-being interventions.
Starting from these premises, it was decided, together with the Department of Personality, Assessment and Psychological Treatment at the University of Valencia and the Italian VR company Become-Hub, to conduct a study involving both Italian and Spanish participants and aimed at evaluating the impact of a VR-based TE on emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, and on the practice of savoring exercises in emerging adults. The study is still ongoing, hence in this chapter preliminary results are presented.

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The Role of VR-Based Transformative Experience on Emotional and Psychological Well-Being, Positive Emotions and Savoring Practice in Italian and Spanish Emerging Adults: Preliminary Results

5.1 Abstract

Background. Savoring involves intentionally generating and intensifying positive emotions, and through savoring strategies, people can amplify the bodily sensations and duration of their positive emotions. In this framework, brief virtual reality (VR) transformative experiences (TEs) allow the exploration of new ways of thinking and foster the ability to recognize positive experiences. This ongoing study therefore seeks to assess the impact of a VR-based TE on emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, and the independent practice of savoring exercises in emerging adults.

Objective and methods. Fifty-one Italian and Spanish emerging adults have been enrolled so far. The experimental group (N = 28) experienced a 10-minute virtual TE focused on savoring, while the active control group (N = 23) listened to the same recorded narrative without VR. Both groups were then guided through four savoring strategies (e.g., to be present, positive mental time travel, gratitude, and behavioral display) and encouraged to practice them over the next week. Both groups filled out the online questionnaires before (t0) and after the TE (t1), and one week later (t2).

Results. After the TE (t1), independent sample Student t-tests revealed that the experimental group perceived virtual TE as significantly more transformative and pleasant and experienced significantly higher levels of awe and hope than the control group. Concerning emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, and savoring amplifying strategies after one week (t2), no differences were found between groups, although paired sample Student t-tests revealed significant improvements in both group. Specifically, the experimental group reported increased levels of emotional and psychological well-being, enjoyment orientation, prioritizing positivity, and savoring amplifying strategies, while the control group reported increased levels of positive emotions and savoring amplifying strategies. Regarding the practice of savoring strategies after one week (t2), the experimental group displayed positive emotions to others significantly more than the control group, felt significantly better after using it and appreciate it significantly more compared to the control group. Furthermore, the experimental group felt significantly better after using the positive mental time travel strategy compared to the control group.

Conclusions. Although these results are preliminary and the study is still ongoing, this study showed that the virtual TE offers some potentialities in terms of personal emotional change and savoring strategies practice compared to the TE without VR. More research is needed to determine the long-term effects and to explore in-depth the combination with savoring strategies.

Keywords: savoring, virtual reality, transformative experience, emerging adults, psychological well-being, positive emotions.

5.2 Introduction

The capacity to consciously create, prolong, or intensify positive emotions is known as savoring (Bryant, 2003; Bryant et al., 2011; Croft et al., 2014). According to Hurley and Kwon, savoring is a form of perceived control and regulation of positive emotions (Hurley & Kwon, 2013). The broaden and build theory of positive emotions and the undoing hypothesis are two well-known positive psychology theories that have been found to be closely related to savoring, which can increase awareness and recognition of positive emotions (Quoidbach et al., 2010; Fredrickson, 2013). Indeed, savoring can enhance well-being by facilitating the development, maintenance, and amplification of positive emotions (Smith et al., 2020). According to research, savoring is associated with fewer negative emotions, fewer depression symptoms, and a greater number of positive emotions and positive reflections on life (Hurley & Kwon, 2012; Cheung et al., 2019). Additionally, savoring positive emotions improves the quality of connections with others and may be a mechanism that supports the capacity to find purpose in challenging circumstances (Smith et al., 2020). Moreover, savoring can be considered as a form of proactive emotional regulation in which people actively seek out and create positive events themselves instead of just reacting to them (Bryant, 2021). As a consequence, this proactive approach not only foster a greater awareness of positive emotions but also encourage people to actively bring pleasantness into their daily lives. In this context, people can have their own perceptions about their capacity to enjoy positive events (savoring beliefs) and can use behaviors or thoughts that can amplify or dampen the intensity and duration of positive emotions (savoring amplifying strategies and dampening strategies) (Bryant, 2003; Cheung et al., 2019). Specifically, Quoidbach et al. (2010) have identified four savoring strategies. The first one is to be present by focusing on the current pleasurable experience. People can also engage in positive mental time travel that involves recalling or anticipating pleasant events, or in gratitude that includes celebrating positive experiences and sharing them with others. Lastly, another savoring strategy is behavioral display, which involves expressing positive emotions through nonverbal actions. Indeed, the positive emotions experienced can be increased and amplified by the use of savoring strategies.

In this framework, Virtual Reality (VR) can be considered a tool that can facilitate the recall of positive experiences and associated positive emotions because it allows the creation of pleasant virtual environments that can stimulate these memories, consequently increasing their vividness and sensory details (Kisker et al., 2021). In this way, VR serves as a spatial frame of reference and facilitates self-referential recall by activating autobiographical memory (Kisker et al., 2021). Consequently, awareness of the positive emotions generated by such positive experiences can be increased and amplified through savoring amplifying strategies. Indeed, VR can be a valuable tool for encouraging the adoption of savoring strategies and the awareness of pleasant experiences in daily life, as well as increasing the ability to actively create positive events daily. In particular, immersion—which refers to extent to which a VR experience can completely engage and captivate users within a simulated environment —is a crucial aspect activated by VR. Specifically, fully immersive VR denotes a level of engagement that may entail the use of head-mounted displays (HMDs) covering the user's field of vision and blocking out the actual surroundings, thereby fostering a heightened sense of presence (Villani et

al., 2007). This gives users the ability to interact with the virtual environment in the first person and gives them the impression that they are physically there (Colombo et al., 2022). Additionally, VR has been shown to be effective in eliciting positive emotions in controlled laboratory settings (Diniz Bernardo et al., 2021; Chirico et al., 2021), and it has been validated as an effective tool for inducing emotional reactions (Baños et al., 2006) and improving emotional regulation (Colombo et al., 2021).

VR can also be considered an effective technology for promoting transformative experiences (TEs) (Malighetti et al., 2023). TEs can be described as brief experiences perceived as extraordinary and exceptional, and can manifest as sudden insight or epiphany (Pizzolante et al., 2024). Such experiences can be evoked through specific conducive circumstances, including narrative metaphorical VR experiences, which allow the exploration of new worlds and new ways of thinking (Malighetti et al., 2023) [17]. They are considered as consistent across different cultures and have been shown to have a significant impact on people at different stages of life, and in multiple ways (Gaggioli et al., 2016; Pizzolante et al., 2024). Accordingly, these experiences contribute to shifts in self-perception, perspectives, and perceptions of others, as well as personal identity and personality, owing to their capacity to expand knowledge and intensify emotional complexity (Riva et al., 2016; Chirico et al., 2022). Consequently, guided virtual transformative experiences may amplify people's self-reflection about positive events in their lives and their ability to learn and use strategies to appreciate them. For example, in the study conducted by Malighetti et al. (2023), the university students of the experimental group were invited every week for three weeks to watch six non-immersive VR videos (two VR videos per week) and listen to audio files for guided reflections on the videos. Specifically, the first two videos guided participants in paying attention to their sensations through breathing techniques, while in the others four videos. In each of the four videos that follow, participants overcome various obstacles that symbolically represent challenges they may have encountered in life and consider their own emotional resources that they can activate in the face of future challenges. The videos all have different content but the same narrative structure and are intended to activate a transformative process through metaphorical experiences. Results showed that the participants of the experimental group showed significantly increased levels of both emotional and psychological well-being compared to the waiting-list control group. This could be as a result of the experimental group being led on a metaphorical journey to find their own resources. By encouraging participants to explore new worlds and challenging their emotional and cognitive schemas, this intervention capitalized on the transformative potential of VR.

Starting from these premises, this ongoing exploratory study aims at evaluating the impact of a VR-based TE on emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, savoring strategies, and on the practice of savoring exercises in Italian and Spanish emerging adults. We hypothesize that the experimental group would (1) have a different perception of the quality of the TE compared to the control group after the TE (t1), (2) increase positive emotions compared to the control group after the TE (t1), (3) increase emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, and decrease negative emotions the following week (t2), (4) increase

savoring amplifying strategies and decrease dampening strategies the following week (t2), (5) increase savoring practice the following week (t2) compared to the control group.

5.3 Methods

5.3.1 Participants and design

So far, this ongoing exploratory study has involved Italian and Spanish emerging adults, and participants were recruited using the snowball method starting from university courses, except for psychology courses, and students contacts. The study was approved by the Ethics Committee of the Università Cattolica del Sacro Cuore of Milan. Participants were randomly assigned to either (a) the experimental group, (b) the control group 1, or (c) the control group 2. The inclusion criteria were age between 18 and 30 years, fluency in the Italian or Spanish language, a Patient Health Questionnaire-9 item (PHQ-9) score of 9 or less, and having a technological tool for Internet access. Demographic characteristics, including age, gender, education level, marital status, and employment status, were collected at the base line and are reported in Table 1.

Table 1. Participants' characteristics.

		Experimental group (N=28)	**Control group (N=23)**
Age, Mean (SD)		24.1 (3.03)	23.5 (2.63)
Nationality (%)	Italy	17 (60%)	14 (60%)
	Spain	11 (40%)	9 (40%)
Gender, N (%)	Male	12 (43%)	10 (44%)
	Female	14 (50%)	13 (56%)
	Other	2 (7%)	0 (0%)
Education level, N (%)	Middle school	2 (7%)	0 (0%)
	Senior high school	6 (21%)	8 (35%)
	Bachelor's degree	10 (37%)	8 (35%)
	Master's degree	6 (21%)	4 (17%)
	PhD	2 (7%)	3 (13%)
	Other	2 (7%)	0 (%)
Marital status, N (%)	Single	12 (43%)	12 (52%)
	Partner	8 (28%)	8 (35%)
	Cohabiting partner	7 (25%)	3 (13%)
	Other	1 (4%)	0 (0%)
Employment status (%)	Student	6 (21%)	9 (40%)
	Worker	14 (50%)	8 (35%)

Student-worker	7 (25%)	4 (17%)
Unemployed	1 (4%)	1 (4%)
Other	0 (0%)	1 (4%)

5.3.2 Measures

The two groups completed the following online questionnaires on Qualtrics (Table 2).

To assess symptoms of depression as an exclusion criterion, the Patient Health Questionnaire-9 item (PHQ-9) was used at the baseline (t0) (Manea et al., 2012). A 5-point Likert scale was used to answer (0 = *not at all* and 4 = *nearly every day*) and the total scores range from 0 to 27 and the cut-off was set to 9. It was decided to set this exclusion criterion because the regulation of positive emotions has been found to be impaired in people with depression disorders (Carl et al., 2014; Carl et al., 2013).

To measure the intensity of 8 positive emotions (e.g., joy, contentment, pride, love, compassion, awe, hope, and gratitude) a 10-point Visual Analogue Scale (VAS) (1 = *not at all* and 10 = *very much*) was used at the baseline (t0) and immediately after the TE (t1).

Moreover, immediately after the TE (t1), an ad hoc questionnaire composed by four items was administered to measure the perception of the TE and its pleasantness (α = .83; ω = .84) (i.e., *How transformative was this experience for you? How pleasant was your transformative experience? Did you discover a new way of thinking? Has this experience made you see new ways of appreciating small everyday moments?*). A 7-point Likert scale was used to answer (1 = *not at all* and 7 = *very much*).

To investigate emotional and psychological well-being at the baseline (t0) and at the end of the intervention (t2), the Mental Health Continuum Short-Form (MHC-SF) was administered (Keyes, 2002; Petrillo et al., 2015). Specifically, the emotional well-being subscale (EWB, item 1-3, α = .75; ω = .76) and the psychological well-being subscale (PWB, item 9-14, α = .81; ω = .82) were used. A 6-point Likert scale was used to answer (0 = *never* and 5 = *every day*).

To investigate positive and negative emotions at the baseline (t0) and at the end of the intervention (t2), the Scale of Positive and Negative Experiences (SPANE) was used (Diener et al., 2010; Corno et al., 2016). This 12-item questionnaire includes two subscales: the SPANE-P (α = .84; ω = .84), which assesses positive emotions (e.g., positive, good, pleasant, happy, joyful, and contented), and the SPANE-N (α = .72; ω = .77) which investigates negative emotions (e.g., negative, bad, unpleasant, sad, afraid, angry). A 5-point Likert scale was used to answer (1 = *very rarely or never* and 5 = *very often or always*).

To measure the extent to which participants are able to bring pleasantness into their daily lives at the baseline (t0) and at the end of the intervention (t2), the Enjoyment Orientation Scale (EOS) was administered (α = .84; ω = .85) (Hervás & Vázquez, 2006). A 7-point Likert scale was used to answer (1 = *strongly disagree* and 7 = *strongly agree*) to this 6-item questionnaire.

To investigate the participants' tendency to pursue pleasant states as a key criterion for structuring their daily life at the baseline (t0) and at the end of the intervention (t2), the Prioritizing Positivity Scale (PPS) was used

(α = .74; ω = .75) (Catalino & Boulton, 2020; Chiesi et al., 2023). A 9-point Likert scale was used to answer (1 = *strongly disagree* and 9 = *strongly agree*) to this 5-item questionnaire.

To investigate savoring amplifying and dampening strategies at the baseline (t0) and at the end of the intervention (t2), the 30-item Ways of Savoring Checklist (WOSC) was administered (Jose et al., 2012). This questionnaire includes two subscales: the WOSC Amplifying (α = .87; ω = .87) which assess savoring strategies such as absorption and counting blessings, and the WOSC Dampening α = .83; ω = .85) which assess dampening strategies such as kill-joy thinking. A 7-point Likert scale was used to answer (1 = *strongly disagree* and 7 = *strongly agree*).

At the end of the intervention (t2), an ad hoc questionnaire was used to investigate the frequency of use of the four savoring strategy, how much better the participants felt after using them, and the degree of appreciation for each strategy. A 5-point Likert scale was used to answer (1 = *not at all* and 5 = *very much*).

Table 2. The study assessments moments and the related questionnaires.

Study assessments moments	Questionnaires
Baseline (t0)	PHQ
	MHC-SF EWB, MHC-SF PWB
	SPANE-P, SPANE-N
	EOS
	PPS
	WOSC Amplifying, WOSC Dampening
	Positive emotions VAS
After the TE (t1)	Positive emotions VAS
	Ad hoc questionnaire to measure the perception the TE and its pleasantness
After the savoring practice week (t2)	MHC-SF EWB, MHC-SF PWB
	SPANE-P, SPANE-N
	EOS
	PPS
	WOSC Amplifying, WOSC Dampening
	Ad hoc questionnaire was used to investigate the frequency of use of the 4 savoring strategy, how much better the participants felt after using them, and the degree of appreciation for each strategy

5.3.3 Procedure

This exploratory study used a between-subjects design and included three assessment moments, e.g., baseline (t0), immediately after the TE (t1), and after the following week of independent savoring practice (at the end of the intervention – t2). Invitations were sent to university students, and those who were interested in

participating contacted the research team. Participants were then invited to fill out the online informed consent forms. After giving informed consent, participants were invited to the Labs of the Università Cattolica del Sacro Cuore of Milan or the University of Valencia and started by completing the online baseline questionnaires (t0 - positive emotions VAS, MHC-SF EWB and PWB, SPANE, EOS, PPS, WOSC) on Qualtrics. Then, the experimental group (N = 28) experienced, during the in-person session, a 10-minute virtual TE *The River and The Leaf* with the Oculus Quest 2 headset created by Italian VR company Become Hub. In this scenario, participants could first listen to natural sounds such as tree rustling and waterfalls, while a narrator's voice guided them along a path leading to a river, where leaves of various colors and shapes fell, until they arrived at a rose garden (Figure 1). For the current study, the original scenario's narrative script was modified to guide participants in reliving and savoring positive personal experiences from the past, present, and future. For the control group (N = 23), the length of the TE, the narrative script, and the narrator's voice were the same, and the participants could listen to it through earphones during the in-person session (audio TE). Consequently, the participants of the control group could only hear the narrative voice integrated with the sounds of nature without seeing the elements of the natural environment.

Figure 1. The steps of the transformative experience *The River and The Leaf*.

Immediately after the TE (t1), participants of both the experimental group and the control group completed the online t1 questionnaires (the ad hoc questionnaire to measure the perception of the TE and its pleasantness and positive emotions VAS). Both groups were then guided by the researcher, through a pre-defined script, to learn

four savoring strategies identified by Quoidbach et al. (2010) for 20 minutes. Specifically, before starting, participants were asked to close their eyes and relax by taking deep breaths. Next, the participants experienced the following strategies.

- To be present: in this exercise participants were asked to bring their attention to the present moment using all senses (hearing, smell, etc.), then paying attention to the breath, positive emotions, and bodily sensations experienced. This exercise thus aimed to promote absorption in the present moment and intensify the perceptual experience.
- Positive mental time travel: in this exercise, participants were guided to choose a past or future positive personal experience and to immerse themselves in the chosen event by trying to experience it as if it was happening in the present moment, paying attention to the breath, emotions, and bodily sensations experienced in order to savor the past or future positive emotions and the present ones.
- Gratitude: in this exercise, participants were asked to pay attention to and savor the positive experiences, even small ones, that they experience on a daily basis and to share these with loved ones. Again, they were then asked to pay attention to the breath, emotions, and bodily sensations experienced. The aim was thus to promote reflection and awareness of the gifts present in one's life.
- Behavioral display: in this exercise, participants were asked to share, in the following days, their positive emotions with others using behavioral expressions such as smiling, laughing, hugging, etc. Then, participants were asked to pay attention to the emotions and sensations aroused by these actions.

After learning the four savoring strategies, participants of both groups were encouraged to autonomously practice them over the next week. During this week, participants could freely decide whether to practice all strategies or only some of them and with the frequency they preferred. At the end of the intervention (after the savoring strategies practice week – t2), participants of both groups completed the online questionnaires (MHC-SF EWB and PWB, SPANE, EOS, PPS, WOSC, and an ad hoc questionnaire to investigate the frequency of use of each savoring strategy, how much better the participants felt after using them, and the degree of appreciation for each strategy).

5.4 Data analysis

Data analysis was conducted using Jamovi 2.3.28. Nationalities and group differences regarding emotional and psychological well-being, positive emotions, negative emotions, enjoyment orientation, positivity prioritizing, and savoring and dampening strategies were examined at baseline using the Student t-test for independent samples. Furthermore, group difference regarding participants' perception of the TE (ad hoc questionnaire) were investigated using the Student t-test for independent samples, and group differences regarding positive emotions (positive emotions VAS) experienced immediately after the TE were investigated by creating the delta scores (by subtracting the pre-TE scores to the post-TE scores) and then using the Student t-test for independent samples.

Moreover, a repeated measures ANCOVA was used with group condition (experimental group and control group) as the between-subjects factor and time (t0 and t2) as the within-subjects factor to investigate the time

x group interactions as they would indicate a significant change due to the intervention. Consequently, for the experimental group (N = 28) and for the control group (N = 23) were considered the MHC-SF EWB, MHC-SF PWB, SPANE-P, SPANE-N, EOS, PPS, WOSC Amplifying and WOSC Dampening scores at baseline (t0) and after the savoring practice week (t2). For the ANCOVA, the centered variables (MHC-SF EWB, MHC-SF PWB, SPANE-P, SPANE-N, EOS, PPS, WOSC Amplifying and WOSC Dampening scores at baseline) were created and used as a covariate to adjust the baseline differences between groups. The covariates were centered by subtracting the mean covariates score from each covariate score.

Furthermore, within subjects differences were investigated for both group using the paired sample Student t-tests, and the frequency of use of the four savoring strategy, how much better the participants felt after using them, and the degree of appreciation for each strategy (ad hoc questionnaire) were investigated using the Student t-tests for independent sample.

5.5 Results

Independent sample Student t-tests were performed to evaluate the differences regarding the psychological dimensions at baseline between the Italian and the Spanish sample. Significant differences in emotional (MHC-SF EWB) ($t(49) = -2.75$, $p = .008$) and psychological well-being (MHC-SF PWB) ($t(49) = 2.62$, $p = .012$), in positive emotions (SPANE-P) ($t(49) = -2.68$, $p = .010$) (positive emotions VAS) (joy, $t(49) = -2.65$, $p = .011$; compassion, $t(49) = -3.14$, $p = .003$), and in dampening strategies (WOSC Dampening) ($t(49) = 2.32$, $p = .024$) were found. Furthermore, the Student t-tests for independent sample were used to investigate the differences at baseline between the experimental and the control group. Significant differences were found in positive emotions (positive emotions VAS) (contentment, $t(49) = 2.01$, $p = .049$; love, $t(49) = 2.70$, $p = .009$; compassion, $t(49) = 2.03$, $p = .047$; awe, $t(49) = 2.13$, $p = .038$).

5.5.1 Participants' experience immediately after the TE

Regarding the participants' experience immediately after the TE (t1), the independent sample Student t-test revealed that the experimental group perceived the TE as significantly more transformative and pleasant than the control group (ad hoc 4-item questionnaire to measure the perception of the TE and its pleasantness) (Table 3).

Table 3. Perception of the TE and its pleasantness immediately after the TE (t1).

	Experimental group M (SD)	**Control group M (SD)**	**Independent sample Student t-tests**	
			t	*p*
Perception of transformativeness	4.67 (1.24)	3.43 (1.61)	3.09	.003[a]
Pleasantness	6.14 (0.84)	5.39 (0.98)	2.92	.005[a]
Opportunity to discover a new way of thinking	4.32 (1.41)	3.73 (1.51)	1.41	.163

Opportunity to see new ways of appreciating small, everyday moments	5.03 (1.37)	4.30 (1.57)	1.76	.083
Transformative virtual experience[b]	5.04 (0.97)	4.22 (1.18)	2.73	.009[a]

[a]Significant ($p < 0.05$)
[b]Total score of the ad hoc questionnaire.
Note. M: mean; SD: standard deviation.

Furthermore, delta scores for each of the 8 positive emotions were calculated by subtracting the baseline scores (t0) from the post-TE scores (t1). After this, independent sample Student t-tests based on the delta positive emotions scores (positive emotions VAS) revealed a significant increase hope and awe for the experimental group (Table 4).

Table 4. Positive emotional change after the TE (t1).

		Experimental group M (SD)	**Control group M (SD)**	**Independent sample Student t-tests**	
				t	*p*
Joy	Baseline (t0)	5.75 (2.35)	5.04 (2.55)		
	After the TE (t1)	6.21 (2.75)	4.78 (2.98)		
	Delta score	0.46 (2.17)	-0.26 (1.83)	1.29	.203
Contentment	Baseline (t0)	6.50 (2.12)	5.26 (2.26)		
	After the TE (t1)	7.29 (2.07)	5.83 (2.50)		
	Delta score	0.78 (1.81)	0.56 (2.50)	0.36	.717
Pride	Baseline (t0)	5.21 (2.94)	4.22 (2.83)		
	After the TE (t1)	5.14 (3.12)	3.83 (3.20)		
	Delta score	-0.07 (2.77)	-0.39 (3.23)	0.38	.705
Love	Baseline (t0)	7.32 (2.71)	5.00 (2.36)		
	After the TE (t1)	7.39 (2.36)	5.74 (3.74)		
	Delta score	0.07 (3.11)	0.73 (3.04)	-0.76	.445
Compassion	Baseline (t0)	4.39 (3.07)	2.74 (2.63)		
	After the TE (t1)	4.46 (3.49)	3.04 (3.44)		
	Delta score	0.07 (1.82)	0.30 (1.76)	-0.45	.648
Awe	Baseline (t0)	4.18 (2.51)	2.65 (2.59)		
	After the TE (t1)	6.89 (2.77)	3.13 (2.53)		
	Delta score	2.71 (2.81)	0.47 (2.12)	3.14	.003[a]
Hope	Baseline (t0)	5.32 (2.91)	4.53 (2.76)		
	After the TE (t1)	6.68 (2.44)	3.83 (3.35)		
	Delta score	1.35 (2.07)	-0.69 (2.47)	3.22	.002[a]
Gratitude	Baseline (t0)	5.93 (2.64)	5.09 (3.27)		
	After the TE (t1)	6.96 (2.66)	5.83 (3.39)		

Delta score	1.03 (3.07)	0.73 (2.61)	0.36	.716

[a]Significant ($p < 0.05$)

Note. M: mean; SD: standard deviation.

5.5.2 Participants' experience after the savoring practice week

A repeated measures ANCOVA with group condition as a between-subjects factor (experimental group N = 28, control group N = 23) and time (t0 and t2) as a within-subjects factor was performed for all variables with centered MHC-SF EWB, or MHC-SF PWB, or SPANE-P, or SPANE-N, or EOS, or PPS, or WOSC Amplifying, or WOSC Dampening baseline scores as covariates for each analysis. The time x group interactions were examined as indicators of significant changes due to the intervention.

Descriptive data are shown as mean (M) and standard deviation (SD) (Table 4). No significant differences were found between groups, thus showing that VR transformative experience and audio transformative experience reached the same outcomes. Nevertheless, paired sample Student t-tests revealed a significant increase in the experimental group in emotional (MHC-SF EWB) and psychological well-being (MHC-SF PWB), enjoyment orientation (EOS), prioritizing positivity (PPS), and in the savoring amplifying strategies (WOSC Amplifying), while a significant increase for the control group only in the positive emotions (SPANE-P), in the savoring strategies (WOSC Amplifying) (within subjects) (Table 5 and Table 6).

Table 5. Comparison between groups in t0-t2: repeated measures ANCOVA interactions effects.

	Experimental group M (SD)		**Control group M (SD)**		**Time x group, interaction effect**		
	t0	**t2**	**t0**	**t2**	***F***	***p***	***Partial η²***
MHC-SF EWB	3.49 (0.91)	3.77 (0.88)	3.29 (0.77)	3.36 (0.98)	0.237	.629	.005
MHC-SF PWB	3.02 (1.10)	3.35 (0.98)	2.86 (0.87)	3.16 (0.88)	0.018	.893	.000
SPANE-P	22.9 (3.42)	23.3 (3.91)	21.2 (3.21)	22.6 (3.58)	0.497	.484	.010
SPANE-N	12.8 (3.29)	12.9 (3.64)	13.5 (2.94)	14.9 (4.39)	0.002	.960	.000
EOS	4.97 (1.05)	5.35 (1.20)	4.62 (0.86)	4.96 (0.90)	0.448	.506	.009
PPS	6.46 (1.37)	7.13 (1.11)	6.19 (1.27)	6.60 (1.30)	0.661	.420	.014
WOSC Amplifying	4.21 (0.90)	4.84 (0.96)	3.73 (0.97)	4.25 (0.79)	0.388	.536	.008
WOSC Dampening	2.77 (1.08)	2.59 (1.07)	2.66 (1.09)	2.89 (1.10)	0.096	.758	.002

[a]Significant ($p < 0.05$).

MHC-SF EWB: Mental Health Continuum Short Form - Emotional Well-Being; MHC-SF PWB: Mental Health Continuum Short Form - Psychological Well-Being; SPANE-P: Scale of Positive and Negative Experiences – Positive affect; SPANE-N: Scale of Positive and Negative Experiences – Negative affect; EOS: Enjoyment Orientation Scale; PPS: Prioritizing Positivity Scale; WOSC Amplifying: Ways of Savoring Checklist – Savoring strategies; WOSC Dampening: Ways of Savoring Checklist – Dampening strategies.

Table 6. Differences within subjects in the experimental group in t0-t2.

	Experimental group M (SD)		Paired sample Student t-tests	
	t0	**t2**	***t***	***p***
MHC-SF EWB	3.49 (0.91)	3.77 (0.88)	-2.41	.023[a]
MHC-SF PWB	3.02 (1.10)	3.35 (0.98)	-2.31	.029[a]
SPANE-P	22.9 (3.42)	23.3 (3.91)	-0.92	.364
SPANE-N	12.8 (3.29)	12.9 (3.64)	-0.13	.893
EOS	4.97 (1.05)	5.35 (1.20)	-2.28	.031[a]
PPS	6.46 (1.37)	7.13 (1.11)	-3.57	.001[a]
WOSC Amplifying	4.21 (0.90)	4.84 (0.96)	-4.31	<.001[a]
WOSC Dampening	2.77 (1.08)	2.59 (1.07)	1.08	.286

[a]Significant ($p < 0.05$).
MHC-SF EWB: Mental Health Continuum Short Form - Emotional Well-Being; MHC-SF PWB: Mental Health Continuum Short Form - Psychological Well-Being; SPANE-P: Scale of Positive and Negative Experiences – Positive affect; SPANE-N: Scale of Positive and Negative Experiences – Negative affect; EOS: Enjoyment Orientation Scale; PPS: Prioritizing Positivity Scale; WOSC Amplifying: Ways of Savoring Checklist – Savoring strategies; WOSC Dampening: Ways of Savoring Checklist – Dampening strategies.

Table 7. Differences within subjects in the control group in t0-t2.

	Control group M (SD)		Paired sample Student t-tests	
	t0	**t2**	***t***	***p***
MHC-SF EWB	3.29 (0.77)	3.36 (0.98)	-0.46	.648
MHC-SF PWB	2.86 (0.87)	3.16 (0.88)	-1.85	.077
SPANE-P	21.2 (3.21)	22.6 (3.58)	-2.21	.037[a]
SPANE-N	13.5 (2.94)	14.9 (4.39)	-1.71	.101
EOS	4.62 (0.86)	4.96 (0.90)	-2.01	.057
PPS	6.19 (1.27)	6.60 (1.30)	-1.36	.185
WOSC Amplifying	3.73 (0.97)	4.25 (0.79)	-3.61	.002[a]
WOSC Dampening	2.66 (1.09)	2.89 (1.10)	-1.08	.289

[a]Significant ($p < 0.05$).
MHC-SF EWB: Mental Health Continuum Short Form - Emotional Well-Being; MHC-SF PWB: Mental Health Continuum Short Form - Psychological Well-Being; SPANE-P: Scale of Positive and Negative Experiences – Positive affect; SPANE-N: Scale of Positive and Negative Experiences – Negative affect; EOS: Enjoyment Orientation Scale; PPS: Prioritizing Positivity Scale; WOSC Amplifying: Ways of Savoring Checklist – Savoring strategies; WOSC Dampening: Ways of Savoring Checklist – Dampening strategies.

Regarding the participants' frequency of use of the savoring strategies after the independent savoring practice week (t2), the independent sample Student t-tests revealed that the experimental group used the behavioral display strategy more than the control group ($t(29) = 2.85$, $p = 0.008$). Furthermore, the experimental group reported to feel significantly better after using it compared to the control group ($t(49) = 2.58$, $p = 0.013$), and

significantly appreciated more this strategy compared to the control group ($t(49) = 2.55$, $p = 0.014$). Moreover, the experimental group reported to feel significantly better compared to the control group after using the positive mental time travel strategy ($t(49) = 2.14$, $p = 0.037$). Regarding the two other strategies (to be present, and gratitude), no differences were found between the two groups.

5.6 Discussion

This ongoing exploratory study aims at evaluating the impact of a VR-based TE on emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, and on the practice of savoring exercises in Italian and Spanish emerging adults. These preliminary findings are promising and demonstrated the potential of virtual TE compared to the audio TE.

Specifically, regarding the perception of the quality of the TE, the first hypothesis (H1) is supported. Indeed, the virtual TE was perceived as more transformative than the audio TE. This finding appears to be consistent with the scientific literature, which emphasizes how VR can facilitate transformative experiences. VR, with its potential to generate sense of presence and stimulate many senses (Riva et al., 2016), can enhance cognitive and emotional involvement by fostering deep feelings such as interest, curiosity, and inspiration (Gallagher et al., 2014; Gaggioli, 2016; Chirico et al., 2018, 2021). In addition, audiovisual effects and storylines embedded in VR can amplify the sense of immersion (Gorini et al., 2011; Gaggioli , 2016). All of these features may have encouraged the connection of past, present, and future positive experiences in emerging adults' personal life to the four leaves and rose of the virtual scenario, resulting in transformative reflections. Furthermore, the virtual TE was evaluated as more pleasant than the audio TE, which could be attributed to the natural setting of the scenario used. Previous research has shown that natural and peaceful surroundings, as well as nature-related auditory elements, might help promote relaxation and pleasantness during the virtual experience (Pizzoli et al., 2019; Riches et al., 2021). Indeed, in *The River and The Leaf*, the emerging adults could see and hear the sound of several natural elements, such as trees, waterfalls, the river with crystal clear water, and the colorful rose garden. In addition, it may have played a role the cognitive effort required in the audio TE to listen while imagining the elements and environment described that may have been perceived less enjoyable, especially for participants who have more difficulty imagining vividly.

Concerning the increase of positive emotions after the TE, the second hypothesis (H2) is only partially supported. Indeed, the virtual TE was able to increase awe and hope compared to the audio TE immediately after experiencing it. Thanks to the VR properties, participants were immersed in a natural environment and could see around them the vegetation, waterfalls, trees and gently flowing river water and hear all around them the sound of these natural elements. Moreover, thanks to the transformative experience script, the emerging adults were able to follow from a first-person perspective the metaphorical journey of personal transformation by following the path of the leaves along the river and savoring their past and present positive experiences until they met the fourth leaf. In the virtual transformative experience, the emerging adults could see this leaf join the stem of the lifeless rose in the center of the rose garden to give it the vital touch it needs to blossom. All these elements may thus have contributed to enhancing awe and hope in emerging adults (Chirico et al.,

2021), as the leaf represents the ability to appreciate one's past, present, and future positive experiences that allow one to truly savor life. This result therefore is in line with previous studies demonstrating that savoring can have a role in fostering hope (Bryant et al., 2021) and highlighting the power of hope in leading to transformation (Snyder et al., 1991), and also with previous research that emphasizes the power of TE to generate awe for its characteristics of uncertainty and perceived vastness, thus providing new insights into one's life and a new way of thinking (Gaggioli et al., 2016; Chirico et al., 2022).

The third hypothesis (H3) is not supported. To this regard, the absence of differences between groups in emotional and psychological well-being, positive and negative emotions, enjoyment orientation, and prioritizing positivity at the end of the intervention although they increase in both groups. Accordingly, these results can be understood in light of the positive effects of the savoring exercises during the independent savoring practice week in both groups (Bryant, 2003; Hurley & Kwon, 2012). Furthermore, the effect sizes were low thus preventing a strong statistical power which would have allowed the identification of any significant differences between the two groups. Consequently, it seems that the positive effects of the virtual TE combined with the savoring strategies and the audio TE combined with the savoring strategies were similar a week later, even though the virtual TE combined with savoring was more effective in the short-term, and this could be due to its engaging properties.

Regarding the increase of savoring amplifying strategies and the decrease of dampening strategies after the savoring practice week, the fourth hypothesis (H4), it is not supported. In this regard, the lack of differences between groups in savoring amplifying and dampening strategies can be explained by the positive effects of the savoring exercises during the savoring practice week in both groups, particularly on the savoring amplifying strategies (Bryant, 2003; Hurley & Kwon, 2012). As far as dampening strategies are concerned, even if there are no difference between groups, the virtual TE combined with savoring appeared to decrease them whereas the audio TE combined with savoring appeared to do the opposite. This result may be due to the virtual TE that made emerging adults savor past, present and future positive experiences also by symbolically connecting them to the natural elements of virtual scenario (e.g., the leaves, the river crossroads, the rose garden, and the rose at the center it). Consequently, these elements may have played a role in fostering awareness of positive experiences in emerging adults' lives and of the use of strategies to amplify the positive emotions aroused by these events during the week of savoring practice, rather than focusing on dampening them.

Regarding the increase in savoring strategies practice after the savoring practice week, the fifth hypothesis (H5) is partially supported. The virtual TE in fact appeared to promote the practice and appreciation of savoring strategies such as behavioral display, and this result may be explained by both the VR properties and the TE script that fostered a reflection about positive experiences and positive relationships in emerging adults' lives. Specifically, the positive relationships were represented by the colorful roses composing the rose garden toward the end of the TE. All these elements may have promoted emerging adults' desire to consciously display positive emotions to their loved ones and savor the associated positive emotions, also taking into consideration the number of relationships that is typically greater at this age than at other age groups because of the typical

changes of emerging adulthood (e.g., completing education, finding a job, leaving the parental home, having a stable romantic relationship, and nurturing old and new friendships) (Arnett, 2000; Antonucci et al., 2004). As a result, emerging adults felt better after implementing this strategy and they particularly appreciated it. Furthermore, the virtual TE promoted emerging adults' feeling better after the positive mental time travel strategy. This might be due to the fact that during the virtual TE the emerging adults were able to immerse themselves in the experience and use more different senses, such as sight and hearing, but also the senses of smell and touch that might have been stimulated due to the presence of nature, trees and roses. Thanks to these elements, it might have been easier for them to use later the positive mental journey strategy by fully immersing themselves in the chosen experience and being able to use their senses more easily to recall or foreshadow all the elements of that positive experience, thus being able to experience the chosen positive past or future event in all its details and savoring the associated positive emotions. All these elements could therefore have led emerging adults feeling better after using this strategy. On the other hand, the absence of differences in the other two savoring strategies (e.g., to be present and gratitude) at the end of the intervention can be explained by the subjective preferences that emerging adults had for savoring strategies and their frequency of use during the practice week (Chadwick et al., 2021). In fact, in this study, emerging adults were free to practice the strategies without any constraints, and it is possible that each emerging adult chose to practice the strategies according to personal preference, for example, practicing one more frequently or all four but less frequently. Another explanation may be related to the fact that emerging adults had only one week to practice the savoring strategies they learned, and this maybe did not allow them to practice all of them with the frequency they wanted because of time constraints.

5.6.1 Conclusions

This ongoing exploratory study focuses on evaluating the impact of a VR-based TE on emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, savoring strategies and on the practice of savoring exercises in Italian and Spanish emerging adults. Based on the finding of this study, the virtual TE was perceived as more transformative and pleasant, as well as more effective in fostering awe and hope than the audio TE. In addition, the virtual TE combined with the savoring strategies practice appeared to encourage the use of savoring strategies such as displaying positive emotions to others, the appreciation of this strategy, and feeling better after using it and the positive mental time travel strategy.

Although these are preliminary results and the study is still ongoing, this study demonstrated that the virtual TE has some potential in terms of personal change, positive emotions aroused, and savoring strategies practice when compared to the TE without the integration of a virtual scenario. In this context, it is possible to identify some study's strengths. Indeed, to the best of our knowledge, this exploratory study was the first to integrate a virtual transforming experience with savoring strategies practice. Furthermore, the inclusion of an active control group was a strength of this study. Furthermore, certain limitations can be identified. For example, we used a snowball sampling method, which may have influenced the generalizability of the results. Furthermore, these findings are only partially generalizable because they are based on a small sample of emerging adults

from Northern Italy and Southern Spain. The study involving a larger sample of Italian and Spanish emerging adults will allow for a broader picture and a greater statical power. Furthermore, we only employed self-report measures; therefore, during the savoring practice week, it would be interesting to take an ecological approach by evaluating emotions and savoring strategies using the Experience Sampling Method, a research technique that involves collecting data from participants in real time in daily life. In this method, participants are required to respond to daily prompts throughout a specified period, allowing researchers to gather self-reports about their feelings and thoughts thus providing a more accurate representation of people's emotional experiences and capturing daily fluctuations in mood and emotions (Colombo et al., 2020).

In conclusion, even if we observed a positive short-term effect of the virtual TE, more research is necessary to determine the long-term effects and to explore in-depth the combination with savoring strategies. Therefore, it will be interesting to investigate the effects of this study with more statistical power. Furthermore, it will be interesting to understand whether there are any variables or emerging adults' characteristics that may influence the perception of the experience as transformative and the use of savoring strategies.

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CHAPTER 6

General Discussion

6.1 Key findings

Taking into account the Mental Health Continuum Model (MHCM), mental health can be considered as a dynamic process and a continuum ranging from flourishing to languishing and it includes several positive psychological dimensions including emotional, psychological and social well-being. Specifically, according to the MHCM, mental health can be influenced by individual, environmental and social factors. For instance, the COVID-19 pandemic negatively impacted both mental and physical health of several populations and different age groups such as emerging adults and older adults, especially those with chronic conditions (Foster et al., 2023; Gruiskens et al., 2023). With regard to physical health, people infected with this coronavirus mainly reported symptoms related to breathing and the respiratory system, including cough, dyspnea, and chest pain both a few days after contracting the infection and weeks or even months later also in combination with other symptoms (Huang et al., 2020; Weng et al., 2021). With regard to mental health, several studies showed the increase of levels of depression, anxiety, stress, insomnia, isolation worldwide and also in the Italian context and that still nowadays have a negative effect on people's well-being (Wu et al., 2021; Busetta et al., 2023). All these factors underscored the need to develop new solutions to counteract the negative psychological impact of the pandemic and, in particular, innovative digital solutions such as digital therapeutics (DTx) based on mental health promotion and focused, as outlined by the MHCM, on increasing people's emotional and psychological resources and well-being. Indeed, DTx are mental health interventions that use software applications to diagnose, treat, manage, and/or prevent mental health conditions and can be considered a valuable option because of their low environmental impact and their ability to reach different populations and age groups remotely (Fürstenau et al., 2023), although, to our knowledge, in the literature there are no DTx exclusively aimed at enhancing well-being. DTx can be based on technologies like mobile or web applications, as well as virtual reality (VR) that, thanks to its features (e.g., sense of presence, immersion, interactivity), produces immersive environments that enable users to immerse themselves in these simulated scenarios and interact with them (Di Natale et al., 2020). Furthermore, VR provides numerous opportunities for improving mental health by generating peaceful and quiet natural environments integrated with auditory natural elements thus fostering relaxation and positive emotions. In addition, specific elements of the VR scenarios can be connected to people's positive personal experiences thus stimulating the autobiographical memory and enhancing positive emotions and emotional regulation (Svoboda et al., 2006). Metaphorical language can be applied to VR by generating virtual worlds and storylines in which people can immerse themselves, observe and listen to a given scene from several points of view, thus acquiring new knowledge about themselves and others and experiencing a personal change (Gaggioli et al., 2016). Another approach focused on mental health promotion refers to positive emotions and their amplification. In particular, savoring, that is the ability to voluntarily intensify and prolong positive emotions (Bryant & Veroff, 2007) and it has proven to be effective in enhancing positive emotions, well-being, life satisfaction as well as in reducing negative affect in different age groups including emerging adults and older adults (Smith et al., 2014; Smith & Hanni, 2019). Moreover, savoring can be promoted through online interventions (Park, 2019; Yu et al., 2020) although few studies have investigated this topic suggesting that it is possible and interesting to integrate savoring in digital mental health

interventions such as digital therapeutics. Taking all these elements into consideration, this doctoral dissertation therefore aimed to investigate the effectiveness of low-impact digital therapeutics based on the integration of savoring and virtual reality for promoting emotional and psychological well-being and decreasing the negative psychological effects caused by the COVID-19 pandemic.

This chapter provides a general discussion that synthesizes the key findings of the four studies included in this thesis. Following this, the strengths and limitations of this dissertation are examined and this chapter concludes with a reflection on the practical implications, as well as recommendations for future research directions.

6.1.1 Study 1 - Breathing in Virtual Reality for Promoting Mental Health: A Scoping Review

As previously mentioned, the pandemic had a significant influence on both mental and physical health by increasing the prevalence of mental health conditions and negatively impacting breathing. Specifically, breathing, in addition to being a compromised element during the pandemic, can also be considered as an effective tool for enhancing well-being and can be integrated in VR-based digital interventions to promote mental health, although it was unclear in the literature how breathing techniques have been combined with VR, and what mental health-related outcomes have these VR and breathing interventions addressed. Indeed, with the a view of creating an innovative digital solution such as a VR-based DTx to foster well-being in the post-pandemic time period, our goal was initially to map studies focused on promoting mental health in the literature that integrated VR and breathing through a scoping review titled *Breathing in Virtual Reality for Promoting Mental Health: A Scoping Review* (Chapter 2). In particular, we aimed at investigating the potential implications of these studies on mental health outcomes, the type of VR employed, as well as potential gaps in the literature. Following the PRISMA-ScR reporting guidelines, we reviewed 18 VR-based breathing interventions. Concerning the integration of breathing techniques and the VR experiences (first research question), this scoping review showed that several breathing techniques, such as diaphragmatic breathing, slow paced breathing, and mindful breathing, can be used during the VR experience. In particular, users can receive specific audio or written instructions suggesting on how to breath properly before entering the virtual scenario or visual cues can be shown during the VR experience. Biofeedback can also be employed by providing a direct connection between the user's breathing and the virtual environment. For example, users can see changes in the virtual scenario colors or specific elements such as trees or rocks in reaction to their breathing. Regarding the employed VR, immersive VR, rather than semi-immersive or non-immersive VR, was used by all the studies probably due to its engaging properties and its ability to filter out external distractions, allowing users to completely engage with breathing exercises and, for example, achieve a deeper state of relaxation or practice their breathing during real-life situations. As a result, thanks to immersive VR, users can immerse themselves in natural surroundings or in real-life environments and, by achieving a high level of presence, have the possibility to focus properly on their breathing.

Regarding the mental health outcomes addressed by the reviewed VR and breathing interventions (second research question), this scoping review revealed that breathing integrated with VR can be an effective strategy to improve the mental health continuum as it enables both clinical and healthy participants to be targeted.

Indeed, it can be used to decrease clinical symptoms (e.g., fear of flying, insomnia, breathing difficulties after the COVID-19 pneumonia) and increase well-being outcomes including relaxation, and breathing awareness. In addition, it can have a positive impact on both mental and physical health, underscoring the strong relationship between these two dimensions. Overall, this scoping review can provide valuable insights for clinical practitioners who want to promote their patients' involvement and adherence in the therapeutic process and also for VR developers who want to create virtual environments aimed at enhancing well-being allowing clinical practitioners or self-help users to choose the virtual scenarios and the breathing modalities they prefer. In summary, the findings emerged from this scoping review showed the unique and promising potential of integrating breathing techniques with VR experiences, although more studies are required to better understand user experience, long-term impacts, and the possibility of tailoring interventions for different clinical and well-being contexts. This scoping review therefore have outlined the versality of VR and its possible integration with other tools and strategies suggesting its potential in becoming the core of a DTx focused on mental health promotion.

6.1.2 Study 2 - Savoring Life During Pandemic: An Online Intervention To Promote Well-Being In Emerging Adults

Emerging adults were deeply influenced by the pandemic because of different factors including the several changes in all life domains they have to face (e.g., finding a job, reaching financial independence, and cultivating friendships and relationships) and the constraints related to the pandemic, such as social isolation and the daily routines disruption (Boursier et al., 2023). As a consequence, numerous studies reported an emerging adults' mental health deterioration over time following the pandemic with effects still visible today especially in Italy (Parrello et al., 2024). For instance, as stated by the 2023 Annual Report of the Istituto Nazionale di Statistica (ISTAT), emerging adults are confirmed as the age group that shows the most worrying worsening of mental health indicators starting, particularly in girls. All this evidence therefore suggests the need to create and implement interventions focused on a well-being promotion approach as highlighted by the MHCM by improving emerging adults resources. Within this framework, savoring appears to be a promising positive psychology approach focused on the ability to generate, maintain and amplify positive emotions. Indeed, it can be considered a valuable tool to foster well-being and it can be promoted through digital interventions with a low environmental impact given its practicality and sustainability, making it remotely accessible.

Taking all these elements into account and considering that there are no studies focusing exclusively on online savoring in the Italian context, we aimed to test the preliminary effects of a self-help online savoring intervention on increasing savoring beliefs and strategies and subjective well-being (SWB) in times of the fourth wave of the COVID-19 pandemic in emerging adults in the research titled *Savoring Life During Pandemic: An Online Intervention To Promote Well-Being In Emerging Adults* (Chapter 3). Specifically, we involved 49 emerging adults who were randomized into the experimental group which completed six online savoring exercises divided in 3 weeks and focused on savoring past, present and future positive experiences,

or the control group which did not receive any intervention. In this study, we collected both quantitative and qualitative data. Regarding quantitative data, after the 3-week self-help online savoring intervention, participants of the experimental group reported significant improvements in savoring beliefs related to the present moment and upcoming positive experiences compared to the control group probably because, as a result of the savoring exercises, they understood more about how to savor positive in progress and future experiences, consequently perceiving themselves more able to savor through these two time orientations as highlighted by previous studies (Park, 2019). On the other hand, there was only a slight improvement of the reminiscence beliefs and this results may be due to the fact that participants felt already able to savoring positive past events at the baseline and this result is in line with previous literature demonstrating that people typically consider themselves better at savoring positive past events (Bryant, 2021). Moreover, the participants of the experimental group reported a tendency toward a significant improvement in savoring strategies compared to the control group suggesting that the savoring exercises may have guided participants in exploring new ways of appreciating positive experiences. However, to the best of our knowledge, no savoring interventions have examined the impact on savoring strategies emphasizing the need to evaluate this dimension in future research (Chadwick et al., 2021). Regarding the intervention's effect on SWB, life satisfaction did not increase probably due to the short duration of the intervention that prevented a change in this cognitive dimension and highlighting that a longer intervention is needed to achieve this change. For instance, in the literature, some interventions found significant improvements in satisfaction with life but they have had a longer duration (e.g., 3 months) (Salces-Cubero et al., 2019). Concerning the intervention's effects on positive emotions, they significantly increase in the experimental group compared to the control group demonstrating that the savoring exercises allowed participants to focus on their positive experiences making them able to appreciate and amplify the associated positive emotions. In contrast, negative emotions did not decrease following the intervention and this result could be linked to the challenging situation of the pandemic (i.e., the fourth wave of the pandemic) that negatively influenced participants' emotional state. Moreover, participants perceived the website on which the exercises were uploaded as intuitive and easy to use.

With regard to qualitative data, from the comments written by the participants after each savoring exercise, it was possible to have a broader overview of the experiences they have savored (e.g., shared and individual experiences in natural or artificial environments) and the emotions (e.g., joy, gratitude, hope, serenity) and bodily sensations they felt during and after the activities. Furthermore, from their comments, it was possible to better understand why they perceived the intervention as useful as highlighted by a participant who stated, "I found this to be a very clear method of learning a simple but sometimes difficult concept without input. It gave me the opportunity to reflect, and stop, and think about the good things, which exist and are considerably more common than the bad ones. I will treasure these exercises, especially in times when everything seems difficult. Thank you". Overall, this online self-help savoring intervention showed great potential for fostering well-being and savoring in emerging adults in times of the COVID-19 pandemic. In addition, it was remotely accessible and had a low environmental impact, demonstrating its practicality and suggesting its potential

integration into a DTx aimed at promoting well-being and counteracting the negative psychological effects of the pandemic.

6.1.3 Study 3 - Integrating Virtual Reality with Savoring to Promote Well-being of Patients with Chronic Respiratory Diseases: a Pilot Randomized Controlled Trial

As previously mentioned, the pandemic had a significant adverse impact on both physical and mental health, compromising psychological well-being and affecting respiratory functions. This was especially relevant for patients with chronic respiratory diseases (CRDs), which are conditions that result in non-reversible airflow restrictions and several extrapulmonary negative effects, who were particularly at risk of COVID-19 infection and had to deal with changes in their chronic care treatments due to the pandemic thus reporting high levels of anxiety, stress, and depression (Pouwels et al., 2021; Gruiskens et al., 2023). Given this, developing and implementing an appropriate and suitable digital solution to improve these patients' well-being is crucial, as underscored by the Mental Health Continuum Model (Keyes 2002, 2007), particularly in the post-pandemic time period. In order to help CRDs patients coping with these issues and taking advantage of the well-established literature on VR and savoring and the information obtained from previous studies on the possibility of integrating VR with other tools to enhance mental health (Chapter 2) and the potential of savoring in the Italian context (Chapter 3), it was decided to develop a first draft of a DTx aimed at improving both mental and physical health of these patients by integrating these two tools in collaboration with the Pulmonary Rehabilitation Unit of IRCCS INRCA Casatenovo and the Italian VR company Become-Hub. Taking all these elements into account and considering that, to the best of our knowledge, no DTx were designed to enhance mental health in CRDs patients, we decided, as recommended by Lee et al. (2023), to conduct a pilot randomized controlled trial in order to reduce potential biases while testing the effectiveness of the DTx intervention, its acceptability, and patients' experience. Consequently, we aimed to investigate the effectiveness of a 2-week VR-based relaxation intervention integrated with savoring in CRDs patients in increasing emotional and psychological well-being, positive emotions, relaxation, oxygen saturation levels (SpO2) and decreasing negative emotions in the study titled *Integrating Virtual Reality with Savoring to Promote Well-being of Patients With Chronic Respiratory Diseases: a Pilot Randomized Controlled Trial* (Chapter 4). In particular, we involved 45 hospitalized CRDs patients from the Pulmonary Rehabilitation Unit of IRCCS INRCA Casatenovo who were randomized into the experimental group which took part in the 4-session VR-based intervention, or into the control group which listened to relaxing music, a tool that has proven its effectiveness in promoting relaxation in patients with these chronic conditions, for 4 sessions (McBride et al., 1999). With regard to the participants of the experimental group, they experienced a relaxing virtual scenario followed by a savoring exercise in each of the 4 sessions of the intervention. Both groups filled out self-reported questionnaires before the intervention, at the end of the 2-week intervention, and in the one-month follow-up, and before and after each session.

Looking at the findings of this research, this VR-based relaxation intervention integrated with savoring has proven to be effective in enhancing emotional and psychological well-being and this result is in line with

previous studies (Malighetti et al., 2023; McGhee et al., 2024). Indeed, the virtual experiences and their pleasant narratives may have guided patients on focusing on their positive physical and emotional states, while savoring may have guided patients in amplifying these positive sensations and connect them with their positive memories (Malighetti et al., 2023). Concerning positive and negative affect, the experimental group reported significant improvements in positive emotions and a significant decrease in negative emotions compared to the control group. These results may be probably due to both the positive effects of the virtual natural environments (Riches et al., 2021; Nukarinen et al., 2022) and the opportunity to savor positive past experiences which has proven to be effective in generating positive emotions and reducing negative ones by counteracting their harmful effects (Smith & Hanni, 2019). Furthermore, patients of the experimental group reported a significant increase in relaxation compared to the control group and this result is in line with previous literature that highlights the virtual natural surrounding relaxation effect especially when combined with natural auditory elements. Moreover, all these psychological changes were maintained at the one-month follow-up demonstrating the beneficial long-term impact of the intervention on all the abovementioned dimensions. This finding suggests that the intervention gave patients tools for coping with daily life after they were discharged from the hospital and the savoring exercises may have positively influenced their well-being over time as highlighted by previous research (Smith et al., 2020; Mikkelsen et al., 2004; Hynninen et al., 2005). In addition, self-reported relaxation and SpO_2 pre- and post- each session were increased similarly in both groups suggesting that VR-based relaxation intervention integrated with savoring and listening to relaxing music have similar relaxation effects in the post-session time period, whereas the VR-based intervention is more effective in the 2-week time period because it allows patients to reflect and enhance their pleasant experiences. With regard to VR acceptance, patients described the intervention as simple and clear, reported extremely minimal levels of VR anxiety, and expressed a positive intention to experience the intervention during their future hospitalizations. These findings are consistent with prior research using VR or savoring with people of similar ages (Smith & Hanni, 2019; Huygelier et al., 2019). Moreover, patients reported a high sense of presence in all the 4 sessions and this result is consistent with earlier studies (Usoh et al., 2000; Birrenbach et al., 2023).

After each session, patients had the opportunity to freely describe their sensations during the VR experience and the savoring exercise and, thanks to these qualitative data, it was possible to have a deeper understanding of the emotions experienced (e.g., joy, awe, love) and of their savored positive events (e.g., positive experiences shared with their loved ones from the past and from the present). Indeed, many patients reported feeling relaxed and were able to connect certain elements of the virtual scenarios to their positive memories. VR in fact can facilitate the visualization of positive memories since, due to its characteristics, it allows for increased vividness of mental simulations thus providing the feeling of being there in the virtual environment (Colombo et al., 2022). Indeed, virtual experiences can help people relive specific positive memories and promote the vividness and sensory details of these memories. Consequently, VR experiences can be experienced in a personally relevant way based on the personal meaning associated to them and can facilitate self-referential recall and processing thereby activating autobiographical memory (Kisker et al., 2021). Indeed, patients were

able to link the elements of the virtual scenarios (e.g., the waterfalls or the sea) to their positive past experiences containing similar elements and then, through the savoring exercise, had the opportunity to savor the positive emotions associated. Finally, most participants of both groups perceived the respective sessions as beneficial and patients belonging to the experimental group expressed their appreciation for the structure and organization of the intervention, and some of them reported that the intervention improved their breathing. Overall, the first version of this VR-based DTx showed its effectiveness in promoting emotional and psychological well-being, positive emotions, and relaxation, and reducing negative emotions in CRDs patients demonstrating the potential of VR integrated with savoring. Specifically, savoring can extend and intensify the positive emotions felt during VR even outside the virtual environment, enabling patients to pay attention and appreciate the positive elements in their lives. This DTx therefore provides patients with tangible tools that they can utilize in their everyday lives and in the challenging situations generated by their chronic conditions.

6.1.4 Study 4 - The Role of VR-Based Transformative Experience on Emotional and Psychological Well-Being, Positive Emotions and Savoring Practice in Italian and Spanish Emerging Adults: Preliminary Results

Following the testing of the integration of VR and savoring in a first draft of a DTx in patients with CRDs and recognizing the limitations of this study regarding the contribution of these two components of the protocol, our objective was to achieve a greater comprehension of how VR influences the amplification of positive emotions. Specifically, our aim was to investigate how a virtual transformative experience (TE; i.e., a brief experience that is perceived as exceptional with lasting effects that influences people's identities, personalities, and perceptions of the world and other people) (Chirico et al., 2022) impacts the savoring practice of emerging adults, an age group particularly affected by the pandemic and currently reporting decreasing levels of well-being as previously mentioned (Busetta et al., 2023). Starting from these premises, we decided, in collaboration with the Department of Personality, Assessment and Psychological Treatment at the University of Valencia and the Italian VR company Become-Hub, to conduct a study involving both Italian and Spanish emerging adults titled *The role of VR-based transformative experience on emotional and psychological well-being, positive emotions and savoring practice in Italian and Spanish emerging adults: preliminary results* (Chapter 5). Indeed, considering that, to the best of our knowledge, there are no studies focusing on the relationship between virtual TEs and savoring, we aimed to investigate the impact of a VR-based TE on emotional and psychological well-being, positive emotions, enjoyment orientation, prioritizing positivity, and the independent practice of savoring exercises in emerging adults while laying the groundwork for the creation of a digital solution that promotes the well-being of emerging adults as highlighted by the Mental Health Continuum Model (Keyes 2002, 2007) and has a minimal environmental impact. Specifically, we have involved 51 Italian and Spanish emerging adults so far who were randomized in the experimental or in the control group. The experimental group experienced the 10-minute virtual TE *The River and The Leaf* focused on savoring, whereas the control group listened to the identical recorded narrative without VR. Four savoring strategies were then explained to both groups (e.g., to be present, positive mental time travel, gratitude, and behavioral display) (Quoidbach et

al., 2010) and participants of both groups were asked to freely practice them over the course of the next week. Before the TE, after, and one week later, both groups completed the online questionnaires. In this framework, the preliminary findings are encouraging and demonstrate the potential of virtual TE compared to the audio TE. For instance, the virtual TE was perceived as more transformative compared to the audio TE suggesting the ability of VR to foster the sense of presence and stimulate multiple senses and the power of metaphorical elements of the virtual scenario (e.g., the leaves, the river, the rose garden) of generate connections with the participants' positive experiences. Indeed, virtual experiences can enhance the vividness and sensory qualities of particular pleasant memories and allow people to relive them (Colombo et al., 2022; Kisker et al., 2021). As a result, depending on the personal meaning given with them, VR experiences can be perceived in a way that is personally meaningful helping people with self-referential recall which can activate autobiographical memory (Colombo et al., 2022; Kisker et al., 2021). Furthermore, the virtual TE was perceived as more pleasant compared to the audio TE demonstrating the positive effects generated by virtual natural and peaceful environments and the auditory natural elements associated (Pizzoli et al., 2019; Riches et al., 2021). Moreover, the virtual TE was able to enhance positive emotions such as awe and hope and this result may be due to both the feeling of actually being in a natural environment experienced by the participants during the virtual TE and the TE storytelling focused on a metaphorical path of personal transformation ending with the blooming of the rose and on savoring personal positive experiences. This finding is consistent with previous research highlighting the power of these positive emotions in leading to transformation (Snyder et al., 1991). On the other hand, no differences between groups were found regarding emotional and psychological well-being, positive and negative emotions, enjoyment orientation, prioritizing positivity, savoring amplifying strategies, and dampening strategies, and this result can be explained by the positive effects generated by the savoring exercises during the savoring practice week in both groups. Therefore, even though the virtual TE combined with savoring was more effective in the short-term, it appears that the positive effects of both virtual and audio TE combined with savoring are similar a week later. In addition, with regard to the savoring strategies practice following the independent savoring practice week, the virtual TE has shown to be effective in promoting the practice and the appreciation of the behavioral display strategy suggesting that the participants had the opportunity to reflect on positive experiences and relationships in their lives, to savor them, and to connect them to specific elements of the virtual TE such as the fourth leaf or the rose garden or the rose. As a consequence, participants reported feeling better after using this strategy and after implementing the positive mental time travel strategy, thus indicating their increased ability to savor a positive past or future experience using all their senses and to fully immerse themselves in the chosen event. Indeed, the virtual TE, due to its features, may have stimulated participants' multiple senses (e.g., sight, hearing) allowing them to use these senses more easily during the positive mental time travel strategy. Overall this ongoing study showed that, when compared to the TE without the integration of a virtual scenario, the virtual TE offers some potential for personal growth, positive emotions, and savoring strategies practice. In addition, this research offers valuable insights for a deeper understanding of the relationship between virtual TE and savoring practice while building the basis for the development of a digital solution aimed at improving emerging adults well-being. Indeed, this

study seeks to find new and valuable solutions for emerging adults by providing concrete tools to use in daily life to notice and appreciate positive emotions and experiences despite and during life's difficulties.

6.2 Strengths

Taking into account the findings of this doctoral dissertation, it is possible to recognize several strengths. First, this dissertation consists of a scoping review and three empirical studies that aimed to provide concrete tools focused on mental health promotion. In addition, each study served as a starting point for the next study. For example, study 1 had the objective to provide an overview of VR-based breathing interventions aimed at promoting mental health outcomes so as to provide insights for clinical practitioners, for VR developers working in the field of mental health, and for future research aimed at fostering well-being by integrating VR and breathing. Related to this, study 3 investigated the effectiveness of a VR-based relaxation intervention integrated with savoring in fostering mental health outcomes such as emotional and psychological well-being and relaxation in patients with chronic respiratory diseases. Moreover, study 2 focused on enhancing savoring beliefs and strategies and well-being in emerging adults through an online savoring intervention, while study 4 also aimed at promoting well-being, positive emotions, and savoring strategies in emerging adults through savoring and its integration with VR. In addition, both study 3 and 4 aimed at fostering well-being thanks to the integration of VR and savoring, with study 4 seeking to further explore the relationship between these tools and the impact of VR on savoring strategies practice.

Second, the studies included in this thesis, and in particular studies 2, 3, and 4, adopted innovative digital approaches to help different populations cope with pandemic-related challenges by promoting mental health while seeking to contribute to the scientific literature on the topics of VR, savoring, and their relationship and integration in digital therapeutics.

Third, studies 2 and 3 of this thesis employed a methodology which included several approaches, such as quantitative self-report measurements, objective data such as peripheral oxygen saturation (study 2), and qualitative data such as participants' memories and opinions, in order to have as complete an overview as possible of the intervention's effects and of the participants' experiences.

Fourth, studies 2, 3 and 4 involved a control group, in particular, in studies 3 and 4 the control group was active thus contributing to improving the interventions' effectiveness.

Fifth, the interventions proposed in the studies of this thesis can be considered practical, sustainable, intuitive to use, and remotely accessible from different devices, making them usable by different age groups (e.g., emerging adults and older adults) and populations (e.g., clinical and healthy populations). Furthermore, these interventions had a low environmental impact underlining the importance of digital technology for pollution reduction and fewer emissions due to less traffic.

6.3 Limitations

The results of the studies presented in this dissertation should be interpreted in light of some limitations. First, these results obtained in these studies can be considered only partially generalizable as they involve samples

from Northern Italy (and Southern Spain for study 4) recruited through convenience and snowball sampling methods. Moreover, the small sample sizes do not allow for large statistical power.

Second, the samples are heterogeneous, as they included healthy emerging adults in studies 2 and 4, and patients with chronic respiratory diseases in study 3. Furthermore, in study 3 the sample involved patients with different chronic respiratory diseases preventing the generalizability of the results on a specific chronic respiratory condition.

Third, in all of the studies in this dissertation, except for study 4, the long-term effects of the interventions were not analyzed, and this precludes an understanding of the effectiveness of the proposed interventions in the following months.

Fourth, while savoring emerges as a practical tool that can be easily used by different populations and age groups, the use of VR is limited by the availability of devices that may not be accessible to all population groups. In addition, older adults may initially have some difficulties in understanding the use of the headset thus requiring initial help. In addition, the occurrence of negative side effects (e.g., cybersickness) of VR was not systematically measured in studies 3 and 4.

6.4 Implications and future directions

This doctoral thesis has several theoretical and practical implications. For example, it contributes to the achievement of a greater understanding of the mechanisms existing between VR and savoring. Related to this, future exploratory research is needed to understand more about the relationship between VR and savoring, to explore how these two tools can influence each other, and how their integration can improve well-being. This thesis also contributes to the scientific literature by expanding knowledge in the field of positive psychology and immersive technologies. In fact, this dissertation integrates theories related to mental health (e.g., the Mental Health Continuum Model) and those related to positive psychology (e.g., the broaden and build theory of positive emotions and the undoing hypothesis) with emerging technology and digital therapeutics, providing a basis for further interdisciplinary research. In addition, by taking the Mental Health Continuum Model into account, the thesis reinforces the view of mental well-being that is not limited to the absence of illness, but includes the deployment of emotional, psychological, and social resources that contribute to people's flourishing and optimal functioning.

Furthermore, this thesis expands the theoretical understanding of using digital solutions such as DTx to promote mental health by introducing new paradigms of evidence-based intervention. Indeed, the dissertation suggests that digital interventions based on the integration of VR and savoring can potentially be integrated into mental health protocols both to counteract the negative effects of the COVID-19 pandemic and to build lasting psychological resources in this post-pandemic period in diverse populations. Digital technologies integrated with positive psychology techniques may indeed reduce barriers to accessing mental health services, reaching populations that are isolated or have difficulty accessing them for a variety of reasons, such as lack of time or travel-related difficulties (Rojas et al., 2019). As a result, this would also ensure opportunities for

low environmental impact by allowing reduced pollution levels and greenhouse gas emissions as a result of less travel and traffic (Coroama et al., 2015; Xu et al., 2022).

Moreover, the digital solutions presented in this thesis, particularly those aimed at healthy emerging adults, had the goal to providing this age group with practical, concrete and accessible tools aimed at promoting well-being. These tools could be made available by schools and universities to their students to foster their psychological resources and promote their mental health. Indeed, numerous studies show low levels of emotional and psychological well-being in college students due to various factors such as academic pressures and financial stress (Skromanis et al., 2018) and these levels have decreased further following the pandemic due to isolation and disruptions in their educational experiences highlighting the need and urgency for schools and universities to find sustainable and suitable solutions for their students to promote their mental health (Lopes & Nihei, 2021). Similarly, these tools could be made available by companies to promote the mental health of their emerging adult workers by fostering greater work-related well-being and greater reflection and awareness of the positive experiences and emotions that characterize their daily lives, both personal and work-related. Future studies could then investigate the impact of these tools in the work context. Indeed, VR enables the creation of immersive and customizable environments to promote relaxation, emotional and psychological well-being, and transformative experiences, while savoring can be considered a valuable and easily adaptable tool effective in promoting positive emotions, well-being and reducing negative affect thus demonstrating that these tools can be used in multiple contexts. Related to this, such tools could be tested with clinical emerging adults to verify their effectiveness in decreasing levels of depression or anxiety. According to the literature, many emerging adults, especially as a result of the pandemic, experience high levels of clinical symptoms such as levels of anxiety and psychological distress that may be caused by both the transitions they are facing such as completing education, finding a job, searching for financial independence, and the academic or work contexts in which they are immersed (Jensen-Campbell et al., 2023). Moreover, such clinical symptoms are increased as a result of the pandemic generating increasing sadness, anxiety, negative affect, and loneliness (Graupensperger et al., 2022; Foster et al., 2023). In this context, both VR and savoring separately have been shown to be effective in previous studies in reducing these symptoms suggesting the potentialities of their integration (Maples-Keller et al., 2017; Zeng, et al., 2018; Doorley & Kashdan, 2021). Future research therefore is needed to test the effectiveness of these integrated tools in emerging adults with clinical symptoms. In addition, the VR-based DTx integrated with savoring presented in this thesis could become a tool available to hospital departments to promote the well-being of inpatients or outpatients. In particular, future studies are needed to further investigate the effectiveness of this DTx in enhancing not only psychological well-being but also physical health in patients with chronic respiratory diseases. Moreover, such digital therapeutics could also be applied to other chronic conditions and physical health conditions, thereby increasing the practical scope of this first version of DTx. Future studies should therefore evaluate the applicability of the proposed digital solution in other clinical populations. Furthermore, future studies could focus on creating, developing and implementing a comprehensive DTx. Indeed, in the studies included in this dissertation it was not possible to develop a complete version of a digital therapeutic since its creation consists of several steps and requires

an iterative development process to assess its feasibility, acceptability, and experience of use (Lee et al., 2023) along with the implementation of pilot randomized controlled trials and randomized controlled trials to test its effectiveness. Consequently, future research is needed to further improve this first draft of DTx and then to conduct randomized controlled trials to test the effectiveness with scientific rigor.

In addition, in order to thoroughly investigate the effectiveness of the digital solutions presented in this dissertation, future studies will need to involve larger samples so as to have greater statistical power. Moreover, future research could analyze the long-term effects of these digital interventions to better understand the effects on emotional and psychological well-being a few months later and better understand whether the changes achieved can be maintained over time thus revealing whether these digital interventions are effective in promoting in people the creation of psychological resources to draw on in case of future difficult situations.

Finally, Italy does not yet have specific regulations regarding digital therapeutics, and in this regard, an interparliamentary group is working to try to package guidelines inherent to their development and use. The findings from this thesis can therefore support the development of policies for the inclusion of DTx in the Italian national health care system, with particular attention to the regulation and reimbursement of the digital therapeutics.

6.5 Conclusions

This thesis explored the effectiveness of VR, savoring, and their integration as innovative and low-impact tools to promote emotional and psychological well-being and counteract the negative psychological effects caused by the COVID-19 pandemic. The studies included in this thesis have therefore integrated mental health and positive psychology theories with the use of VR technology and DTx digital therapeutics applications, developing and testing innovative digital solutions aimed at promoting mental health in two groups that are particularly vulnerable and have been negatively affected by the COVID-19 pandemic, namely emerging adults and patients with chronic respiratory diseases.

The results of this thesis highlight significant new insights, both theoretical and practical. From a theoretical perspective, the integration of VR and savoring offers new perspectives for the enhancement of positive emotions and the promotion of emotional and psychological well-being. In addition, this thesis allows for a broadening of knowledge about DTx and especially highlights the need to develop DTx focused on promoting mental health with the goal of fostering people's optimal functioning. Indeed, the findings of the present dissertation help fill important gaps in the literature, especially in the Italian context, and open new directions for future research. On a practical level, the well-being promotion interventions illustrated in this thesis demonstrate how innovative digital solutions can overcome traditional barriers related to access to mental health care, such as geographic limitations and those related to travel difficulties, thereby supporting mental health promotion through a flexible and inclusive modality. In particular, the integrated use of VR and savoring has proven to be a promising instrument for inducing relaxation, amplifying positive emotions, and generating transformative experiences, with potential applications in clinical, educational, and work settings. In addition,

the adoption of digital approaches helps reduce the environmental impact of traditional therapies, reinforcing their value in terms of sustainability.

Despite these promising results, the thesis identified some limitations, including the need to investigate the long-term effects of these digital interventions in order to assess the duration of their positive effects over time, the importance of expanding the sample to more diverse cultural and demographic backgrounds, and the importance of achieving higher statistical power. These considerations therefore offer insights for future developments, such as expanding these innovative digital solutions that integrate VR and savoring to additional populations and health conditions.

In conclusion, this thesis highlights the potential of synergies between VR, savoring, and digital technologies to improve emotional and psychological well-being. These findings not only contribute to the advancement of research in positive psychology and DTx, but also offer practical tools to address existing challenges related to mental health, sustainability, and accessibility of care. Developing and implementing these innovative solutions is a crucial step in promoting mental health in the post-pandemic time period.

6.6 References

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