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Navigating the Digital Frontier: Opportunities and Challenges of Virtual Reality in Mental Health

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Abstract

This dissertation investigates the potential of virtual reality (VR) to transform mental health care by fostering empathy, promoting well-being, and alleviating psychological distress. It highlights VR's role as a positive technology, capable of enhancing eudaimonic well-being by fostering purpose, engagement, and personal growth, while complementing its established benefits in reducing negative mental health symptoms.

The first study, a systematic review, explores how VR and other digital technologies can enhance empathy among healthcare professionals, a key factor in patient satisfaction and treatment adherence. It demonstrates VR's capacity to immerse clinicians and health workers in patients' perspectives, promoting empathy and emotional insight.

The second study reviews the use of VR interventions to promote positive mental health, finding strong evidence of VR's efficacy in reducing stress and fostering well-being but identifying gaps in its impact on eudaimonic well-being. Insights from this review informed the development of a VR program evaluated in a pilot study.

The third study examines the feasibility and effectiveness of the H.O.M.E._Positivity VR program in reducing psychological distress and enhancing well-being among young adults. The results demonstrate significant improvements in mental health, suggesting that VR can foster positive emotions and psychological resilience. A larger follow-up study is underway to validate these findings.

The general discussion synthesizes the findings, addressing theoretical and practical implications, including challenges such as inconsistent definitions of empathy and barriers to VR adoption. Recommendations include advancing VR's integration into clinical practice, scaling interventions, and conducting more robust research to fully realize its potential in mental health care. This work underscores VR's transformative role in promoting well-being and shaping the future of mental health interventions.

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Introduction

1.1 Scope and Problem

The digitalization of healthcare is set to transform patient care globally. Technologies like AI, and Virtual Reality (VR) could improve access to clinicians, enhance real-time diagnosis, and integrate with physical systems to create a cyber-healthcare network (Torous et al., 2020; Trenfield et al., 2022). Among these innovations, VR emerges as a particularly promising tool, capable of redefining how care is delivered, experienced, and understood(Cerasa et al., 2022; Halbig et al., 2022; Torous et al., 2020). This dissertation explores the role of digital technologies—especially VR—within healthcare and mental health settings, emphasizing their capacity to cultivate empathy, enhance well-being, and mitigate the burden of mental health challenges.

1.2 VR definition: the bright and dark side

Extended Reality (XR) is an umbrella term that encompasses various immersive technologies, including VR, augmented reality (AR), and mixed reality (MR). These technologies create different levels of interaction between the physical and digital worlds, offering various ways to enhance real-world experiences with digital elements. XR blurs the boundaries between the tangible and virtual, enabling users to interact with both environments simultaneously or shift smoothly between them, depending on the application. One of the most well-known components of XR is VR, a technology that creates immersive, computer-generated environments that users can interact with in real-time. Typically experienced through headsets equipped with displays, VR entirely blocks out the physical world and transports users into a 3D digital environment.

In contrast to VR, Augmented Reality (AR) does not remove users from their physical surroundings but enriches them. AR overlays digital information onto the real world, integrating virtual objects and data with the physical environment. This can be experienced through devices like smartphones, tablets, or AR glasses, allowing users to see and interact with the real world and digital content simultaneously. For example, Pokémon GO, a popular AR app, allows people to play and interact with Pokémon (little monsters that resembled animals) by overlaying them to the real world through the phone's camera.

Finally, Mixed Reality (MR) takes the integration of physical and digital elements a step further, enabling more complex interactions between the two. In MR, virtual objects are not just overlaid onto the real world—they are aware of and can interact with it. For instance, a virtual character might navigate around real furniture or manipulate physical objects. MR devices often utilize advanced sensors and spatial mapping technologies to anchor digital content to specific locations in the real world, creating a seamless blend of both realities. Imagine cooking a recipe while wearing a head-mounted display that not only recognizes and highlights the ingredients you need but also overlays a virtual knob to control the stove.

Together, VR, AR, and MR technologies form the spectrum of Extended Reality (see Fig 1). XR is not confined to a single application or industry; it spans entertainment, education, healthcare, manufacturing, and beyond. It has the potential to revolutionize how we work, learn, communicate, and experience the world around us, offering new ways to interact with both the physical and digital landscapes.

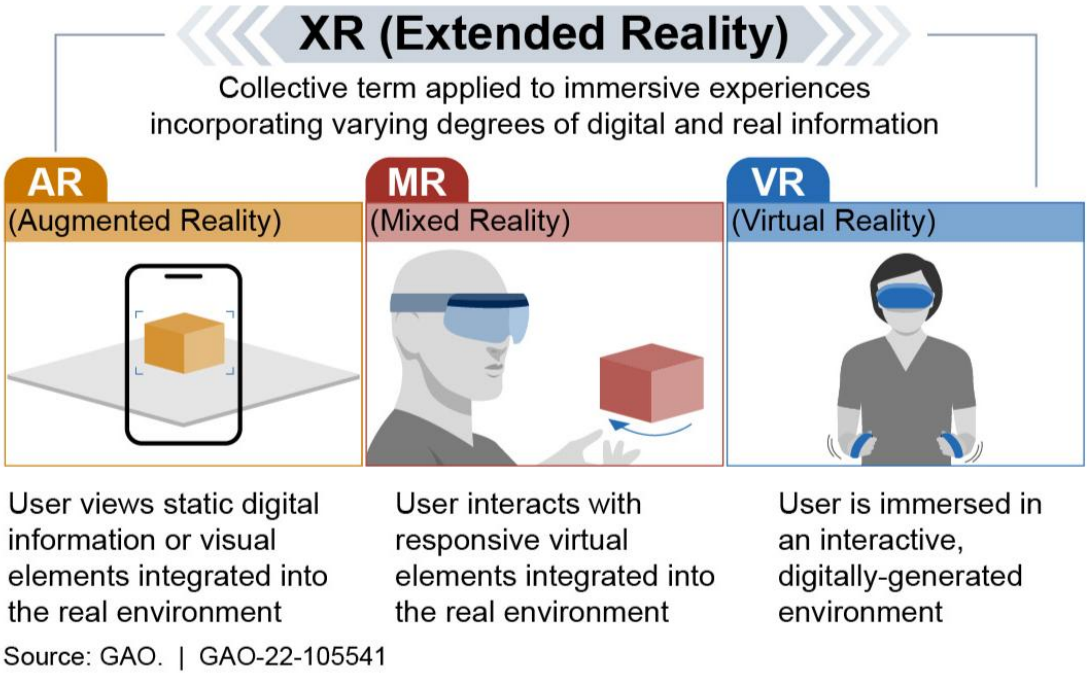

Figure 1. The continuum of extended reality.

Our focus will mostly center around Virtual Reality. These environments can be entirely virtual or simulate real-world settings, providing users with the sensation of being present within these spaces.

The term sense of presence (in this context an abbreviation for the term telepresence) refers to the subjective feeling of being truly "there" within a virtual environment, as though it is a real space (Riva, 2022). The definition provided by the International Society for Presence Research today define presence as

“a psychological state in which even though part or all of an individual’s current experience is generated by and/or filtered through human-made technology, part or all of the individual’s perception fails to accurately acknowledge the role of the technology in the experience.” (Presence Defined – ISPR, 2000)

The sense of presence in virtual reality depends on multisensory stimulation, which is essential for creating the illusion of being in a real environment. When multiple senses—such as vision, hearing, and touch—are engaged simultaneously, the brain integrates these inputs to construct a unified, immersive experience. This synchronization of sensory information enhances the realism of the virtual environment, making it feel more tangible and believable. The more senses involved, the more convincing and immersive the virtual experience becomes, increasing the user’s sense of presence within the virtual world (Gallace et al., 2012).

While VR offers unparalleled opportunities for immersive experiences and a heightened sense of presence, it is important to consider the potential risks and challenges associated with its use. As highlighted in the last OECD Digital Economy Outlook (2024), five potential sources of risk can be identified: privacy, distracted driving (e.g., Faccio & McConnell, 2018), cognitive development of children, simulator sickness, and overuse and addiction.

For the purpose of the current work, we will focus solely on the risk of simulator sickness (Kolasinski, 1995) in VR environments, as addressing this issue during the development of VR software is essential to ensure feasibility, acceptability, and scalability.

Motion sickness, often referred to as "simulator sickness" in the context of VR, is a critical challenge that developers must address to enhance user experience and broaden the technology's adoption. Symptoms of motion sickness in VR include eye fatigue, disorientation, nausea, dizziness, and general discomfort (Kolasinski, 1995). These symptoms are primarily caused by a mismatch between the sensory inputs perceived by the user—such as visual and vestibular cues—and the brain's expectation of movement and spatial orientation.

Research highlights several factors contributing to motion sickness in VR. For instance, Chang et al., (2020) emphasized the role of hardware specifications like frame rate and latency, as well as software design elements such as field of view, camera movement, and user interaction paradigms. Addressing these factors

during the design and development phase can significantly reduce the prevalence and severity of motion sickness.

As VR technology continues to grow exponentially, understanding the mechanisms behind motion sickness and designing environments that mitigate its effects are essential. By doing so, developers can create VR experiences that are more inclusive and accessible, facilitating broader adoption across various sectors, including education, healthcare, and entertainment.

1.3 The use of Virtual Reality in HealthCare and Mental Health settings: Barriers and Opportunities for Clinicians and patients

Digital technologies, particularly Virtual Reality (VR), are revolutionizing the healthcare field by offering transformative opportunities for both patients undergoing treatment and healthcare professionals seeking education and training. For patients, VR provides innovative interventions such as exposure therapy for anxiety disorders and immersive experiences that promote well-being by facilitating personal change and fostering new perspectives. These tools have been shown to significantly reduce anxiety symptoms and enhance emotional and cognitive adaptability (Botella, Banos, et al., 2017; Riva et al., 2016).

For clinicians, including both medical professionals and psychologists, VR serves as an effective tool for education and skill enhancement. Through virtual standardized patients (VSPs) and other simulated environments, healthcare professionals can develop theoretical knowledge and practical competencies, particularly in communication and empathy, without the constraints of traditional methods. These training methods are not only scalable but also adaptable to the evolving digitalization of healthcare systems (Kononowicz et al., 2019; Pottle, 2019; Stevens et al., 2006).

By bridging the gap between patient care and professional development, VR has the potential to improve the quality of treatments, advance therapeutic outcomes, and modernize healthcare training. Its dual role in enhancing patient experiences and empowering healthcare providers underscores its value as a versatile and powerful tool in the rapidly changing landscape of healthcare (Laughey et al., 2021; Riva, 2022).

The following sections will explore how VR's potential for enhancing empathy and personal self-reflection can be leveraged in clinical psychology and the broader healthcare context, highlighting its applications in therapeutic interventions and empathy training for healthcare professionals.

1.3.1 Opportunities in the Healthcare System

1.3.1.1 The concept of empathy

VR can be considered an effective tool to foster empathy and perspective-taking (Lacle-Melendez et al., 2024) and to facilitate personal change (Riva et al., 2016). According to Cuff et al. conceptualization (Cuff et al., 2016; pp.16), empathy can be defined as "an emotional response (affective), dependent upon the interaction between trait capacities and state influences. Empathic processes are automatically elicited but are also shaped by top-down control processes. The resulting emotion is similar to one's perception (directly experienced or imagined) and understanding (cognitive empathy) of the stimulus emotion, with the recognition that the source of the emotion is not one's own." This operationalization emphasizes empathy's twofold nature, consisting of cognitive and affective components that interact dynamically (Heyes, 2018; Shamay-Tsoory et al., 2009). Cognitive empathy (i.e., Decety & Jackson, 2004)can be defined as the ability to understand the mental states of other individuals and to be able to take their perspective or point of view. On the other hand, affective empathy refers to the ability to share and respond to another person's emotional state (i.e., Cox et al., 2012; Reniers et al., 2011).

Over the past decade, several studies have investigated VR's potential to elicit personal change, perspective-taking, and empathy (Hamilton-Giachritsis et al., 2018; Herrera et al., 2018; van Loon et al., 2018). Given these findings, VR can alter individuals' perspectives on the world and how they perceive each other (Riva et al., 2016).

1.3.1.2 Enhancing Empathy and Communication in Medical Education Through Virtual Reality

As stated by Peabody, "The secret of the care of the patient is in caring for the patient." (Peabody, 1984). Indeed, empathy toward patients plays a crucial role in the outcome of any treatment, both from a mental and physical view. The education of medical students should, therefore, give great importance to training empathetic skills, but as the literature on the topic highlights, this factor is often undervalued or only partially addressed (Laughey et al., 2021; McNally et al., 2023). Moreover, the education of the future

professional should adapt in accordance with the swift transition of the medical systems toward digitalization of service and care (Pottle, 2019). VR presents significant opportunities for the healthcare system, particularly in enhancing patient care and professional training. As a powerful tool for fostering empathy, VR allows healthcare professionals to experience patient scenarios from the patient's perspective, leading to a deeper understanding of their emotions and needs (Brydon et al., 2021; Dyer et al., 2018).

The most adopted tools for the education of medical students remain the use of standardized patients, where an actor is instructed to play the role of a patient in order to train medical students (Flanagan et al., 2023). Even if this approach represents the gold standard in medical education, it is often costly to implement and does not allow the training of multiple students together, which exponentially increases the time destined for the education of every single medical student. Recently, the so-called virtual standardized patient (VSP) has also been adopted for educational purposes. A VSP consists of a digital representation of a user or individual within a virtual environment (Stevens et al., 2006b). Those avatars can be designed to reflect various characteristics such as appearance and sometimes personality. VSPs are increasingly being used in medical education to support the acquisition of theoretical knowledge and communication skills. Several studies highlight the effectiveness of VSPs in these areas (for a review on the topic, see Kononowicz et al., 2019).

In terms of communication skills, multiple studies have found that students using virtual patients report improvements in their ability to communicate effectively. Quail and colleagues (2016) showed that students gained similar levels of confidence and communication skills whether they interacted with virtual patients, standardized patients, or real patients. However, students found conversing with VPs slightly more challenging but still derived comparable benefits (Quail et al., 2016). Deladisma and colleagues (2007) specifically examined students' empathetic responses to virtual patients and found that while the students' empathy was not as strong as with standardized patients, VPs still provided valuable training in empathy and non-verbal communication skills (Deladisma et al., 2007).

Virtual patients also offer advantages in terms of cost and scalability. Since standardized patients are resource-intensive, VSPs provide a more sustainable and accessible method for repeated, safe practice. This

is particularly important in communication training, where students need the opportunity for extensive practice without the constraints of using real patients or actors (Stevens et al., 2006a).

Moreover, the various empathy training developed highlights the versatility of VR as an instrument to stimulate self-reflection and the adoption of different perspectives. Those characteristics can be leveraged to foster empathy and cognitive changes, making it a valuable asset also in the context of clinical psychology.

1.3.2 Opportunities in Clinical Psychology

From a psychological perspective, VR can be regarded as a sophisticated human-computer interface that enables individuals to immerse themselves completely in a digitally generated environment. (Schultheis & Rizzo, 2001).

1.3.2.1 VR in Clinical Psychology

Over the past three decades, the use of VR in psychotherapy has significantly increased (refer to Table 1 in Chapter 3). Since the early 1990s, VR has been applied in treating several mental health conditions. However, the early generations of VR devices were marked by several limitations, including low display resolution, a restricted field of view, and uncomfortable designs (Riva, 2022), accompanied by high cost and the need for a high level of technological expertise. The first portable and cost-effective HMD was the Oculus Rift, released by Oculus VR in March 2016, and revolutionized the VR application, making it accessible to the public and researchers. Indeed, many clinical interventions have been developed and tested during these years, demonstrating positive clinical outcomes in various domains (for a meta-review, see Riva et al., 2019).

Compared to traditional methods, VR offers the unique ability to recreate and simulate real-world situations in controlled environments, something that is often difficult or even impossible to achieve in classical clinical settings. These immersive characteristics address the limitations of existing methods by allowing for greater personalization and interaction, thereby enhancing the ecological validity of psychological interventions. This can, in turn, increase the interventions' relevance and effectiveness in addressing specific psychological challenges.(Bell et al., 2024)

Therefore, VR offers a more intense and controlled environment for self-reflection (Riva et al., 2016). Essentially, this technology operates as an "enhanced imaginal system" (Vincelli, 1999; Vincelli et al., 2001), a form of experiential imagery that can elicit emotional responses with a depth comparable to genuine experiences (Baños et al., 2004). This distinctive capability positions VR as a powerful medium for facilitating personal transformation (Riva et al., 2016) and enhancing empathy and perspective-taking (Lacle-Melendez et al., 2024b).

An important advantage for clinical psychology is that VR allows clinicians to observe and analyze emotional and cognitive reactions in real-time (Gaggioli et al., 2014). This contrasts with traditional methods, where reactions are often assessed retrospectively, limiting the immediacy and context of responses. By utilizing VR, therapists can gain insights into a patient's state during immersive experiences, leading to more effective interventions and tailored therapeutic approaches. This real-time analysis can enhance the understanding of clients' emotional responses, fostering better therapeutic relationships and outcomes (Gaggioli et al., 2014).

1.3.2.2 VR Psychological Interventions

Up to date, the most common use of VR in psychological treatments refers to exposure therapy (VRET), with several studies showing that VR is able to reduce anxiety symptoms significantly in different anxiety disorders (e.g. Botella, Fernández-Álvarez, et al., 2017a; Cardoş et al., 2017; Maples-Keller et al., 2017). The literature also substantiates the effectiveness of VR in the treatment of eating and weight disorders (Cardi et al., 2012; Clus et al., 2018; Riva, 2017; P. A. Schroeder et al., 2024) demonstrating a reduction in the level of anxiety triggered by food (Ferrer-Garcia et al., 2019; Natali et al., 2024) and in the reconsolidation of negative memories (Mira et al., 2016; Pla-Sanjuanelo et al., 2019). Moreover, VR demonstrated to be effective in evaluating cue reactivity, as it has been shown to heighten subjective cravings in individuals affected by different addictions (Bordnick et al., 2005, 2008; Hone-Blanchet et al., 2014; J. Lee et al., 2004), in the treatment of psychosis (Rus-Calafell et al., 2018), and in pain management (E. Chan et al., 2018; Massetti et al., 2016).

In conclusion, the evolution of VR technology over the past three decades has significantly expanded its application in psychotherapy, making it a valuable tool for treating a wide range of psychological

disorders. From its early, costly, and technologically demanding beginnings, VR has become more accessible and effective, particularly after introducing affordable HMDs like the Oculus Rift in 2016. Today, VR is widely used in exposure therapy, with substantial evidence supporting its ability to reduce anxiety symptoms, treat eating and weight disorders, and assist in body representation updates. Additionally, VR's effectiveness in evaluating cue reactivity and its applications in treating psychosis and managing pain further demonstrates its versatility and therapeutic potential in clinical settings. However, it remains less clear whether this tool can also be used to foster well-being in addition to reducing negative symptoms.

1.3.3 Barriers to Adoption

VR holds great promise in clinical psychology and healthcare, offering innovative ways to treat patients and train professionals. However, several barriers hinder its widespread adoption in these fields, including high costs, limited research, and resistance to new technologies.

In clinical psychology, one significant challenge is the cost of VR equipment. Beyond the hardware expenses, which are becoming more affordable (Riva, 2022), the cost of creating and distributing VR content tailored for therapeutic use remains an obstacle. Most VR content development has been driven by the gaming and entertainment industries (Pimentel et al., 2021), leaving a gap in academic and healthcare-specific resources. This makes it difficult for practitioners to find high-quality, clinically relevant VR tools at an affordable price. For example, a private practice therapist may struggle to justify the expense of a VR system, especially when much of the available content is not designed for therapeutic interventions.

Additionally, the need for clinician training presents another obstacle. Many mental health professionals are not familiar with VR technology and may require extensive training to integrate it effectively into their practice. Without sufficient training, clinicians might struggle to deliver the desired therapeutic outcomes, which could undermine the perceived value of VR in clinical settings (Levac et al., 2017; Twamley et al., 2024).

In the broader healthcare system, integrating VR into existing training programs poses significant challenges. Healthcare institutions often have well-established curricula, and incorporating new technology like VR requires adjustments to these programs (Mantovani et al., 2004). This integration can be a slow and complicated process, as it demands resources, time, and approval from governing bodies (Baniasadi et al.,

2020; Williams et al., 2023). Moreover, there is often resistance to adopting new technologies, particularly among healthcare professionals who are accustomed to traditional methods of training and patient care(Zweifach & Triola, 2019). This resistance is not necessarily due to a lack of belief in VR's potential but can stem from the perceived complexity of learning a new system or the fear of it disrupting current workflows.

The scalability and accessibility of VR solutions present additional barriers. While VR has demonstrated potential in in several areas, scaling these solutions to reach larger populations can be difficult. For example, using VR in rural settings, where access to advanced technologies is already limited, may pose a significant challenge. The infrastructure required to support VR, such as high-speed internet and technical support, may be unavailable in underserved regions, making it harder to ensure equitable access to this technology (Moffatt & Eley, 2011).

Virtual Reality (VR) presents substantial opportunities in both clinical psychology and healthcare, offering transformative tools for therapeutic interventions, professional training, and patient care. Its ability to enhance empathy, facilitate personal change, and improve motor and cognitive rehabilitation makes it an invaluable asset. However, to fully realize its potential, several barriers must be addressed, including the high costs of implementation, resistance to new technologies, and challenges with scalability and accessibility. Bridging these gaps will require a concerted effort to create affordable, evidence-based VR solutions, provide comprehensive training for clinicians, and ensure equitable access to technology in underserved areas. By overcoming these obstacles, VR can be more effectively integrated into both mental health and healthcare systems, offering far-reaching benefits for professionals and patients alike.

1.4 The Positive psychology and positive technologies framework

As stated by Botella and colleagues (2012, pp.1) "Positive Technology (PT) can be defined as the scientific and applied approach for improving the quality of our personal experience with the goal of increasing wellness and generating strengths and resilience in individuals, organizations, and society". The theoretical foundation of this approach is rooted in Positive Psychology and focuses on leveraging technology to enhance the quality of experiences. As a result, PTs make it possible to explore and understand how digital technologies can be utilized to promote mental health and well-being. (Botella, Banos, et al., 2017; Botella et al., 2012; Riva et al., 2012; Wiederhold, 2012).

Within the PT framework, Botella et al. (2012) and Riva et al. (2012) developed a classification of PTs grounded in the three domains identified by Keyes (Keyes, 2002): subjective, psychological, and social well-being. The authors argue that each of these dimensions is associated with key variables at hedonic (emotion regulation), eudaimonic (flow and presence), and social (collective intentions and social connections) levels (Riva et al., 2012).

1.4.1 Using VR to promote subjective well-being: a hedonic perspective

1.4.1.1Theoretical Background

The first area of intervention in PT reported by Riva and colleagues (Riva et al., 2012) is related to affective quality. Within this domain, the theoretical models regarding the conceptualization of well-being are those of the hedonic perspective (Kahneman et al., 1999) and subjective well-being (Diener et al., 1999), which emphasize the importance of positive emotions and life satisfaction for individual health. Research highlights the central role of positive emotions in promoting well-being and fulfillment (Fredrickson, 2000, 2004; Fredrickson & Joiner, 2002; Garland et al., 2010). These emotions are also closely associated with an improvement in quality of life (Kuppens et al., 2008), better health and longevity (Diener & Chan, 2011), and improved cognitive functioning (Dolan, 2002). From a hedonic perspective, technology-mediated interventions (see Pavic et al., 2022 for a review) aim to modify the user's affective state through the stimulation and induction of positive emotional states (Baños et al., 2017). Traditionally, research has primarily concentrated on negative emotions and pathology, with limited attention given to positive emotions and well-being (Alexander et al., 2021). However, recent efforts have aimed to explore and define the wide

range of positive emotions, showing that they extend beyond simple notions like "joy" and "happiness" (Alexander et al., 2021; Fredrickson, 2004). In line with Fredrickson's (2004) "Broaden and Build Theory of Positive Emotions," positive emotions serve a critical adaptive function by broadening an individual's momentary thought-action repertoire. This expansion of thinking and behavior allows individuals to explore new ideas, develop skills, and build resources, which in turn enhances overall well-being and resilience over time. Unlike negative emotions, which narrow focus and promote specific survival responses, positive emotions like joy, gratitude, or love encourage creativity, exploration, and social bonding. The "broaden" aspect refers to the immediate cognitive and behavioral flexibility, while the "build" aspect highlights how repeated experiences of positive emotions accumulate into lasting psychological, physical, and social resources. These resources help individuals cope better with challenges and promote long-term growth and well-being.

Moreover, the induction of positive affect, in line with Fredrickson's (2000) "Undoing Effect of Positive Emotions" would help mitigate and reduce the psychophysiological consequences of negative emotions. Therefore, PT interventions within the affective domain do not aim for direct action on the user's lifestyle but use positive emotions, such as relaxation and joy, as mediators and tools for promoting personal well-being (Riva et al., 2012).

1.4.1.2 Positive Mood Induction Procedure using VR

A well-known and widely used strategy to induce positive emotion is the positive mood induction procedures (MIPs) (Baños et al., 2012; García Palacios & Baños Rivera, 1999; Martin, 1990). MIPs can be defined as strategies whose aim is to provoke a transitory emotional state in a non-natural situation and a controlled manner. the mood induced tries to be specific and pretends to be an experimental analogue of the mood that would happen in a certain natural situation" (García Palacios & Baños Rivera, 1999, p.16). The seminal study from the groups of Baños (2008) and Riva (2007) has proven the possibility of inducing positive emotion using VR. Today, those early findings have been substantiated by several studies. As pointed out by Pavic and colleagues in their review of the literature (Pavic et al., 2022), four aspects should be taken into consideration when inducing positive emotion through the use of VR, namely, the level of immersion, the level of interactivity, the content of the VEs, and finally, the sensory modality involved in positive VR experiences.

Immersion, a key element of the sense of presence in virtual environments (VE), refers to the system's ability to fully engage the user's senses and attention. It reflects the degree to which a VR system can create a convincing, immersive experience through vivid sensory input like detailed graphics, realistic sound, and responsive interactions. The more a system surrounds the user with stimuli that simulate reality, the deeper the immersion becomes (Berkman & Akan, 2019; Gorini et al., 2011). VR encompasses a variety of devices with differing levels of immersion, which can lead to emotional experiences ranging from mild to intense (Diemer et al., 2015; Visch et al., 2010). Pavic et al. (2023) investigated the level of immersion and the virtual environment (VE) content needed to induce positive emotions, using both subjective (i.e., self-report) and objective (i.e., physiological) measures. They compared the effects of exposure to 360-degree videos of natural and social contexts across two platforms: screen displays and immersive head-mounted displays (HMDs). The results demonstrated the superiority of immersive HMDs in inducing subjective positive emotion and eliciting higher arousal compared to less immersive screen displays. These findings underscore the importance of immersion in enhancing emotional responses within virtual reality contexts.

The second aspect to consider in inducing positive emotion through VR is the level of interactivity and user engagement within the VEs. Interactivity refers to the degree of user control over the environment and the responses that the system offers based on user actions. In VR, interactivity is key to making experiences immersive, personalized, and emotionally engaging. PT interventions are based on the key concept of “Flow” or “Optimal Experience,” defined by Csikszentmihalyi (1990) as the dynamic in which the individual experiences deep involvement and focus while performing an activity, fostering internal motivation and facilitating the expression of personal abilities and the development of new positive resources. In positive psychology, the concepts of Flow and Optimal Experience are closely connected to the “Transformation of Flow,” originally defined by Delle Fave (1996) as the individual's ability to identify, develop, and harness new positive resources following engagement in an optimal experience. Riva and colleagues (2006) later contextualized this process within PT, suggesting the possibility of using technology, to immerse individuals in optimal experiences, stimulating new positive psychological resources that can be transferred to real-life contexts where they are most needed.

Bluman and colleagues (2023) explored the effectiveness of virtual reality (VR) for inducing joy, focusing on the roles of interactivity and prior mood. The authors randomly assigned 124 participants, to

either a neutral or negative mood condition, as well as to an interactive or non-interactive joy induction scenario. The participants' mood was manipulated through a VR scenario, simulating either a terror attack (negative mood) or a neutral train station scene (neutral mood). Participants then entered a virtual park, where some could interact playfully with objects (interactive condition) while others could not (noninteractive condition). The results showed that interactive VR experiences reduced negative affect more effectively than noninteractive experiences, regardless of the participants' prior mood. However, playful interaction in VR only increased joy when participants began in a neutral mood, not when they started in a negative mood. The study highlights interactivity as a key design element for reducing negative emotions but suggests further research is needed to understand how to convert a prior negative mood into positive emotion.

A third core aspect of positive emotion induction to be considered is the content of the VE. The majority of the studies present in the literature involve the use of the natural environment to foster relaxation and positive emotion (Chirico et al., 2018; Pavic et al., 2022). Fewer studies have investigated other types of content; for example, Richesin and colleagues (2021) showed that drawing in VR can lead to a reduction in negative affect and anxiety levels, producing effects comparable to those of traditional art-making methods. Some studies also explored the possibility of manipulating the environmental content to express emotions (e.g., Baños et al., 2009; Wagener et al., 2022). Wagner and colleagues (2022) explored how the autonomous creation of VE affects emotional engagement and well-being. To address this, the researchers developed Mood Worlds, a VR application that allows users to visualize and express their emotions by creating their own VE. The results of an exploratory evaluation with 16 participants showed that Mood Worlds effectively supported emotional engagement and increased positive emotions and well-being, suggesting that allowing users to autonomously design their own virtual environments enhances positive affect.

Therefore, it is important to have personalized and flexible environments that can adapt software to meet the needs of patients. Gardini and colleagues (2023) proposed a protocol for the validation of a flexible VE that can be used both for treating various disorders and promoting positive mental health. The VE of the software H.O.M.E. (How to Observe and Modify Emotions) consists of a four-room house where different objects can be used to address a range of disorders, including eating disorders and addiction. Additionally, each room contains a specific tool, called the "resource box," designed to enhance participants' resources and

well-being. A more in-depth description of H.O.M.E will be given in the fourth chapter of this dissertation since it is part of a pilot study we carried out to assess his effectiveness and feasibility.

Finally, the fourth central aspect of inducing positive emotion in VR is the sensory modality involved in positive VR experiences. Using various sensory modalities in VR has a twofold effect on emotion induction. The multisensory stimulation in the VE allows a greater sense of presence (Gallace et al., 2012) and can be precisely manipulated to induce emotion (e.g., music, scent, and relaxing environmental sounds). An example is the study proposed by Habak and colleagues (2020a). The authors developed a VR program -*Edge of the Present*- to promote optimism and future-oriented thinking through a single 10-minute session. Participants explored a sparsely furnished room with doors and windows that opened to reveal immersive, positive landscapes (such as alpine scenes, rainforests, and beaches), accompanied by environmental effects like a warm breeze and sound. Greater engagement with the room enriched the environment, with elements like ferns growing inside the space. This exploration fostered a sense of hopeful anticipation, teaching users that openness and curiosity led to rewarding experiences, which were then integrated into their virtual space. The study found that just 10 minutes in this immersive environment positively impacted mood and significantly increased well-being.

In conclusion, VR has proven to be a powerful tool for promoting subjective well-being from a hedonic perspective by inducing positive emotions such as joy, relaxation, and awe. Through immersive, interactive, and personalized virtual environments, users can experience enhanced emotional engagement, which contributes to foster well-being. The use of multisensory stimuli further strengthens these effects by creating more vivid, emotionally charged experiences. As demonstrated by programs like *Edge of the Present*, even brief VR interventions can have a significant positive impact on mood and overall psychological health.

Shifting from a purely hedonic focus, the next area of exploration involves the eudaimonic perspective. While hedonic approaches emphasize pleasure and positive emotions, the eudaimonic perspective centers on fostering positive growth, purpose in life, and long-term fulfillment. Digital technologies, including VR, offer unique opportunities to support individuals in achieving deeper personal

development and meaning through targeted interventions aimed at enhancing self-awareness, autonomy, and psychological resilience.

1.4.2 From hedonic to eudaimonic: how digital technology can foster positive growth and purpose in life

Subjective well-being, often referred to as "hedonia," emphasizes life satisfaction by focusing on positive emotions, pleasure, and an enhanced quality of life (Diener et al., 1999). This approach prioritizes short-term happiness and enjoyable experiences. In contrast, psychological well-being, or "eudaimonia," highlights the importance of long-term fulfillment through personal development, the pursuit of life goals, and optimal functioning (Lent, 2004; Ryff, 1989). While these two approaches may appear distinct—hedonia targeting immediate happiness and eudaimonia seeking deeper meaning—they share the common goal of enhancing overall well-being. This overlap has led to integrative theories that combine both perspectives (Henderson & Knight, 2012). Some scholars even argue that hedonia and eudaimonia represent complementary aspects of well-being (Kashdan et al., 2008; Waterman, 2008).

PT aims not only to create interventions that modify affective quality and induce pleasant emotions but also to help individuals engage in meaningful experiences that strengthen personal resources and foster positive qualities (Riva et al., 2012). This focus aligns more closely with the eudaimonic perspective, prioritizing optimal functioning and the relationship between the individual and their environment, as effectively represented by Carol Ryff's six-dimensional model of psychological well-being (Ryff, 1989).

Currently, the literature on virtual reality (VR) and positive technology at the eudaimonic level is fragmented, with limited studies addressing the topic specifically. One notable example is the software developed by the Rosa Baños group, known as EMMA's World, which was initially created for treating stress-related disorders (Baños et al., 2009b). EMMA's World immerses users in meaningful virtual environments that enhance the emotional processing of past experiences and promote a more optimistic outlook on the future, making it one of the first VR environments focused on improving eudaimonic well-being.

More recent studies have explored the potential of VR applications to enhance purpose in life and personal resources. For instance, Huang and colleagues (2024) investigated the effects of a nostalgic

storytelling VR experience compared to a neutral text-reading VR experience on participants' eudaimonic well-being. The findings showed that the nostalgic storytelling VR significantly increased hedonic and eudaimonic gratifications (such as media enjoyment and appreciation), social connectedness, and overall well-being when compared to the neutral experience. The nostalgia-inducing VR experience enhanced participants' appreciation, which subsequently improved their well-being, providing promising data for the development of similar applications.

Supporting these findings, Kosa & Johnson-Glenberg (2023) examined whether eudaimonic VR games were more effective than hedonic VR games, hedonic desktop games, or noninteractive videos for reducing daily stress and managing mood. In their study, 202 university participants were randomly assigned to one of four conditions (EudVR, HedoVR, HedoDesk, and VidDesk). In this context Hedonic game used was the famous game Tetris whereas the Eudaimonic game was Luna, published and developed by Funomena LLC in 2017. "Luna" is an interactive fable where players follow the journey of a young bird whose peaceful slumber is interrupted by a mysterious owl. The game emphasizes themes of learning from unexpected mistakes and bringing life back to environments and present characteristic eudaimonic features such as opportunities for introspection, touching emotional states, encounters that evoke a sense of purpose and emotional resonance, and realistic portrayals of adversity to overcome. Results indicated that eudaimonic VR games, along with hedonic VR games and hedonic desktop games, were effective in inducing positive moods and facilitating recovery experiences compared to the control group that only watched relaxing videos. Notably, the eudaimonic VR condition outperformed the others in reducing stress and alleviating negative emotions, underscoring the need for further research on VR applications aimed at fostering eudaimonic well-being.

Overall, these studies highlight the significant potential of VR technologies to provide enjoyable experiences, promote meaningful engagement, and provide long-term psychological benefits. However, more research in this area is needed to better understand and leverage VR's power to enhance and foster well-being.

1.4.3 Design Virtual Psychological Intervention to enhance Eudaimonic well-being

1.4.3.1 The dual continuum perspective

Understanding well-being requires a nuanced approach that encompasses both the absence of mental illness and the presence of positive mental health. The dual continuum model proposed by Keyes (2002) provides a framework for this understanding. According to Keyes, mental health and mental illness exist on two separate, yet related, continua. One continuum ranges from flourishing (high levels of well-being) to languishing (low levels of well-being), representing positive mental health. The other continuum ranges from no mental illness to severe mental illness. This model emphasizes that mental health is not merely the absence of illness but also the presence of positive psychological functioning, purpose, and life satisfaction.

This perspective aligns closely with the dichotomy of hedonic and eudaimonic well-being explored in this section. Integrative approaches that combine hedonic and eudaimonic perspectives offer a comprehensive pathway to fostering flourishing, as outlined in Keyes's model (2009).

Today, most psychological interventions using VR focus primarily on alleviating negative symptoms such as reducing anxiety or depression. While targeting these factors can indirectly contribute to eudaimonic well-being by alleviating distress and creating a foundation for personal growth, it is also essential to design interventions that explicitly aim to enhance dimensions of eudaimonic well-being, such as purpose, personal growth, and life meaning.

VR can be helpful in develop interventions that specifically target eudaimonic dimensions and can provide clearer insights into the mechanisms and outcomes of psychological well-being.

1.4.3.2 Elements central in designing Eudaimonic VR psychological intervention

To achieve these outcomes effectively, VR interventions can be designed based on well-established psychological mechanisms and evidence-based guidelines.

As highlighted above, a central element to the effectiveness of VR intervention is immersion. Immersion is influenced by the system's technical capabilities (e.g. multisensory integration) and the individual's subjective experience, namely the sense of presence experienced by the individual. A stronger sense of presence is connected to increased user responses, where reactions to virtual stimuli closely resemble those in real-world interactions(Bell et al., 2024). This heightened presence is often linked to more engaging and immersive VR experiences. Research has shown that the effectiveness of VR-based therapy is significantly influenced by the sense of presence, which is shaped by elements such as place illusion, plausibility, and the perception of body ownership. The latter, where individuals feel their virtual body replaces their physical one, has proven particularly useful in treating conditions like perceptual body distortions in eating disorders (Riva, Malighetti, et al., 2021) and generate self-compassion(Cebolla et al., 2019; Navarrete et al., 2021). These insights underscore the potential of psychological interventions in VR that not only leverage the sense of presence but also prioritize personalization and gradual skill-building. By integrating these elements, VR interventions can effectively foster psychological well-being and empower individuals to navigate their mental health challenges.

Encouraging reflection is another essential aspect of VR intervention design(Riva et al., 2016). Embedding reflective prompts within the VR experience or conducting post-session discussions can help users process their emotions and insights, reinforcing the long-term benefits of the intervention. In designing psychological interventions to foster well-being, incorporating emotionally evocative elements within the virtual environment is crucial. Emotional triggers embedded in these environments can enhance users' engagement, making the experience more immersive and meaningful compared to traditional methods (Bell et al., 2024). These triggers, whether visual, auditory, or situational, can help elicit specific emotions and facilitate therapeutic processes, such as emotional processing, resilience-building, or stress relief.(Baños et al., 2012)

When carefully tailored to the individual's goals and psychological needs, these elements can amplify the intervention's effectiveness.

In this regard, to maximize the impact of these interventions, personalization is crucial. Tailoring the content to align with individual users' goals, values, and cultural backgrounds ensures that the virtual experience resonates deeply and addresses specific well-being needs. This emphasis on personalization aligns with broader trends in healthcare, such as the European agenda's focus on personalization in medicine. By prioritizing individualized care, VR-based psychological interventions echo the larger movement towards precision health strategies, which aim to address unique patient profiles and deliver targeted, impactful solutions(August & Gewirtz, 2019).

Lastly, scalability and accessibility are key factors in the success of VR interventions. Designing interventions that are affordable and accessible can extend their reach, enabling broader populations, including those in underserved or resource-limited settings, to benefit from these advanced tools.

By incorporating these mechanisms and principles, VR interventions can effectively bridge the gap between hedonic pleasures and eudaimonic purpose, transforming mental health care by not only reducing distress but also actively promoting flourishing and a deeper sense of purpose, aligning with Keyes's dual continuum model of mental health.

1.5 The current dissertation

This dissertation presents a series of studies, all focused on the possible applications of digital technologies, (particularly VR) in clinical settings. These applications involve both clinicians and patients populations. For these reasons, the issues addressed by this research project include how VR could be applied to increase empathy in healthcare professionals, as well as how VR could be applied to promote well-being, and to alleviate mental health problems in distressed individuals. The dissertation consists of 2 systematic reviews and one pilot investigation testing a new VR software, which adopts a transdiagnostic approach.

The primary aim of the first two reviews of the literature is to summarize key findings in this area, highlighting both the advantages of these technologies and the existing gaps in the literature—particularly regarding the impact of Positive Technologies, such as VR, on eudaimonic well-being. Based on current research, it is hypothesized that VR can significantly enhance eudaimonic well-being by fostering a sense of connection with other people (empathy), purpose, engagement, and personal growth. This approach, thus, add and complement VR's established benefits in alleviating negative mental health symptoms.

Chapter 1: Could Empathy Be Taught? The Role of Advanced Technologies to Foster Empathy in Healthcare Professionals: A Systematic Review

The first study, actually submitted in its revised version to the *Journal of Medical Systems*, is a systematic review that focuses on how digital technologies can enhance empathy among healthcare professionals, which is crucial to the patient-clinician relationship. This investigation highlights the significance of empathy in interactions between medical practitioners and patients, influencing patient satisfaction and treatment adherence. Key findings of the study highlight a lack of a consistent definition of empathy across studies, which complicates the development of effective training programs. Wearable devices, particularly VR, show promising results by providing immersive experiences that enhance healthcare professionals' ability to empathize with their patients.

However, empathy in therapeutic settings goes beyond just strengthening the clinician's skills; it also involves providing patients with tools for self-reflection, imagination, and emotional expression. VR interventions offer unique opportunities in this regard. By immersing patients in controlled, interactive environments, VR enables them to explore their emotions, visualize abstract thoughts, and engage in imaginative scenarios that might be difficult to access in traditional therapy. This can foster greater emotional insight and encourage more open communication with therapists, ultimately contributing to emotional healing and resilience. In line with this, the next area of exploration will focus on how VR interventions can promote positive mental health and well-being.

Chapter 2: The Use of Virtual Reality Interventions to Promote Positive Mental Health

The second study (Li Pira et al., 2023), published in JMIR Mental Health journal, provides a comprehensive literature review on the use of VR interventions to promote positive mental health, serving as a foundational reference for subsequent research. The review presents strong evidence supporting the beneficial effects of VR therapy in reducing stress and negative symptoms. However, the impact of VR treatments on positive functioning remains unclear, with some studies indicating minimal or no effect on various dimensions of positivity. The discrepancies in outcome measures and their varying sensitivity to clinical changes may contribute to these inconclusive results. Nonetheless, VR interventions have been shown to effectively address stress while promoting positive mood in the general population. These interventions may be cost-effective and scalable, particularly when they do not require guidance from a counselor or therapist.

The insights from this review served as a critical foundation for the development and application of a the new VR software tested in the third part of this dissertation. Based on the current state of the art, we refined the software to target improvements in well-being, positive mental health, and personal resources. This literature review directly informed our approach, leading to the pilot study and ongoing larger-scale evaluation of the program.

Chapter 3: Effectiveness of a Virtual Reality program in treating psychological distress and promoting positive mental health: A pilot feasibility study.

The third study, actually submitted in its revised version to the International Journal Applied Positive Psychology, investigates the feasibility and effectiveness of a VR software program called H.O.M.E., developed by the UNIBO research group. This pilot study is part of a broader investigation linked to my doctoral project, which aims to evaluate the efficacy of VR-delivered interventions in enhancing mental health and well-being among young adults. The results from the pilot study indicate a positive impact of the VR intervention on university students' mental health, leading to significant reductions in psychological distress, as measured by the Depression, Anxiety, and Stress Scale (DASS), alongside increases in overall well-being, assessed using the Mental Health Continuum (MHC) and Positive and Negative Affect Schedule (PANAS). These findings align with prior research highlighting VR's potential to improve mental health outcomes. Notably, the study demonstrated not only a decrease in distress but also an increase in well-being, suggesting that the intervention fosters positive emotions and psychological resilience.

Additionally, we are currently conducting a follow-up study with a larger sample size, using a modified 2.0 version of the software that incorporates lessons learned from the pilot. This validation study aims to further explore VR's impact on mental health and well-being, ensuring a more robust evaluation of the intervention's effectiveness.

Chapter 4: General Discussion

Chapter 4 synthesizes the findings from the previous studies, offering a comprehensive discussion of the potential of digital technologies, particularly VR, in enhancing empathy and promoting mental health and well-being. This chapter summarizes the key contributions of the studies, including the systematic review on fostering empathy among healthcare professionals, the literature review on VR’s role in supporting positive mental health, and the pilot study on VR interventions for reducing psychological distress and enhancing well-being.

Following this, the theoretical background of the studies is explored, along with the gaps in the literature, such as inconsistent definitions of empathy, and the varying effectiveness of VR in promoting positive mental health. The broader implications of these findings for clinical practice, medical education, and mental health interventions are addressed, with particular emphasis on how VR could be integrated into healthcare and therapeutic settings.

Finally, the chapter concludes by suggesting future research directions, including the need for more robust evaluations of VR interventions, further development of software tailored to specific clinical conditions, and strategies for scaling VR-based mental health programs.

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Chapter 1: Could Empathy Be Taught? The Role of Advanced Technologies to Foster Empathy in Medical Students and Healthcare Professionals: A Systematic Review

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Abstract

Background: The physician-patient relationship relies mostly on doctors' empathetic abilities to understand and manage patients' emotions, enhancing patient satisfaction and treatment adherence. With the advent of digital technologies in education, innovative empathy training methods such as virtual reality, simulation training systems, mobile apps, and wearable devices, have emerged for teaching empathy. However, there is a gap in the literature regarding the efficacy of these technologies in teaching empathy, the most effective types, and the primary beneficiaries - students or advanced healthcare professionals-. This study aims to address this gap through a literature review following PRISMA guidelines.

Methods: A comprehensive literature search was conducted in the PsychINFO, Scopus, PubMed, and Web of Science databases using specific keywords. Inclusion criteria for articles were established, and two researchers independently rated the selected articles, resolving any disagreements by consensus.

Results: Out of 1137 articles screened, a total of 14 articles were included in this review with a total of 1285 participants, who received empathic training integrated with the use of digital technologies. Only 9 articles defined the construct of empathy, focusing on cognitive, affective, clinical, or cultural aspects. Empathy was assessed with various methods and promoted through various digital technologies, including wearables (e.g. HMDs, SymPulse™ armband) and non-wearable devices (computer monitors, Mobile Apps, Kinect System). Participants were primarily medical students (68.1%), with few healthcare workers (31.9%) and nurses (2.9%). All digital technologies effectively promoted empathy among the target population except for 3 studies that involved advanced career healthcare workers.

Conclusions: This review highlights the potential efficacy of digital technologies in fostering empathy among medical students, though not as effectively among advanced healthcare professionals. These insights have implications for designing targeted educational programs that

address the distinct needs of healthcare professionals at varying career stages. Limitations and future research directions are also discussed.

Keywords: empathy, empathy-training, healthcare worker, digital technologies.

1. Introduction

1.1 The construct of empathy in the Health Care context

The physician-patient engagement is pivotal in the success of medical treatment (Graffigna et al., 2015; Marzban et al., 2022). Physician-patient engagement encompasses the cooperative and interactive bond shared between the healthcare workers (HCWs) and their patients. It transcends the mere exchange of information or direction-giving by the doctor; instead, it involves a dynamic interplay where both individuals engage in decision-making, goal establishment, and treatment strategizing (Ippolito et al., 2020; Kennedy et al., 2021; Roter et al., 1998). One of the key roles in establishing engagement among both parts is the physicians' empathetic response, which refers to the ability of HCWs to deeply understand and share the feelings of their patients, creating an environment of trust and emotional support. For instance, an empathetic physician may acknowledge a patient's fears about a diagnosis by not only providing clear explanations but also offering reassurance through active listening and compassionate communication (Roter et al., 1998). Overall, it has been demonstrated that empathy enhanced patients' comprehension about treatment choices and active engagement in decisions regarding therapy (Derksen et al., 2013; Keshtkar et al., 2024).

The theoretical model of Davis (Davis, 1980) defines the construct of empathy in two components: cognitive, and affective. Cognitive empathy permits the physician to understand and perceive the patients' thoughts, feelings, and perspectives without necessarily sharing those emotions (Hojat, 2007); whereas affective or emotional empathy implies that physicians share the emotions experienced by the patients (Morse et al., 1992). In the area of healthcare, clinical empathy encompasses both cognitive and affective elements, but it is specifically tailored to the healthcare context (Jeffrey et al., 2016; Moudatsou et al., 2020). In particular, the concept of clinical empathy considers the ability to observe, to feel and to express the awareness of the patients' emotions (Haslam, 2007; Tan et al., 2021). For this reason, clinical empathy was defined as the heart of patient care (Hojat et al., 2020).

The literature on the antecedents and consequences of empathy provides critical insights. Empathy, a multifaceted construct is influenced by individual and contextual factors and can be shaped by demographic variables like gender, age, and ethnicity (Hojat et al., 2020). Structured educational programs in healthcare and social care disciplines significantly enhance empathic skills, promoting a mindset essential for effective

practice (Moudatsou et al., 2020). Early academic experiences and exposure to patient-centered care further contribute to empathy development (Hojat, 2007). In healthcare, empathy has profound consequences. Higher empathy levels among practitioners improve patient satisfaction and therapeutic outcomes (Keshtkar et al., 2024). Empathy also strengthens the therapeutic alliance, fostering trust and understanding (Jeffrey et al., 2016). Beyond individual interactions, Haslam (2007) highlighted the broader implications of empathy in humanizing medical practice, which can lead to systemic improvements in patient care. However, most of the investigations on physician-patient relationship do not clearly disclose the type of empathy considered or the specific component of interests. Thus, the large heterogeneity of findings is due to the lack of consensus on the dimension of empathy mostly considered in healthcare settings (Weigel, 2017; Guthridge and Giummarra, 2021). This lack of clarity hampers the development of targeted interventions, ultimately affecting the quality of patient care and outcomes. To advance in this field, it is crucial to establish a common ground regarding the specific dimensions of empathy that are most beneficial in healthcare settings.

1.2 Barriers to HCWs and medical students' empathy

Several barriers to empathy between HCWs and patients have been observed. One significant barrier is physicians' anxiety and time pressure, which often prevents doctors from fully listening to patients during daily rounds. Another impediment to fostering empathy lies in the failure of many physicians to acknowledge patients' emotional needs as integral to both illness and care. Additionally, a third obstacle surfaces when negative emotions escalate during conflicts between patients and physicians (for a review on this topic see Elayyan et al., 2018). More specifically, critics have repeatedly condemned the current medical approach for evolving into a narrow and inflexible system that neglects the subjective experience of human suffering (Halpern, 2014; Barak et al., 2022). Furthermore, a decrease in empathy has been observed not only among physicians in advanced careers but also among medical students (Neumann et al., 2011; Hill et al., 2018). Among medical students, several factors contribute to this decline in empathy, including heavy academic workloads, traditional teaching methods, institutional culture, the prioritization of theoretical knowledge over humanistic aspects, burnout, and stress (Boshra et al., 2022).

1.3 Digital Empathy Training

Given the importance of empathy in clinical settings and the barriers that impede its practice, several empathy training programs have been developed for HCWs (Kelm et al., 2014). Most of the programs have been focused on asking HCWs to adopt the patient's perspectives through imagination or, more commonly, through role-play (Nestel and Tierney; 2007). Preliminary results have indicated positive outcomes and enhanced empathy (Patel et al., 2019). In this context, essential support has been given by the recently adopted digital technologies as educational mediums. An example of technology adopted in education curricula are the Mobile Applications. In the context of education, and thanks to the widespread consumption of Mobile Apps, many higher education organizations have implemented mobile learning to offer flexibility in learning (Davies et al., 2012; Ponce et al., 2014). For example, a Mobile App was used to provide emergency care for infant airway obstruction and the instructional content consisted of causes, frequency, suspicious signs, and emergency care (Kim et al., 2017).

Another digital technology that has exploded in educational context is Virtual Reality (VR). VR refers to a computer-generated environment that simulates a realistic sensory experience, often including sight, sound, and sometimes touch. Users typically experience VR through a headset or goggles that immerse them in a simulated environment, allowing them to interact with and navigate through digital spaces or scenarios as if they were physically present. In medical education, it has been adopted to train HCWs in surgical practice, as it allows for the simulation of a realistic medical experience (Pottle, 2019; Dyer et al., 2018). This technique has been demonstrated to be efficacious in fostering empathy in people belonging to outgroups, including gender, age or ethnicity (Oh et al., 2016; Banakou et al., 2016; Ventura et al., 2020). For educational purpose the virtual avatar has also been adopted. It is a digital representation of a user or individual within a virtual environment projected through a computer screen or Head Mounted Display. Avatars can be customized to reflect various characteristics, including appearance, clothing, accessories, and sometimes personality traits. Within medical training, researchers have used virtual patients, a subset of virtual agents, to support both the acquisition of theoretical knowledge as well as communication skills (Danforth et al., 2009; Jiang et al., 2022). The published literature demonstrates that utilizing virtual patients, whether as independent learning modules or alongside traditional classroom teaching, enhances students' proficiency in clinical reasoning, ethical decision-making, and communication skills (Plackett et al., 2022).

However, considering the growing use of technologies in education including Mobile Apps and Virtual Reality and Virtual Patients, few literatures investigate its potentiality in empathy training.

1.4 Objectives

This systematic review aims to address a critical gap in the literature by summarizing the most recent (last 10 years) research on the role of digital technologies in fostering empathy among healthcare workers and medical students. Specifically, the objectives of this review are: (1) to evaluate the benefits and the effectiveness of digital technologies in enhancing empathy within healthcare contexts; (2) to identify existing research gaps and propose areas for future investigation; and (3) to provide actionable insights for stakeholders, including educators, policymakers, and practitioners, regarding the integration of digital empathy training into healthcare education. By doing so, this review seeks to contribute to both the academic understanding of digital empathy and the practical advancement of empathy-based training in the healthcare field.

1.5 The present study

The research questions of the present review (RQ) are:

- **RQ1**: How is the construct of empathy defined and measured by the selected literature?
- **RQ2**: On which factors (i.e., affective/cognitive) of empathy do the various digital empathy training primarily focus?
- **RQ3**: Could digital technologies be effective to promote and foster empathy among HCWs? If yes, which empathy factors are more propense to change?
- **RQ4** Which type of digital technologies are more effective?
- **RQ5**: Who benefits more from empathy training, medical students or HCWs in advanced career?

2. Method

A systematic review was conducted to extract recently published scientific papers that focused on using digital technologies to induce empathy in a population of medical students or HCWs. The identification, screening, and selection process is summarized in **Figure 1**. The review focused on the last 10 years (from 2014 onward) since in this time frame digital technologies have known rapid development with dramatic changes in hardware, software, and cost feasibility and their application in social and clinical fields emerged. This review adheres to the Preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Page et al., 2021).

2.1 Eligibility criteria

To be included in this review, the studies should involve: (1) a population of HCWs or medical students, (2) examine the change in empathy (3) the use of digital technologies, and (4) be quantitative study. Studies were excluded if they (1) did not provide an assessment of empathy, (2) empathy was assessed only after training and not at baseline; (3) were not experimental studies (e.g., systematic reviews, protocols, or book chapters); and (4) were not written in English language.

2.2 Search strategy

A systematic literature search was conducted on the following electronic databases: PsycINFO, PubMed, Web of Science, and Scopus. All database searches were performed in March 2024 by entering the following keywords and Boolean operators in the title and abstract section: *(((empathy OR compassion OR "interpersonal relationship") AND (training)) AND (medical OR medicine OR health OR healthcare)) AND (digital OR virtual OR technology)*. The search results were then filtered for year (only the last ten years) and language (only English language). Additional papers were identified from the citations from the retrieved references.

2.3 Quality Assessment of the Articles

To assess the quality of the selected studies we employed the Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields (QUALSYST) (Kmet et al., 2004). For the present review only the quantitative scoring system was employed by 2 authors for all the included articles.

3. Results

3.1 Search outcome

The initial screening identified 1459 articles. Most of them were extracted from the EBSCOhost (PsychINFO) (856/1459, 58.7%) and Scopus (238/1459, 16.3%) databases. The other articles were extracted from Web of Science (201/1459, 13.8%) and, PubMed (164/1459, 11.2%). After removing duplicates, 322 publications were identified and individually assessed based on the study title and the information provided in the abstract (**Figure 1**). Out of the total 1137 papers, 1053 (92.6%) were disqualified based on the specified inclusion and exclusion criteria. The full texts of 84 (7.4%) articles were reviewed to determine their eligibility for inclusion. Of these 84 studies, 15 (17.8%) did not include specific training on empathy, 9 (10.7%) included empathy training but did not involve the use of digital technologies, 35 (41.7%) were not quantitative studies, 10 (11.9%) did not compare empathy levels before and after the training, and it was not possible to obtain the full text of 3 (3.6%) papers; therefore, they were excluded. Finally, 2 (2.4%) papers were added based on the reference found during the full text screening process. A total of 14 (16.7%) articles met all the inclusion criteria and were included in this review with a total of 1285 participants, who received empathic training integrated with the use of digital technologies.

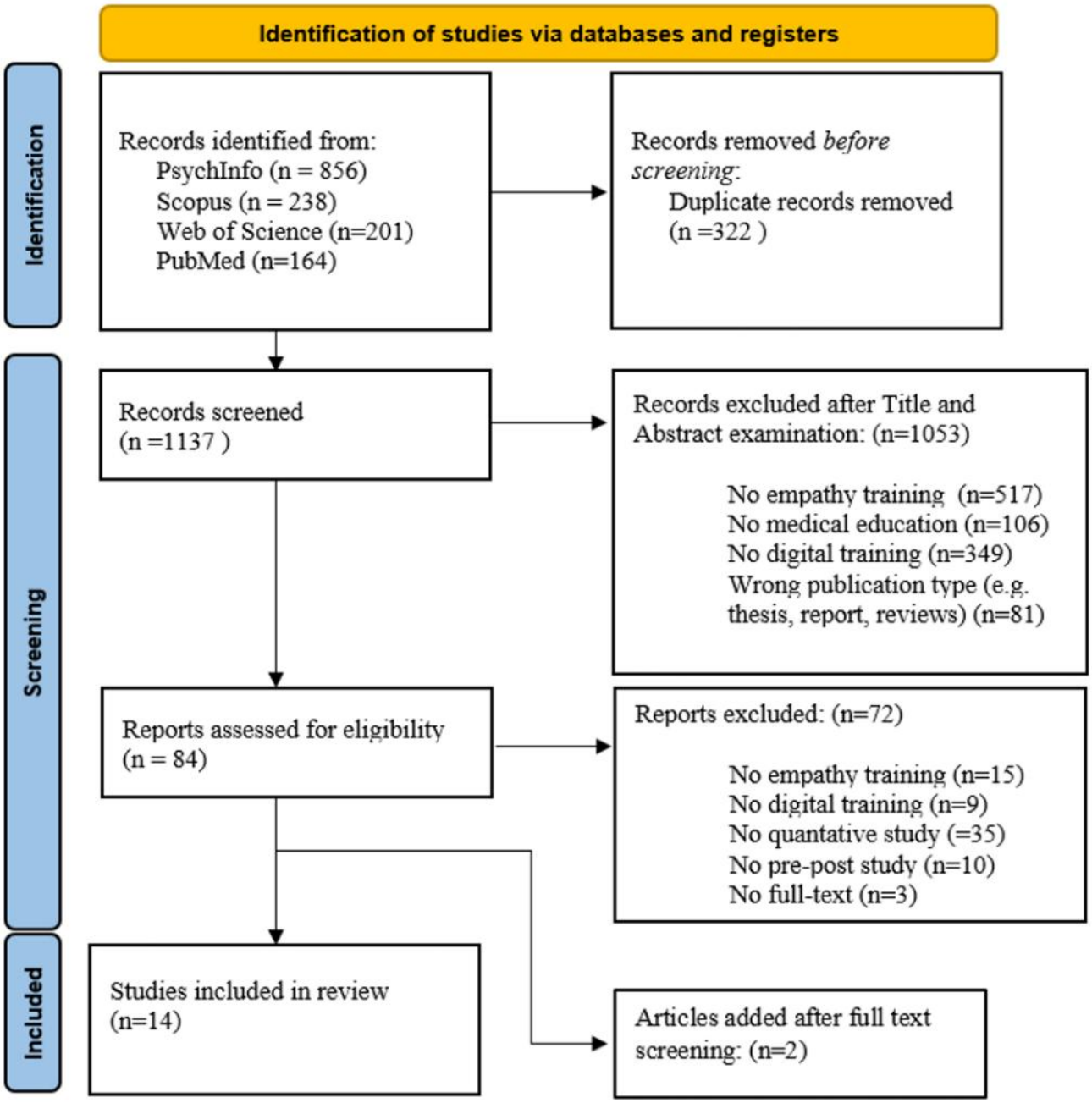

Figure 1: Flowchart of the screening and selection process of the included articles

3.2 Empathy construct definition and assessment (RQ1)

Of the 14 articles included, only 9 (64.2%) defined what the authors consider empathy, whereas the remaining 5 articles (Hess et al., 2022a; Manuel et al., 2023a; Quail et al., 2016; Sauvé et al., 2022a; Tong et al., 2017a) did not clearly define the construct (see **Table 1**). Of the articles that defined the concept of empathy, 4 (28.6%) focused on cognitive and affective factors of empathy (Anishchuk et al., 2023a; A. Foster et al., 2016a; Olsen & Oertel, 2020; Palanica et al., 2018), whereas 4 (28.6%) focused more deeply on

the concept of clinical empathy (Gilbert et al., 2023; Halton & Cartwright, 2018; McCalla et al., 2023; Yao et al., 2022), and 1 (7%) focused on cultural empathy (Everson et al., 2015).

To respond to RQ1, we also evaluated how the included studies assessed the empathy change in the participants. Most of the studies used the self-report Jefferson scale for Empathy (Hojat et al., 2018) (4/14, 28.6%) and the expert-rated scale Empathic Communication Coding System (Bylund & Makoul, 2005) (ECCS) (3/14, 21.4%). Of the remaining papers, each study utilized a different scale to measure empathy or related constructs. For details on these scales, please refer to **Table 2**. In conclusion, among the included studies, the concept of empathy was scarcely defined and assessed with great heterogeneity

Table 1: Empathy definitions

Reference	Empathy definitions	Empathy Factors
Anishchuk et al., 2023	Clinical empathy is not simply "detached concern" but rather emotional atonement, and it describes the clinical skill of emotional resonance and curiosity about the meaning of a clinical situation for the patient. It is a clinical skill involving the active assessment of a patient's emotions and responding to patient cues. Most recently proposed as "empathic concern," clinical empathy can be understood as "the attitude of genuine interest towards the experience of the other" which comes from an "engaged curiosity".	Clinical Empathy
Olsen et al., 2020	A two-phase process: (a) understand and appreciate another person's feelings and emotions and (b) communicate understanding back to the patient in a supportive way with a focus on the communication through voice.	
Foster et al., 2016	Empathy is a complex phenomenon, conceptualized as having an affective component (the ability to share emotional experiences), a cognitive component (understanding the emotions of another person), and a behavioral component (the clinician's verbal and nonverbal expression of empathy toward the patient).	
Palanica et al., 2018	The ability to understand and accurately acknowledge the feelings of another, eliciting a more receptive response from the observer. Clinical empathy involves both cognitive and affective components, which include (1) understanding the patient's situation, thoughts, and feelings, (2) verifying its precision with the patient, and (3) responding to the patient in a helpful manner.	
Halton et al., 2018	Empathy can be described as having two interrelated dimensions: cognitive and affective. Cognitive empathy measures the skills-based aspect of learning, where a person is able to recognize and understand another's experience (Kourakos et al., 2018). Then affective empathy links to the transformative aspect of the learning cycle, where the understanding resonates emotionally with the individual and they start to be able to interpret their knowledge, exploring concepts beyond the facts they are presented with (Kourakos et al., 2018).	Cognitive and Affective Empathy
McCalla et al., 2023	Empathy encompasses knowing, comprehending, and perceiving what another person is experiencing,	
Gilbert et al., 2023	Empathy is a complex and dynamic task that requires a sustained cognitive effort and emotional maturity.	
Yao et al. 2022	To have empathy is to understand the value and scope of another's felt emotion and consider this affective state from their perspective	
Everson et al., 2015	Cultural empathy refers to the learned ability to perceive and share experiences through the unique lens of values, beliefs and perspectives of people from cultural backgrounds different to one's own.	Cultural Empathy
Hess et al., 2022	No clear definition is provided	
Manuel et al., 2023	No clear definition is provided	
Quail et al., 2016	No clear definition is provided	
Sauvè et al., 2022	No clear definition is provided	
Tong et al., 2017	No clear definition is provided	

3.3 Aspects of Empathy Addressed by Training Programs and Their Theoretical Backgrounds (RQ2)

Empathy training programs in healthcare employ a variety of approaches, each targeting different facets of empathy, including emotional resonance, cognitive perspective-taking, and practical clinical application. A significant portion of these programs is devoted to refining *interpersonal communication skills*, with a particular emphasis on fostering clinical empathy. For example, Manuel and colleagues (Manuel et al., 2023b) underscored the importance of techniques like motivational interviewing in enhancing communication between HCWs and patients. Similarly, Olsen and colleagues (Olsen & Oertel, 2020) and Gilbert and colleagues (Gilbert et al., 2023) utilized virtual patients to improve communication skills within clinical scenarios. Feedback mechanisms have also been highlighted as crucial for enhancing empathetic performance, as evidenced by the work of Foster and colleagues (A. Foster et al., 2016b) and Yao and colleagues (Yao et al., 2022) who demonstrated the efficacy of real-time feedback in enhancing verbal empathy. For a review on conversational agent and patients' engagement see Cevasco and colleagues (2024). Another significant focus of empathy training programs is on the *cognitive aspect* of empathy. Some of the training incorporates exercises and simulations that encourage HCWs to understand and appreciate the diverse cultural backgrounds and experiences of their patients. For instance, Everson and colleagues (Everson et al., 2015) utilized immersive cultural simulations to expose nursing students to scenarios in developing country hospital wards, thereby enhancing their cultural empathy. Similarly, Sauve and colleagues (Sauvé et al., 2022b) developed simulations aimed at promoting intercultural empathy, such as the Stand Up for Indigenous Health (SU4IH) program.

In some instances, training programs adopted a comprehensive approach, addressing *cognitive and emotional dimensions of empathy*. Anishchuk and colleagues (Anishchuk et al., 2023b), for instance, developed a module on clinical empathy that focused on recognizing and understanding patients' feelings and experiences, as well as effectively communicating this understanding to patients. Likewise, Hess and colleagues (Hess et al., 2022b) proposed interventions for Parkinson's disease that encompassed lectures, breakout sessions, and immersive virtual reality experiences, aimed at enhancing empathetic interactions with patients. Beyond cognitive and emotional empathy, certain programs explore alternative dimensions of empathy. For example, Palanica and colleagues (Palanica et al., 2018) introduced the construct of *tele-*

empathy; a class of technology used to accurately identify, digitize, and characterize symptoms in a specific patient, generating a representative physiological response in a non-patient to elicit empathy for a particular health condition. Tong and colleagues (Tong et al., 2017b) investigated the potential of embodied video games to raise awareness and foster positive attitudes among HCWs, although the impact on empathy was less pronounced.

In conclusion, the majority of articles included referred to clinical empathy, with a specific focus on communication skills and understanding of different cultural backgrounds of patients or the implications of their symptoms.

3.4 Type of technology used (RQ3) and effectiveness (RQ4)

Main results are synthesized in **Table 2**. We considered the different types of technologies employed by the articles included and their efficacy in promoting empathy. All the studies documented improvements in some dimension of empathy among the target population, except for 3 studies (21.4%) (Hess et al., 2022b; Tong et al., 2017b; Yao et al., 2022). Two of the studies that did not show significant improvements were computer-based training that used Virtual Patients (Hess et al., 2022b; Yao et al., 2022) and one of them used body motion sensors (Tong et al., 2017b). In fact, the digital technologies adopted by the investigators can be divided into *wearable or no-wearable*. The former are: the Head Mounted Display (HMD) adopted in 2 (Everson et al., 2015; McCalla et al., 2023), out of 14 studies (14.3%) and the wearable arm band SymPulse™ used in 1 (Palanica et al., 2018) study (7.1%). The no-wearable technologies are the computer monitor, used in 8 out of 14 studies (57.1%), the Mobile Apps, used in 2 out of 14 studies (14.3%), and the Kinect System (1/14, 7.1%). Thus, the majority of the interventions (10/14, 71.4%) used no-wearable technology including computer and Mobile Apps, and only 4 (28.6%) of them used wearable devices including HMD and sensors.

The studies where Mobile Apps were applied (Sauvé et al., 2022b;Halton et al., 2018), and those that used VR- the Head Mounted Display (HMD) (Everson et al., 2015; McCalla et al., 2023) all showed significant improvements of empathy after training. Palanica and colleagues (2018) used the wearable armband SymPulse™, a device to deliver electrical stimulation aimed at mimicking the Parkinson's tremors experienced by the patients and showed promising results in promoting emotional empathy in the

experimental group compared to control. Similarly, Tong and colleagues (Tong et al., 2017b) showed no significant improvements in the level of empathy but a significant improvement in willingness to help using a body motion sensor to simulate the experience of a chronic pain condition. However, none of the studies analyzed the individual components of empathy, such as emotional and cognitive empathy. Instead, the authors reported the results for the overall construct.

Considering the *point of view of the digital experience*, most of the studies (10 out of 14, 71.4%) employed a first-person view, where the user is the protagonist of the scenario, and 4 studies (28.6%) used a third-person view, where the user observe a virtual scenario. Regardless of the point of view, 5 of the included studies were implemented from the doctor's perspective, 3 included both the perspective of the doctor and the patient, and 7 (50%) of the studies were implemented from the patient's perspective. The majority of investigations documented some significant improvements in empathy levels from pre- to post-intervention except for one study using the third-person perspective (Tong et al., 2017b), which employed the use of a no-wearable device from the patient's perspective, and two first-person studies (Hess et al., 2022b; Yao et al., 2022), which employed both no-wearable technologies from the patient or doctor perspectives.

Finally, the digital technologies applied in the 14 included articles of this review differed in terms of *interactivity*. Most of the empathy training included the possibility of interacting with the digital environment (8/14, 57.2%). Five of them were text-based answers or questions to an avatar (35.7%), and 2 were based on Mobile App interactions (14.3%), or interaction with the avatar (1/8, 7.2%). Conversely, 6 studies applied a no-interactive digital training: 5 of them (42.8%) were based on the passive view of 360-degree video regarding the patient's condition or web educational material. 1 study showed a different approach from all the other interventions, by using a device able to record the muscle activity of a patient with Parkinson's disease to give the experience to live with muscles impairments and tremors.

Of the 3 studies that showed no significant changes on empathy scores, two were interactable (Tong et al., 2017b; Yao et al., 2022) and one was not (Hess et al., 2022b).

3.5 Targeted population (RQ5)

The screened articles included a population mainly composed of medical students (780/1146, 68.1%), and HCWs. (366/1146 31.9%). Considering the category of the HCWs, nurses were the less

represented group with only 34 (2.9%) participants included in the studies. All of the studies that did not show a significant improvement in empathy levels (Hess et al., 2022b; Tong et al., 2017b; Yao et al., 2022)included only physicians or healthcare professionals.

3.6 Risk of bias assessment

The mean quality score for 14 articles was 61% ranging from 46% (Olsen & Oertel, 2020) to 100% (A. Foster et al., 2016b). The main reasons for lower scores were the lack of blinding of investigators or participants (71.4%), and the lack of a control group (57%). The higher scores included appropriate study design to respond to research questions and described and presented appropriate analysis. The detailed quality assessment of each study is provided in **Table 2**.

Table 2: Summary of the included studies

Study	Anishchuk et	Olsen et al.,	Foster et al.,	Halton et al.,	Hess et al.,
Sample	37(F=28) Dental nurse (N=3) Dental	42(F=37) Nursing student	70 (F=33) Medical student	104(F=66) Employees of pharmaceutical	35 (F=33) Home health professional
Study design	Single group pre-post training assessment.	Within pre-post design VP condition Role Play condition	RCTCG= Control $VPEG_2$= Backstory $VPEG_1$=	Mixed methods pre-post design	Single group pre-post training assessment.
Empathy Measures	Jefferson Scale of Empathy	Reflect on empathy displayed on 1-5 likert	Empathetic Communication Coding System	Toronto Empathy Questionnaire	Interpersonal Reactivity Index
Type of Technology	Computer (video presentation + online lessons)	Computer-based virtual patients	Computer-based virtual patients	Mobile APP	Web symposium (computer)
Outcomes	Significant increase between pre-post training (t (36) = 3.6 p = 0.001) and effect size d = 0.59	Significant increase between pre-post, t(157) = 5.15, p <.001. Significant impact of the condition,	Only the difference between the empathy-feedback VP [mean (SD), 2.91 (0.16)] and the backstory VP	Significant increase between pre-post training (t (73) = 3.1, p = 0.002) and effect size d = 0.45	No significant changes in empathy
Quality	0.82	0.46	1.00	0.55	0.55
Training duration	3 weeks	1 session per condition	1 session per group + 1 SP interaction	36h constructed narratives	3 10-12 minutes session of VR
Perspective	Third person/Non	First person/Non wear/Dr.	First person/Non wear/Dr.	First person/non wear/Pz.	First person/Non wear/Pz.
Interactivity	No	Yes	Yes	Yes	No

Tong et al.,	Yao et al.,	Sauve et al.,	Quail et al.,	Palanica et	McCalla et	Manuel et al.,
15(F=4) Healthcare job related (N=2)	25 (G1) and 27 (G2) (F=25) healthcare professionals.	29 (F=NA) physician students-	62 (F=62) undergraduate speech pathology students.	27 (F=10) helathcare professionals (EG=13; GC=14).	69(F=57). Psychology and Education (n = 17),	72(F=68) Physician(N=57) Nurse(N=31)
Mixed method pre-post training assesment	Two non-randomized conditions: Post-interview Feedback Condition (G1), Scaffolded Ping-pong	Single group pre-post training assessment.	RCT: Nursing Home (G1), Standardized Patient (G2), Virtual Learning (G3).	RCT: EG= perform motor function tasks (e.g., buttoning a shirt and printing out one's name) with	Single group pre-post training assessment.	RCT EG= Virtual Reality, CG= asynchronous web-based platform.
Revised Compassion for Others Scale and willingness of help (1 item) (Pommier,	Empathic Communication and Coding System.	Ethnocultural Empathy Scale.	Jefferson Scale of Empathy Health Care Provider Students Version.	Jefferson Scale of Empathy Health Care Provider Students Version (only	Jefferson Scale of Empathy Health Care Provider Students Version.	Motivational Interviewing Treatment Integrity behavioural coding system.
Body motion sensors	Computer based Virtual Patients	Mobile App: Stand Up for Indigenous Health (SU4IH).	Computer based Virtual Patients	SymPulse™ is an arm band that simulate the involuntary	Virtual Reality (Pico G2 4K head-mounted displays).	Computer-based and web-based training
No significant difference in level of empathy. Significant difference in willingness to help t (13) = 2.132, p	No significant difference between groups for high-empathy level responses (p=.58), medium (p>0.05), and	Significant difference on empathy score between pre and post test (p < .001).	Significant difference between the pre and post-test only for the Nursing Home (CG) condition (p <	Trait empathy = no significant difference between condition (p > 0.90). State empathy =	Significant difference from before to after the empathy training (p = <.001).	Significant difference from before to after the empathy training for the EG (p = .04) compared to the CG
0.55	.67	.57	.78	.75	.61	.78
1 session	3 weeks (2nd week in unactive)	1 session	5 weeks, 1-hour por week	1 session	1 session	90-minute training sessions 2
Third person/Non wear/Pz.	First person/non wear/Dr.	First person/Non wear/Pz.	First person/Non wear/Dr.	First-person/wear/Pz.	Third person/wear/Pz.	Third person/Non wear/Pz. &
Yes	Yes	Yes	Yes	No	No	No

Everson et	Gilbert et al.,
460(F=405) Nursing student	72(F=48) Medical student
Single group pre-post training assessment.	One group longitudinal design
Modified version of the Kiersma Chen Empathy Scale (Kiersma et al., 2013).	Empathic Communication Coding System
Head mounted System	Computer-based virtual patients
On average, participants reported significantly higher mean scores on the MKCES post-simulation	There was a statistical difference in ECCS scores based on empathic opportunity ($\chi 2$ [3] = 7.66, P < 0.05)
0.77	0.65
1 session	4 VP interviews during 12
First-person/wear/Pz.	First person/Non wear/Dr.
No	Yes

4. Discussion

For a successful clinical relationship, empathy expressed by medical students and HCWs in advanced career, plays a key role in cognitively and affectively enhance the understanding of patients' emotions (Moudatsou et al., 2020). However, the increasing rates of burnout, excessive workload and emotional distress among HCWs are seriously compromising the capacity to build a positive and collaborative physician-patient relationship (Elayyan et al., 2018). For this reason, several training programs were added to medicine educational curricula supported by digital technologies (Gilbert et al., 2023; Halton & Cartwright, 2018; Sauvé et al., 2022b). However, to the best of our knowledge, no conclusive data are available for explaining if these digital technologies could be effective in training and fostering empathy and, if yes, which types of technologies were more effective and what targeted population would benefit the most from them (medical students or HCWs in advanced careers). The present review aimed at filling this gap and investigating if digital technologies could be the potential medium to foster empathy in healthcare professionals, both students and HCWs.

In regards to RQ1 and RQ2, the first important observation that emerged from the review is that there is not a clear consensus about the definition of empathy construct. As we can see from **Table 1**, the authors used several empathy definitions including clinical empathy, cognitive and affective empathy, and cultural empathy. However, several studies did not define the construct, but focused primarily on the technological aspect of the research, without a clear theoretical background. To effectively develop empathy training, future research should adopt a theory-driven approach, should clearly define the specific aspects of empathy to be targeted, should outline the methods to address them, and justify the reasons for these choices. This lack of consensus is also reflected in the different empathy measures adopted by the authors of the included studies to assess the change from baseline to after the empathy training. In fact, out of the 14 included articles, 9 different empathy questionnaires were assessed. The lack of a clear definition of the construct in these studies, coupled with a predominant focus on the technological aspects of the research, likely contributes to the heterogeneity of the results presented in the present review.

In regard to RQ3 and RQ4, two types of digital technologies used in the included studies emerged: wearable and no-wearable ones. The former are the VR-HMD and the armband SymPulse™ . The latter are

the Mobiles Apps, the computer-based training and the motion sensor Kinect. Those technologies differed also in terms of interactivity and perspectives (doctors' point of view vs patients' point of view). Therefore, they could provide participants with different types of experience in terms of presence and immersion in the clinical scenario, that could influence the effectiveness of the empathy training and the final outcomes of the studies. All the digital technologies adopted in the included studies effectively promoted some dimensions of empathy among the target population except for 3 studies. Two of the studies that did not show significant improvement were computer-based training (no-wearable, less immersive) that used Virtual Patients (Hess et al., 2022b; Yao et al., 2022) and one of them used body motion sensors (Tong et al., 2017b).

All the Mobile App studies and those that included HMD showed efficacy in improving empathy compared to baseline. The interactive and immersive nature of these technologies tends to engage users more deeply, fostering a stronger empathetic response (Barbot & Kaufman, 2020) compared to traditional teaching. For example, in the study of Halton and colleagues (Halton & Cartwright, 2018) the participant takes the perspective of the patient with inflammatory bowel disease and is prompted to face some of the challenges that are typical of this disease to experience barrier and limitation that the illness poses on the patients. Also, the VR-HMD permits to experience a high sense of presence with the content and a high sense of embodiment (Kilteni et al., 2012) with the virtual patients or HCWs. For example, in the study of McCalla and colleagues (McCalla et al., 2023) a participant is invited to take the third-person perspective of an older woman with type 2 diabetes and results indicate a high degree of identification with the avatar.

One interesting result comes from the wearable armband SymPulse™ used by Palanica and colleagues (Palanica et al., 2018) which showed promising results in promoting empathy. This study used a device to deliver electrical stimulation aimed at mimicking the Parkinson's tremors experienced by the patients.

Regarding RQ5, all training programs that failed to significantly improve empathy involved experienced HCWs, regardless of the differences in interactivity and engagement among digital devices. This lack of efficacy could be due to the fact that HCWs in advanced careers need different kinds of training compared to medical students, and that the empathy skills may change over time during the medical career (Hojat et al., 2018; Neumann et al., 2011; Schrötter et al., 2024). Alternatively, medical students are often

younger and, as digital natives, they could have more familiarity and acceptability of the digital training as compared to older HCWs who could be more skeptical about these innovations in medical training (Machleid et al., 2020).

In conclusion, the findings of this review seem to suggest that there is no "one size fits all" solution in the context of empathy training. Different technologies offer different experiences of presence and immersion, which can influence the training outcomes. Therefore, future training programs should carefully consider the choice of technology and aim for a tailored approach to meet the diverse needs of healthcare professionals. For example, Ma and colleagues (Ma et al., 2021) demonstrated that playing a game about a child diagnosed with cancer in VR resulted in a greater sense of spatial presence and increased empathy compared to non-VR on a nursing students' population. Additionally, taking the perspective of the virtual healthcare provider, compared to the patient's family perspective, elicited higher levels of empathy in VR compared to 2D computer (Ma et al., 2021). These pilot investigations seem to suggest that the stronger immersion generated by the VR technologies may lead to a greater change in empathy scores, and the point of view adopted by these technologies may act as a moderator.

Foster and colleagues (2016) reported greater empathy levels only when virtual patients provided feedback on participants' empathic responses. Thus, a greater emphasis should be placed on enhancing empathic communication skills through these trainings, whether using virtual patients or other methods, to ensure a comprehensive development of both cognitive and affective empathy in healthcare providers. Nonetheless, most of the studies that employed virtual patients did not provide any kind of feedback on the response offered by the participant.

5. Conclusion

This review aimed to address the effectiveness of digital technologies in fostering empathy among healthcare professionals. A key observation is the lack of consensus on the definition of empathy, leading to varied interpretations and inconsistent results in empathy training programs. Establishing a common understanding of empathy's dimensions and adopting a theory-driven training approach are essential to advancing this field of research.

The review identified two types of digital technologies: wearable (e.g., VR-HMD and SymPulse™ armband) and non-wearable (e.g., mobile apps and motion sensors), all effective in improving empathy. However, effectiveness varied between medical students and experienced HCWs, suggesting the need for different training approaches for different target populations.

Overall, the findings indicate that there is no universal solution for empathy training, and future programs should carefully select technology and tailor approaches to meet the diverse needs of healthcare professionals.

6. Limitations and future directions

The review presents some limitations. First, the great heterogeneity in the assessment of empathy made the comparisons among the different interventions difficult at this stage of the research. It is important for future research to unify the use of a standard questionnaire to measure the core characteristics of empathy in the healthcare context. Finally, another limitation is that none of the included studies examined the mechanisms underlying the effectiveness of the empathy training through careful experimental manipulation.

Future studies should increase the sample size, by including a variety of HCWs, with different professional seniority and should adopt a randomized controlled design. Furthermore, future studies should include measurements that help to understand empathy not only in terms of psychometrics, but also in terms of actual behavioral change. For example, instead of solely relying on self-reported empathy scales, researchers could observe and evaluate changes in participants' real-world behaviors (e.g increased in prosocial actions).

Data Availability

Data sharing does not apply to this paper as no new data were created or analyzed in this study.

Compliance with Ethical Standards

Disclosure of Potential Conflicts of Interest

The authors declare that they have no conflict of interest. No financial or non-financial support was received from any organization for the submitted work.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors. As a systematic review, this work synthesizes data from previously published studies, all of which had received ethical approval at the time of their original publication. Therefore, no additional ethical approval was required for this study.

Informed Consent

This study do not involve any direct interaction with human participants, informed consent was not required. All studies included in the review had obtained informed consent from their participants as per the ethical standards at the time of the original research.

Funding Declaration

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Chapter 2: The Use of Virtual Reality Interventions to Promote Positive Mental Health

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Abstract

Background: A large body of research has documented the efficacy of psychological interventions integrated with virtual reality (VR) therapies in treating psychiatric disorders. However, the concept of positive mental health calls for a 2-fold approach in which both symptoms and positive functioning should be addressed by modern interventions.

Objective: This review aimed to summarize studies that applied VR therapies by embracing the positive mental health perspective.

Methods: A literature search was conducted by entering the following keywords—"virtual reality" AND "intervention" OR "treatment" OR "therapy" AND "mental health" NOT "systematic review or meta-analysis"—and limiting it to "journal article" and the English language. To be included in this review, articles had to present at least one quantitative measure of positive functioning and one quantitative measure of symptoms or distress and had to investigate adult populations, including populations with psychiatric disorders.

Results: A total of 20 articles were included. They described various VR protocols that were applied for the treatment of anxiety disorders (5/20, 25%), depression (2/20, 10%), posttraumatic stress disorder (3/20, 15%), psychosis (3/20, 15%), and stress (7/20, 35%). Most of the studies (13/20, 65%) showed the beneficial effects of VR therapies in improving stress and negative symptoms. However, 35% (7/20) of the studies showed no or a small effect on the various dimensions of positivity, particularly in clinical samples.

Conclusions: VR interventions might be cost-effective and largely scalable, but further research is needed to develop existing VR software and treatments according to the modern positive mental health approach.

1. Introduction

1.1 Background

The implementation of virtual reality (VR) programs in psychotherapy has been increasing over the past 3 decades (Baghaei et al., 2021; A. H. Schroeder et al., 2022; van Loenen et al., 2022), especially after the past COVID-19 pandemic (Table 1). Since the early 1990s, VR has been used to treat disorders such as

specific phobias, panic disorder, and posttraumatic stress inside a head-mounted display (HMD) or inside a room where the images were projected on the walls (cave automatic virtual environment) (Lindner, 2020). Today, many protocols are available for the treatment of different psychopathologies, from VR exposure therapy (VRET) to protocols dedicated to eating disorders, depression, obsessive-compulsive disorder (OCD), and psychosis.

Table 1: Cumulative record of publications

Year	Cumulative record of publications, n
2012	7
2013	9
2014	11
2015	6
2016	4
2017	10
2018	17
2019	28
2020	52
2021	63
2022	31

However, the current definition of mental health, which emerged from the positive psychology perspective, entails 2 related components: symptoms or psychopathology and well-being and positive functioning (Keyes, 2002; Ruini, 2017). According to this model, psychopathology and well-being coexist along a continuum where the states of mental illness and languishing are the negative components in contrast to the state of flourishing, which is the positive component. Languishing is defined as a state of emptiness in which the individual experiences few instances of well-being and is considered vulnerable to the development of psychiatric disorders. Flourishing, in contrast, is also labeled as optimal human functioning and is characterized by the presence of high levels of emotional, psychological, and social well-being. The treatment of symptoms and distress has been the main focus of the mental health agenda over the past decades. However, according to this complete mental health model, the promotion of well-being and optimal human functioning should receive the same attention. According to the positive psychology perspective, positive psychological interventions can be conceived as "treatment methods" or intentional activities that aim to cultivate positive feelings, behaviors, or cognitions (Sin & Lyubomirsky, 2009). Longitudinal investigations have shown that cross-time gains in well-being predicted cross-time declines in mental illnesses and vice versa (Keyes et al., 2010). Various authors have observed that positive and negative characteristics can be considered at opposite ends of a single dimension and that their valence can vary according to the specific context (Kashdan & Rottenberg, 2010; Ruini, 2017; Wood & Tarrier, 2010). For example, anger can become adaptive when it helps individuals reach their goals or fight for their ideas, depression can exist in the continuum with happiness, and it may become adaptive in encouraging people to change suboptimal aspects of their lives. Similarly, anxiety and calmness exist on the same continuum and are often assessed using similar items but with opposite coding procedures. As a consequence, mental health involves a complex balance of positive and negative psychological characteristics, and modern interventions should be able to address both components. Wood and Tarrier (2010) proposed a positive clinical psychology framework in which clinical interventions may help individuals move away from symptoms and implicitly have an equal and opposite effect on well-being. Thus, the authors call for an integration between positive and

clinical psychology in which psychological interventions should treat distress as well as they should promote well-being. According to Keyes (2002), the promotion of well-being in the long run can be considered the most cost-effective mental health policy as it allows for the maintenance of optimal functioning in the population and prevents the onset of psychiatric disorders and the economic burden of expensive treatments.

Digital technologies can be considered valid tools to pursue this goal. Recently, with the advent of the pandemic, digital technologies have been used to deliver web-based psychotherapeutic interventions for addressing the psychological effects of COVID-19 or promoting positive functioning and well-being (Asiain et al., 2022; Cieślik et al., 2020). The latter applications can be subsumed under the umbrella of "Positive Technology" research (Riva, 2012).

As stated by Riva (2012), "Positive Technology consists in the scientific and applied approach to the use of technology for improving the quality of our personal experience." The core theoretical framework of this approach comes from the field of positive psychology and aims to use technology to manipulate the quality of experience, increase well-being, and generate strengths and resilience at the level of individuals, organizations, and society. Therefore, owing to "Positive Technology," it is possible to study and understand how digital technologies can be used to promote health and well-being (Gorini et al., 2010). VR, owing to its ability to create controlled and tailored experiences that enhance the user's sense of presence (Gorini et al., 2010; Riva, 2005, 2012), has proven to be an important tool for increasing well-being. In particular, VR can affect 3 characteristics of personal experience that can promote personal well-being. VR can induce positive and pleasurable experiences; foster engagement and self-realization; and support and enhance connection and interpersonal relationships among individuals, groups, and organizations (Botella et al., 2012b). Studies conducted thus far have demonstrated the effectiveness of VR in several areas of application (Kim et al., 2020). However, a limited body of research has used the complete mental health approach and tested whether modern, digitalized interventions were able to address symptoms and distress and promote well-being. A notable exception is a review published recently in this journal (Babbage et al., 2022) that focused on the promotion of well-being through digital technologies. It found that self-help interventions improved well-being in young people aged 9 to 25 years. However, the review targeted the young population only. This population has very specific psychological features that change according to the stage of development of the

participants. The results of this review cannot be generalized to the rest of the population. Similarly, other research groups have developed digital interventions for older adults and documented encouraging results for the promotion of positive mental health in the aging population (Botella et al., 2009; Lluesma-Vidal et al., 2022; Thangavel et al., 2022).

1.2 Objectives

This systematic review aimed to fill this literature gap by summarizing the most recent (last 10 years) research in the field. To the authors' knowledge, the current literature lacks a systematic review of studies that provide a global assessment of the benefits of VR in treating symptoms and promoting well-being in adult populations. Therefore, the primary goal of this work was to collect and summarize scientific literature on the application of VR therapies according to the positive mental health framework, which includes not only data regarding the efficacy of VR treatments in improving symptoms but also data on the impact of these technologically advanced interventions in promoting positive functioning. In doing so, we hope to provide the reader with a broader understanding of the impact of these emerging digital therapies on the global mental health of adult individuals.

Considering the large number of private and public investments in digital technologies for mental health, this review may provide important initial data on their worthiness for promoting complete mental health in the adult population through the use of VR.

2. Methods

2.1 Design

A systematic review was conducted to extract recently published scientific papers that dealt with measures of positive functioning and symptoms and distress in adult populations. We focused on the last 10 years (from 2012 onward) as during that period, the Positive Technology research agenda was scientifically recognized and, since then, many VR protocols have been developed. This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009).

2.2 Search Method

A systematic literature search was conducted on the following electronic databases: EBSCOhost (PsycArticles and PsycInfo), PubMed, and Scopus.

The literature search was conducted by entering the following keywords: “virtual reality” AND “intervention” OR “treatment” OR “therapy” AND “mental health” NOT “systematic review or meta-analysis.”

2.3 Selection Criteria

Inclusion:

To be included in this review, the studies should involve (1) measures of positive functioning, (2) measures of symptoms and psychological distress, (3) adult populations, and (4) a description of a psychological intervention delivered using the VR system.

Exclusion:

Studies were excluded if they (1) did not provide an assessment of positive functioning; (2) did not provide an assessment of symptoms; (3) were not experimental studies (e.g, systematic reviews, protocols, or book chapters); (4) included only older adult or child populations; and (5) included adult populations with eating disorders, gambling, or substance use disorders. The latter clinical conditions were excluded as the source of positive emotions and well-being could be directly related to the exposure in the virtual environment to the objects of their addiction and could be a manifestation of the disorder itself (Hall-Simmonds & McGrath, 2019; Johnson & Wood, 2015; Ruini, 2017). Thus, individuals diagnosed with these clinical conditions may have a more complex balance between symptoms and positive functioning (Brandel et al., 2017; Hall-Simmonds & McGrath, 2019; Lamers et al., 2015) and may require complex treatments with medications or further treatment ingredients (Bohart, 2002; Johnson & Wood, 2015; Ruini, 2017; Weiss et al., 2016).

2.4 Data Collection

The titles and abstracts of the articles assessed for potential inclusion were identified and independently inspected by 1 reviewer, who excluded duplicates and articles that did not meet the inclusion

criteria. All potentially relevant articles were then fully assessed by other 2 reviewers, who decided on inclusion. Uncertainty was resolved by coming to a consensus. Data were extracted using a predesigned template with the following specified headings: study, sample size, outcome measures, treatment conditions, follow-up, main findings, and limitations.

2.5 Risk of Bias and Quality of the Articles

To assess the bias of the individual studies, the following tools were used to sample a selection of quantitative studies: the Cochrane risk-of-bias tool (Higgins et al., 2011) for between-group studies and the Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields (Kmet et al., 2004) for single-arm or within-subject studies. The risk of bias was calculated by one of the authors for all the included articles.

3. Results

3.1 Search Outcome

The first screening identified 682 articles. Most of them (626/682, 91.8%) were extracted from the EBSCOhost and Scopus databases. Only a few articles (56/682, 8.2%) were extracted from PubMed. After removing duplicates, 676 publications were identified and individually assessed based on the study title and the information provided in the abstract (see the review flowchart in Figure 1). Of these 676 papers, 501 (74.1%) were excluded according to the aforementioned inclusion and exclusion criteria, whereas the full texts of 174 (25.7%) articles were examined before the decision was made on whether to include them. Of these 174 studies, 76 (43.7%) did not assess well-being in combination with psychopathology or symptoms, 51 (29.3%) were not empirical studies, 26 (14.9%) did not include our target adult population, and it was not possible to obtain the full text of 1 (0.6%) paper; therefore, they were excluded. A total of 20 papers met all the inclusion criteria and were included in this review.

Appendix 1 presents a summary of the findings from the 20 studies included in the review. Of these 20 studies, only 8 (40%) were randomized controlled studies, of which 3 (38%) used a waiting list as a control condition; 6 (30%) were pilot studies; 4 (20%) were case series or single-arm conditions; 1 (5%) had a within-subject design; and 1 (5%) had a between-subject design with 3 intervention groups. Hence, the

quality of the included papers was low considering the high percentage of pilot and non–randomized controlled trial (RCT) studies.

The risk of bias was found to be low for both between-group and single-arm or within-subject studies. A total of 20% (2/10) (Matsumoto et al., 2021, Malbos et al., 2020) of the studies assessed using the Cochrane risk-of-bias tool showed some concern relative to the overall risk of bias, and 10% (1/10) of the studies (Jones et al., 2021) assessed using the Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields showed some concern related to the quality of the study (see Table 2 and Figure 2 for a summary).

A total of 900 participants received an intervention integrated with the use of VR technologies. The main outcome measures used to evaluate the effects of the VR therapies on symptoms were questionnaires and interviews considered the gold standard in the evaluation of those specific psychopathologies (i.e., the Beck Depression Inventory for depression or the State-Trait Anxiety Inventory for anxiety). Some investigations also used general indicators of distress such as the Depression, Anxiety, and Stress Scale or the Patient Health Questionnaire (Appendix 1). Conversely, when considering positive functioning, the authors referred to different domains of positivity, including positive emotions, self-compassion, social functioning, and relaxation (see Table 3 for a summary). The Positive and Negative Affect Schedule (PANAS) and measures of quality of life were the most commonly used indicators.

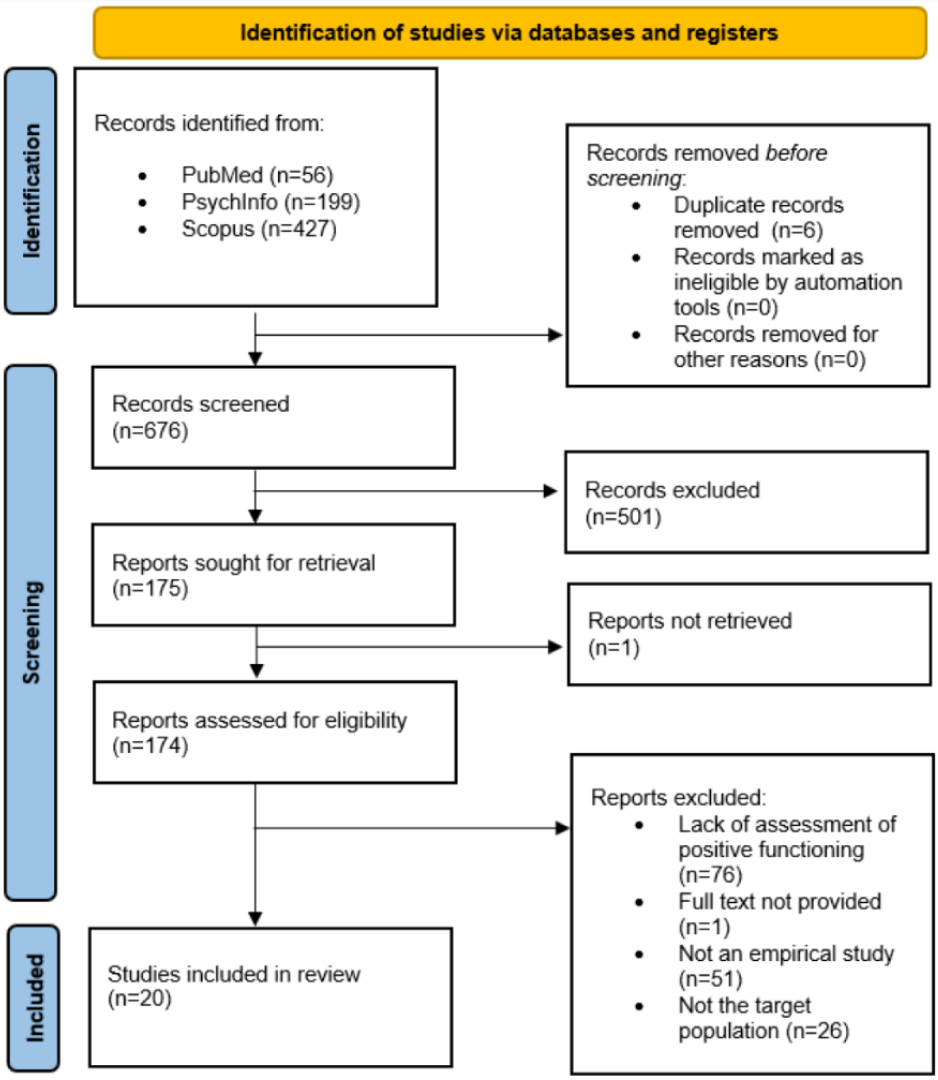

Figure 1: Flowchart depicting the identification and selection of the articles.

Study	Quality Assessment
Lindner et al., 2020	0,95
Geraets et al., 2019	0,86
Jones at al., 2020	0,5[a]
Tang et al., 2021	0,77
Falconer et al. 2016	0,95
Habak et al. 2020	0,86
Thompson et al. 2020	0,95
Chan et al. 2021	1
Desai et al. (2021)	0,9
Riva et al. (2021)	1

Table 2: Quality assessment carried out using the Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields.

Figure 2 Risk of bias carried out using the Cochrane Risk of Bias Tool

Table 3: Summary of scales for positive functioning used in the included studies.

Study	Assessment of positive functioning
Specific Phobia	
Mar Rus-Calafell et al. (2013)	**LIS**
Linder et al. (2020)	**BBQ**
SAD	
Kampmann et al. (2016)	**EQ-5D**
Geraets et al. (2019)	**MSAQ**
GAD	
Malbos et al. (2020)	**SF-12**
PTSD	
Jones at al. (2020)	**DERS**
Tang et al. (2021)	**DERS and qualitative analysis**
Vlake et al. (2022)	**SF-36, HQ-5D, HRQoL**
Depression	
Caroline J. Falconer et al. (2018)	**QLS-SF**
Habak et al. (2021)	**SWEMWBS**
Psychosis and Schizophrenia	
Du Sert et al. (2018)	**QLS-SF**
Pot-Kolder et al. (2018)	**MSAQ**
Thompson et al. (2020)	**EQ-5D**
Stress and adjustment disorder	
Chan et al. (2021)	**PANAS**
Desai et al. (2021)	**PSQI, QUALITATIVE THEMATIC ANALYSIS**
Riva et al. (2021)	**SCS, SRSI3**
Gaggioli et al. (2014)	**SWLS**
Cebolla et al. (2019)	**PANAS, SMS, SOFIS, MSCS**
Matsumoto et al. (2021)	**PSYCHOLOGICAL CHECK TEST**
Richesin et al. (2021)	**PANAS**

In the following sections, we briefly illustrate the various studies included in this review, each organized under the clinical conditions for which the VR interventions were applied.

3.2 Specific Phobias and Anxiety Disorders

A total of 25% (5/20) of the studies, with 142 participants, were included in this category, ranging from the treatment of specific phobias to generalized anxiety disorders and social anxiety.

Regarding the treatment of specific phobias, Lindner et al (Lindner et al., 2020) studied the effectiveness of VRET in the treatment of arachnophobia. A total of 25 participants (19 female) underwent automated VRET composed of 8 sequential levels with increasingly realistic and frightening spiders. The results showed a significant effect of treatment on phobia symptoms (P<.001; Cohen d=1.26) and a small effect on positive functioning (P<.001; Cohen d=0.49). The results were maintained at the 6-month follow-up. These results suggest that automated VRET applications could be promising automated treatments for this disorder, with a positive effect also on patients' well-being.

The efficacy of VRET was further supported by Rus-Calafell et al. (2013), who compared VRET with a classic mental imagery exposure therapy to treat fear of flying. In this case, 15 patients (13 female and 2 male) were randomly assigned to 1 of 2 groups and received either VRET (mean age 37.14, SD 14.28 years; sex, 6/7, 86% female) or mental imagery therapy (mean age 36.13, SD 12.59 years). VRET comprised 3 different scenarios (room, airport, and plane). Participants completed 6 individual treatment sessions of 60 to 75 minutes over a period of 3 weeks and were asked to buy a plane ticket to use during the 15 days following the end of treatment. The results indicated that both groups improved similarly in posttreatment and follow-up assessments. Analysis of the scores obtained immediately after the real flight and 6 months after treatment revealed that the VR group continued to improve on some of the measures (Fear of Flight Questionnaire), whereas the mental imagery group did not; moreover, participants in the VR group experienced less anxiety during the real flight. Regarding positive functioning, the participants in the VR group and the therapists agreed that the degree of severity and interference in the patient's daily life had decreased, whereas in the mental imagery group, patients reported a significant improvement just in the severity of symptoms and not in interference. In summary, both mental imagery exposure therapy and VRET were effective in treating fear of flying. However, VRET was shown to perform better in the maintenance of outcomes and perceived interference of fear in the participants' lives.

A total of 10% (2/20) of the studies included in this review assessed the potential benefits of VRET in the treatment of social anxiety disorder (SAD). In total, 50% (1/2) of these studies adopted a 3-arm randomized controlled approach with 3 different groups. Kampmann et al. (2016) randomly assigned patients diagnosed with an SAD to individual VRET (n=20), individual in vivo exposure therapy (iVET; n=20), or a waiting list (n=20). The treatments proposed by Kampmann et al. (2016) comprised ten 90-minute sessions twice a week, and the virtual situations provided for the VRET group covered one-to-one and group scenarios designed to provoke anxiety in individuals with SAD. The results of the study showed an improvement from the pre- to post assessment time points for both VRET and iVET but with a greater decrease in symptoms for iVET than for VRET. This trend was also confirmed after the 3-month follow-up. iVET but not VRET improved the positive functioning of the participants as measured using the EUROHIS Quality of Life Scale; however, this difference was not significant after the 3-month follow-up.

The second study (Geraets et al., 2019) assessed the feasibility and potential effect of VR-based cognitive behavioral therapy (VR-CBT) in patients with SAD without a control group. The authors recruited 15 patients with SAD, who underwent up to 16 VR-CBT sessions. Questionnaires regarding clinical and functional outcomes, as well as diary assessments of social activity, social anxiety, and paranoia, were completed at baseline, posttreatment assessment, and the 6-month follow-up. The treatment comprised a 40-minute VR session, and patients were able to explore different virtual scenarios that the therapist could manipulate in terms of crowdedness, ethnicity, intensity, frequency of hostile looks, interpersonal distances, and watching or staring behavior. The VR exercise allowed the patients to test their beliefs and approach or avoidance behaviors while the therapist provided feedback on cognitions and behaviors. The results showed a general improvement in all the outcome measures—social interaction anxiety was significantly reduced at posttreatment compared with baseline assessment (P=.008; Cohen d=0.9), depression was significantly reduced at posttreatment assessment (P=.01; Cohen d=1.1), and positive functioning (measured using the Manchester Short Assessment of Quality of Life) increased between baseline and posttreatment assessment (P=.02; Cohen d=0.5). This improvement was maintained at follow-up.

Malbos et al (2020) assessed the efficacy of VR combined with relaxation in patients with generalized anxiety disorder by comparing VR relaxation therapy with a standard mental imagery exposure therapy. A total of 27 participants (13 female) were randomly assigned to VR relaxation therapy or mental imagery. The therapy was delivered in 6 weekly sessions of 30 minutes—the first 3 sessions were used to teach relaxation techniques that the participants were free to choose and repeat in the remaining 3 sessions. At the beginning of each session, VR relaxation therapy participants could select 6 different relaxing virtual situations to exercise the relaxation techniques. The results showed significant improvements in anxiety, worry mood, and positive functioning in both groups, although the 2 groups were not statistically different.

In summary, VRET has proven to be effective, useful, and user-friendly for patients with phobias and anxiety disorders in reducing the related symptomatology. However, further research is needed to draw inferences about the effectiveness of this advanced technology in improving positive functioning as the data regarding this domain are still weak, with 20% (1/5) of the studies included in this category not showing any improvement or additional advantage in promoting well-being for VRET compared with standard in vivo therapies.

3.3 PTSD Symptoms

A total of 15% (3/20) of the studies examined the effect of a VR program on posttraumatic stress symptoms, as well as indicators of positive functioning. The first 67% (2/3) of these articles described a single research trial, not published yet. The third article (1/3, 33%) described an intervention aimed at preventing the long-term posttraumatic psychological consequences of being hospitalized in the intensive care unit (ICU).

Jones et al. (2021) presented the initial data of a new computer-assisted rehabilitation virtual environment developed to treat combat-related PTSD symptoms in the first 11 patients recruited for this RCT study. The multimodal motion-assisted memory desensitization and reconsolidation (3MDR) therapy consists of six 90-minute sessions where participants initially walk on a treadmill (placed inside a virtual room) while listening to self-selected music reminiscent of their military deployment. Then, 1 to 7 images are projected, and the participant has to describe the traumatic scenario as well as the associated physical sensations, emotional words, and thoughts. A ball displaying a series of numbers (which the participants read out loud)

briefly appears, moving back and forth horizontally across the screen. This cycle is repeated for all 7 images. Jones et al. (2020) demonstrated that 3MDR significantly improved PTSD symptoms and emotion regulation strategies (assessed using the Difficulties in Emotion Regulation Scale).

A further pilot study with the same VR intervention was published (Tang et al., 2021), with a specific focus on the issue of emotion regulation. In this study, 9 participants were interviewed, and the qualitative analyses of these interviews were correlated with their scores on the Difficulties in Emotion Regulation Scale. After the intervention, participants reported better emotion regulation, with an increased ability to recognize, accept, and cope with emotions (positive and negative).

The third study, conducted by Vlake et al. (2022), explored the effects of an ICU-specific VR (ICU-VR) program on the psychological distress and quality of life of 89 patients hospitalized in the ICU because of COVID-19 infection. After hospital discharge, they were assigned to the ICU-VR intervention to prevent the onset of possible posttraumatic symptoms. The intervention consisted of watching a 14-minute–long informational video in VR, where the person was welcomed into the ICU and every machine and procedure was described in detail. The results of this investigation showed that ICU-VR improved patients' perceived quality of, satisfaction with, and rating of ICU aftercare and decreased psychological distress up to 6 months after hospital discharge. However, the intervention did not significantly improve psychological recovery or quality of life.

3.4 Depression

In total, 10% (2/20) of studies addressing depression were included in this review. They involved 94 patients and applied 2 different VR interventions.

In the first study, Falconer et al. (2016) addressed self-criticism in a sample of 15 individuals with depression (10 females and 5 males; mean age 32 years) by promoting self-compassion. The authors developed an immersive VR scenario (a virtual room) in which participants could interact compassionately with a crying virtual child while in a virtual adult body. In the second phase of the protocol, participants were in the child's body and could experience a recording of their compassionate gestures and words being delivered to them from this first-person perspective in the body of the child. The same protocol was repeated for a total of 3 weekly sessions. Depressive symptoms, self-compassion and self-criticism were also assessed

(Appendix 1). By having participants in an adult and then a child virtual body in succession, the authors documented that the VR scenario effectively provided a self-to-self situation, enabling participants to deliver compassionate sentiments and statements to themselves. After each session, patients increased their recognition of the self in the body of the adult and the child, and they reported feeling comforted while in the body of the child. Statistical analyses revealed a significant linear decrease in depressive symptoms (measured using the Patient Health Questionnaire–9) from baseline to follow-up, with over half of the patients reporting reliable levels of improvement. The self-compassion scale demonstrated improvements at postintervention measurement, whereas self-criticism decreased significantly. Considering its brevity (3 sessions), the authors concluded that this VR scenario could be easily integrated into traditional psychotherapies to treat individuals with depression (Falconer et al., 2016a).

In the second study included (Habak et al., 2021), a new VR program—Edge of the Present—was developed and applied to promote optimism and future thinking in 79 individuals with depression (53 female, 23 male, and 3 intersex), with an average age range of 25 to 34 years. They were assessed with a pretest-posttest research design using the PANAS, Short Warwick-Edinburgh Mental Well-being Scale, and Beck Hopelessness Scale. The VR protocol included a single 10-minute session with the Edge of the Present software. It consisted of a sparsely furnished room with doors and windows that participants explored freely. Edge of the Present is designed to reward such exploration with positively experienced imagery. Hence, the door opens onto a series of spectacular immersive landscapes (7 different vistas, including alpine scenes, lush rainforest, tropical beaches, and a desert) accompanied by environmental effects such as a warm breeze, intensifying the sensory experience. The greater the engagement with the room (ie, opening and closing a door or window), the more increasingly enriched the bare room becomes by the outside landscape (ie, ferns growing inside the room). Edge of the Present provokes a sense of hopeful anticipation—each time the door is opened, there is a new landscape for the user to experience and be incorporated into their world (the room). Thus, through their virtual explorations, the user learns both that openness and curiosity lead to positively reinforcing experiences and that elements of these experiences and environments become integrated into the room they are inhabiting (ie, to enrich the internal world of the user). The primary outcome measure in this study was hopelessness as measured using the Beck Hopelessness Scale, which decreased significantly from pre- to postintervention measurement. Changes in positive and negative mood

and increases in well-being were measured using the PANAS and the Short Warwick-Edinburgh Mental Well-being Scale. These results suggest that 10 minutes within the immersive virtual environment can have a positive impact on mood and a significant increase in well-being following the participant's involvement in Edge of the Present.

These 2 investigations showed that the VR protocol developed to treat depressive symptoms can also have a beneficial effect on different areas of positive functioning, from self-compassion to positive emotions and subjective well-being, in line with the positive mental health approach.

3.5 Psychosis and Schizophrenia

In total, 15% (3/20) of the studies evaluated the benefits of VR treatment in patients with schizophrenia or other psychotic disorders. A total of 150 patients were included, and 3 different VR programs were tested.

du Sert et al. (2018) used an RCT design to test the effect of a VR intervention using an avatar to treat patients with drug-resistant schizophrenia and compared them with a treatment-as-usual condition. The intervention consisted of 7 weekly sessions; the first one was dedicated to the creation of a specific avatar for each patient that represented their most recurrent persecutor. In sessions 1 to 3, the therapist induced a dialogue between the patients and their avatars to improve emotional regulation and assertiveness. Self-esteem was emphasized in session 4, reinforced by enabling the patients to express themselves and consider their personal qualities. In the final consolidation sessions, patients were encouraged to apply what they had previously learned. Over the course of the therapy, the avatar's interaction with the patient became gradually less abusive and more supportive. The authors assessed both symptoms and positive functioning before and after the intervention and at follow-up and concluded that the beneficial effect of the VR intervention consisted in changing the way patients relate and respond to their voices by tackling emotional regulation, enhancing self-esteem, and promoting acceptance rather than directly challenging beliefs about the voices (du Sert et al., 2018).

In another RCT, Pot-Kolder et al. (2018) addressed the issues of paranoid ideation and social functioning in a sample of 116 patients with psychosis; 58 of them were randomized to receive VR-CBT treatment, and 58 were randomized to the waiting list. The VR-CBT consisted of 4 virtual social

environments (a street, bus, café, and supermarket) where various avatars were placed to interact with the patients. The therapist could vary the number of human avatars (0-40), the characteristics of the avatars (including sex and ethnicity), and the avatars' responses to the patient (neutral or hostile and eye contact) to match the paranoid fears of the patient. Patients and therapists communicated during VR sessions to explore and challenge suspicious thoughts during social situations, drop safety behaviors during social situations, and test harm expectancies. No homework exercises were given between sessions. The treatment included 16 sessions. The primary outcome of this RCT was patients' social participation, which did not change significantly after treatment. The same nonsignificant change was also observed for positive functioning, but social functioning and paranoid ideation significantly improved in the VR-CBT condition compared with the waiting list (Pot-Kolder et al., 2018).

Similarly, the third investigation addressed improving social-cognitive functioning in 19 patients in the early stages of psychosis. It was a pilot study in which a virtual world environment platform (Second Life) was used to adapt a traditionally face-to-face–delivered social cognition and interactional training. The social cognition and interactional training–VR intervention consisted of 10 sessions (2 individual and 8 group sessions with 3-5 participants). The first 3 sessions focused primarily on emotion recognition, the next 3 sessions focused on attribution bias and paranoia as an emotion, and the last 2 sessions focused on "skills acquisition" using a cognitive behavioral therapy (CBT) framework to discuss examples of social difficulties faced by the participant. After the intervention, a significant increase in emotion recognition and a significant decrease in the anxiety and depression subscale of the EQ-5D were observed. This is the first study to use a virtual world to deliver structured group therapy in early psychosis with a specific focus on social interactions. It documented a positive effect with good feasibility and acceptability from participants (Thompson et al., 2020).

In summary, the 3 VR protocols applied in the treatment of patients with psychosis demonstrated to have a beneficial effect on their paranoid symptoms and also a positive effect on self-esteem, acceptance, and emotion regulation strategy. However, the positive effect on social interactions in the real world has yet to be confirmed.

3.6 Stress and Adjustment Disorder

A total of 35% (7/20) of protocols using VR interventions for addressing stress were included in this review, with a total of 403 participants.

The first protocol is the one used by Gaggioli et al (2014) in the context of stress-associated disorders. The authors evaluated the effectiveness of an interreality protocol for the prevention and management of psychological stress compared with stress management training based on CBT and a waitlist control group in a sample of 121 workers (61 high school teachers and 60 nurses) with high levels of perceived stress and low levels of self-efficacy. The interreality protocol included virtual experiences—controlled by the therapist and focused on learning coping skills and improving self-efficacy—and specific real-world experiences where the person's behaviors and emotions were constantly monitored through the use of wearable biosensors and smartphones to assess the situation and improve the coping skills used in real time. After a 5-week treatment (10 sessions, 2 times per week), reductions in perceived stress and improvements in coping skills were observed in both conditions (interreality and CBT); however, the use of interreality resulted in a significant reduction in chronic "trait" anxiety and a significantly greater increase in emotional support skills compared with CBT (for more details on the outcome measures, see Appendix 1).

The second protocol identified is the one used in the study by Cebolla et al. (2019) in compassion-based interventions. The study involved 16 college students (mean age 30.56, SD 10.86 years) who participated in a self-compassion meditation supported or not (control condition) by an embodied VR system. The Machine To Be Another (TMTBA) is a VR system based on a body swap, and this study involved the use of a visor (VR Oculus Rift) that remotely controlled a camera placed in front of the torso of an actor trained to imitate the performer's precise movements. The system allows the person to identify with another person's body, whose torso, legs, and arms they can see. In the TMTBA-VR condition, the self-compassion meditation was played to the participant for 15 minutes, allowing a third-person perspective of oneself. The study showed that following a 2-week meditative practice yielded increased awareness and attention to mental events and bodily sensations, with no differences between the groups. Furthermore, the VR condition yielded an increase in positive affect toward oneself and self-care behaviors, which were significantly higher than those in the traditional meditation condition. Finally, in the TMTBA condition,

adherence to meditative practice after 2 weeks was higher in participants with lower visual imagery. According to the authors, these data emphasize the important role that VR could play in psychological interventions where mental imagery is often used (see Appendix 1 for more details on the outcomes measured). The results obtained by Cebolla et al. (2019) showed the positive role of VR in compassion-based interventions, emphasizing the need for future studies on this topic.

VR was also found to be effective in managing stress without the guidance of a counselor, as demonstrated by the Digital–Structured Association Technique (SAT) method developed and evaluated by Matsumoto et al. (2021). The Digital-SAT method is an adaptation of a stress management technique used in SAT therapy and consists of re-enacting a stressful physiological response and then counterbalancing it with the visualization of pleasant images using VR technology, which leads to a reduction in discomfort. The intervention protocol involved the combined use of 2 apps to implement the Digital-SAT method: the VR app, aimed at reducing emotional stress by displaying pleasant images through an HMD, and the chat bot app, aimed at improving the continuity of the intervention through an automated chatbot. Matsumoto et al. (2021) found that the combined use of the VR app and the chat bot app produced a better emotional stress reduction effect after 4 weeks, and they encouraged the continuous implementation of the intervention in a sample of 70 nurses exposed to mental and physical strain and pressure (see Appendix 1 for detailed outcome measures). The Digital-SAT method can be considered a promising tool for improving self-care autonomously even in work and daily life settings as it does not necessarily require the involvement of a therapist.

Another area where the application of VR aims to promote positive functioning and manage stress is the context of art. In this regard, Richesin et al. (2021) compared 2D and 3D art making on measures of stress, anxiety, and mood in a sample of 44 psychology students. Specifically, the 3D intervention involved the use of an HMD (Oculus Quest) and a drawing app (Google Tilt Brush), which participants used to draw freely for a period of 15 minutes using any available tools. This condition was compared with a traditional art-making intervention, and the main outcomes of this study were physiological and self-report measures of stress, anxiety, and well-being (see Appendix 1 for more details on the outcome measurements). The study showed that drawing freely using VR can lead to a reduction in negative affect and anxiety levels (state and trait) similar to the effect of the traditional method of art making, but only the 3D group showed a

significantly greater decrease in heart rate than the control group. The authors suggested that VR could be a useful tool in art therapy, but the results may be a consequence of the novelty effect.

Another 15% (3/20) of studies examined the effectiveness of VR in stress management during the COVID-19 pandemic. The study by Chan et al. (2021) involved 2 experiments that explored and compared the effects of VR nature and VR urban environments on the mental condition of individuals who experienced isolation because of COVID-19. The protocol consisted of 7-minute sessions of exposure to both urban and natural environments once per week. A total of 30 students participated in the first study, and 20 older adults participated in the second one. Their positive and negative affect, as well as their connectedness with nature, were assessed before and after treatment. The results from the student and older adult groups showed that walking in a virtual forest decreased stress and negative affect owing to its connection with nature, although no effect was observed on positive affect.

The study designed by Desai et al. (2021) explored whether using a virtual heart-based meditation program was associated with the improvement of stress levels and quality of sleep during the COVID-19 pandemic. A total of 63 participants underwent 1 weekly virtual trainer-guided group heartfulness relaxation and meditation session for 8 weeks while self-practice was recommended. The results showed a decrease in stress, assessed using the Perceived Stress Scale, and improvements in sleep quality, assessed using the Pittsburgh Sleep Quality Index.

The aim of the last study (Riva et al., 2021) was to evaluate the effectiveness of a VR protocol (the "Secret Garden" 360-degree VR experience) to assist individuals in coping with the psychological burden related to the COVID-19 pandemic, improving their well-being, and reinforcing social connectedness. In each session, 40 participants who had experienced at least 2 months of quarantine could travel through a virtual garden for 10 minutes for a total of 7 sessions once per week. The results showed that the intervention was associated with improvements in depression and stress but not in perceived hopelessness. There was also a significant increase in social connectedness.

In summary, VR protocols were effective in reducing stress and promoting self-care and positive coping skills also without the presence of a therapist. However, the VR protocols and assessment measures used were very heterogeneous.

4. Discussion

4.1 Principal Findings

This review aimed to collect and summarize the literature on the application of positive mental health interventions integrated with VR that yielded beneficial effects for both symptoms and indicators of positive functioning. The first observation derived from this review is the paucity of studies that assessed both distress and well-being despite the increasing number of published articles in recent years (Table 1) and the increasing use of digital technologies in mental health practice. A possible explanation for this phenomenon is that positive outcomes are not widely evaluated in research and clinical practice compared with the assessment of symptoms or indicators of distress. This may represent an existing imbalance between the traditional and the positive psychology perspective (Sin & Lyubomirsky, 2009; Wood & Tarrier, 2010) or simply the need to limit the survey burden and time dedicated to assessment in current research. In any case, we included only 20 investigations over 10 years of research.

Starting with anxiety and phobias, the use of VR in this field mainly involves traditional exposure therapy delivered through VR devices (VRET). Although exposure therapy is a traditional and effective method to treat anxiety disorders, we included studies that applied this technique supported by VR devices as exposure implies behavior changes and opportunities for learning new skills, which are strongly associated with increases in self-efficacy and mastery (Maddux, 1995). Various authors have suggested that exposure therapy may indirectly promote positive characteristics such as courage, persistence, goal setting, and planning and could trigger positive affect, a sense of pride, and satisfaction once the exposure activity is successfully performed (Breuninger et al., 2019; Johnson & Wood, 2015; Ruini, 2017). Thus, it can be included under the wide umbrella of positive interventions (Sin & Lyubomirsky, 2009; Wood & Tarrier, 2010). Exposure therapy is generally delivered in the presence of a clinician, but 20% (1/5) of the included studies (Lindner et al., 2020) used an automated exposure protocol. All the included protocols (5/5, 100%) were effective in reducing the symptomatology of the patients, but they were not equally effective in improving their positive functioning. The results of the study by Rus-Calafell et al. (2013) showed an improvement in the interference of the phobic object in life only for the VR therapy compared with the imagery control condition, whereas Kampmann et al. (2016) found that VR therapy did not improve positive

functioning at all as compared with a waitlist control. Finally, Malbos et al. (2020) showed that VR relaxation improved positive functioning but not more than a classic imagery intervention. From this picture, VRET seems to be effective and useful for patients in reducing the symptomatology related to phobias and anxiety disorders (see also the studies by Baghaei et al., 2021; Schroeder et al. 2022; and van Loenen et al., 2022). However, further research is needed to draw inferences about the effectiveness of this advanced technology in improving positive functioning as the data regarding this domain are still inconclusive.

The same inferences can also be drawn for other mental health problems analyzed in this review. For instance, for PTSD, we only found 15% (3/20) of studies that assessed positive functioning (ie, emotional regulation) together with symptomatology. In total, 67% (2/3) of these studies referred to the same intervention protocol, consisting of exploring a virtual room on a treadmill followed by the presentation of 7 images associated with 3MDR, which can be considered a technologically advanced form of traditional trauma intervention—exposure therapy and eye movement desensitization and reconsolidation (S. L. Foster, 2012). The results of this VR intervention were promising—PTSD symptoms improved, together with better use of emotion regulation strategies. Participants reported a better ability to recognize, accept, and cope with emotions after treatment. However, these studies involved only a few patients who were treated with one specific VR protocol. Similarly, the results of the study by Vlake et al. (2022) showed a decrease in distress among COVID-19 ICU survivors but not a significant improvement in the positive functioning of the patients.

The studies on depression were based on different types of protocols, but also in this case, the findings regarding improvements in positive functioning are inconclusive. One of the studies focused on self-compassion, and participants were required to compassionately interact with an avatar first and then re-experience the effect of their interaction by taking on the role of the child avatar. In the second study, participants had to explore a virtual room, and such exploration was rewarded with positive experiences as the virtual doors opened onto a series of spectacular immersive landscapes. Both studies showed promising results and highlighted the benefits of the protocols in decreasing the severity of depressive symptoms. However, concerning positive functioning, the results of the first treatment showed that the protocol did not yield any change in self-compassion, only in self-criticism, whereas the second intervention yielded an improvement in individuals' positive affect and a significant increase in well-being following the

participants' involvement in the virtual procedure. The first investigation contributes important data on the crucial differentiation between symptom improvements (ie, a decrease in self-criticism) and the promotion of positive functioning (ie, an increase in self-compassion). These findings emphasize the need to implement interventions specifically focused on well-being promotion and not merely on symptom reduction (Donaldson et al., 2011; Lyubomksky et al., 2005; Ruini, 2017; Sin & Lyubomirsky, 2009).

The second VR intervention, in contrast, shares the same theoretical framework of traditional behavior activation therapy, where positive and rewarding activities are prescribed to help patients with depression experience pleasure and engagement in their lives (Layous et al., 2014; MacLeod & Luzon, 2014). Hence, both investigations confirm the observation that depressive disorders can be addressed by changing the complex balance between positive and negative affect (Fava & Ruini, 2003; Ruini & Cesetti, 2019). VR may play an important role in this regard, but further studies are needed to develop the most suitable protocols for enhancing well-being in individuals with depression.

VR treatments for individuals with psychosis and schizophrenia were focused on social functioning and positive relationships. A total of 15% (3/20) of the studies included in this review were based on social interaction with one or more avatars to improve social interactions and cognitive functioning. du Sert et al. (2018) showed that the VR intervention was effective in changing the way patients related and responded to their voices by tackling emotional regulation, enhancing self-esteem, and promoting acceptance as compared with treatment as usual. These results are in line with those of Thompson et al. (2020), who found a significant increase in emotion recognition and a significant decrease in anxiety and depression in their pilot study. In contrast with these results, Pot-Kolder et al (2018) did not register a significant change in patients' social participation and positive social functioning compared with the waitlist condition. Only the dimensions of social functioning and paranoid ideation improved when compared with the control group. However, it should be noted that the authors used the same VR intervention that Geraets et al. (2019) used in the treatment of individuals with SAD, and in this case, the intervention was able to show an improvement in social functioning. When the protocol was delivered to patients with psychosis, findings showed that the intervention based on a one-to-one or group interaction with an avatar yielded general beneficial effects on paranoia and other psychotic symptoms but not necessarily on the social participation and positive interpersonal functioning of patients (see the study by Schroeder et al. (2022) for a review). Further research

is needed to clarify whether the beneficial effect of the VR intervention might be linked to the severity of the clinical condition of participants, their cognitive bias, their preexisting social skills, or other peculiar issues yet to be investigated (Broyd et al., 2016; Riches et al., 2016).

Outside the domain of psychiatric conditions, this systematic review analyzed VR interventions aimed at promoting well-being and reducing stress, including COVID-19 pandemic distress. As many protocols involving the use of VR are being developed in this field, a summary of their findings might be useful to understand whether these interventions were beneficial in decreasing the stress and anxiety related to the virus and social isolation and in restoring well-being after the pandemic. In total, 10% (2/20) of the included studies (S. H. M. Chan et al., 2023; Riva, Bernardelli, et al., 2021) were based on a virtual natural scenario that the participant could explore, whereas another protocol reproduced an ICU in which patients were hospitalized because of COVID-19. The interventions with virtual natural scenarios were shown to be effective in reducing stress, negative affect, and depression and increasing social connectedness, in line with the well-established association between feelings of well-being and being in contact with nature (in this case, through a virtual landscape) (Baños et al., 2012b; Brooks et al., 2017; Browning et al., 2020). However, the protocol by Chan et al. (2023) did not yield an improvement in positive affect, and the one by Riva et al. (2021) was not effective in improving perceived hopelessness. Finally, Desai et al. (2021) proposed a heart-based relaxation protocol that showed a decrease in stress and a better quality of sleep. These data support the use of VR in addressing the stress and negative feelings associated with the pandemic, but its beneficial effects for restoring well-being have not been confirmed, with the sole exceptions of social connectedness and sleep quality.

Other than stress related to COVID-19 and the pandemic, VR interventions also showed their utility in relieving and preventing stress more generally. Gaggioli et al. (2014) showed that a VR exposure-based therapy prompted a significant reduction in perceived stress and improvements in coping skills in workers. Moreover, the group that underwent the VR intervention showed a reduction in chronic “trait” anxiety and a significantly greater increase in emotional support skills. Compassion-based interventions have also been developed and delivered using VR, and the study by Cebolla et al. (2019) showed that this intervention was effective in increasing positive attitudes toward the self and others and decreasing negative qualities toward the self. However, the data do not fully support an additional benefit of using VR compared with traditional

meditation techniques. Finally, 10% (2/20) of the studies included in this review showed that VR interventions were effective in reducing emotional stress also without the guidance of a counselor (Matsumoto et al., 2021) and in reducing negative affect and anxiety levels (state and trait) using virtual art therapy (Richesin et al., 2021). In summary, when considering nonclinical populations such as workers or college students, VR interventions showed their utility and effectiveness in reducing stress and promoting positive function (ie, emotional support skills and compassion toward others and the self) even without the guidance of a therapist or counselor. These data are very promising considering the large scalability of these VR protocols after the pandemic and among the general population (Bell et al., 2020). However, solid evidence that VR interventions are more effective compared with traditional ones (ie, mindfulness, traditional CBT, relaxation, and art making) is still to be completely demonstrated.

4.2 Limitations

One of the main limitations of this review was its heterogeneous nature. It included different populations (clinical and nonclinical) treated with many different VR protocols and evaluated using different outcome measures. This is particularly true for the assessment of positive functioning, where no consensus emerged among investigations with the sole exceptions of the PANAS and the EQ-5 used EUROHIS Quality of Life Scale in 15% (3/20) of the studies. Hence, there were not enough quantitative data to support a meta-analysis. Accordingly, this work aims to provide a summary of the progress made in the last decade and delineate future directions to follow for researchers and clinicians interested in promoting positive mental health through VR interventions.

Another limitation of this study was the absence or exclusions of specific clinical domains (such as OCD, eating disorders, and addiction-related disorders), where many other VR protocols have been recently developed (Asiain et al., 2022; Cieślik et al., 2020). For OCD, we found no studies that assessed positive functioning along with negative symptoms. We decided not to include eating disorders and addiction-related disorders as the positive functioning of these clinical populations was found to be intertwined with their disorders (Brandel et al., 2017; Hall-Simmonds & McGrath, 2019; Johnson & Wood, 2015). Thus, when analyzing the effects of VR interventions, these clinical conditions might need to be considered from a different perspective.

Finally, the studies included in this review account only for adult populations, leaving out children and older individuals. The reason for this choice lies in the fact that these populations present specific features in terms of mental health; in older adults, core issues are correlated with memory loss and physical and cognitive decline, whereas in children and adolescents, issues such as self-esteem, identity, and personality development are the main challenges associated with distress and well-being. Moreover, the features of psychological distress and well-being in these populations are strongly influenced by age and the stage of development or aging (Owens & Waters, 2020; Ryff, 2013). We found that many studies that used VR to promote the mental health of children and older adults (Babbage et al., 2022; Botella et al., 2009; Lluesma-Vidal et al., 2022; Thangavel et al., 2022) focused on aspects that differed from those in studies on adults, such as neurological and cognitive development or decline, respectively.

4.3 Conclusions and Future Directions

In conclusion, this review provides robust evidence supporting the beneficial effect of VR therapy in improving stress and negative symptoms. However, in participants, the impact of VR treatments on positive functioning remains unclear, with 35% (7/20) of the studies showing no or a small effect on various dimensions of positivity, ranging from positive affect to relaxation, self-compassion, and social interaction. The variety of outcome measures included and their different sensitivities to clinical changes might be the reason why the results on the beneficial effect of VR interventions in promoting positive functioning are still inconclusive (Fava et al., 2004). It is of crucial importance that future research systematically addresses the impact of VR interventions also on individuals' positive functioning to identify the most suitable protocols for enhancing well-being in individuals with different mental health conditions (from those with psychiatric disorders to those dealing with stress or the negative consequences of the recent COVID-19 pandemic). Indeed, our review showed that VR interventions applied in the general population were effective both in addressing stress and promoting positive mood, social connectedness, and better sleep quality. These data suggest that VR interventions might be cost-effective and largely scalable, particularly when they do not require the guidance of a counselor or therapist.

However, this review also suggested that the beneficial effect of VR interventions might be linked to the severity of the clinical condition of participants (ie, the same VR protocol with the interaction with an

avatar was able to improve social functioning in individuals with social anxiety but not in patients with paranoia). Previous work has documented the peculiar combinations of personal resources and vulnerabilities that characterize clinical populations (Brandel et al., 2017; Hall-Simmonds & McGrath, 2019; Ryff, 2013). In particular, it was found that clinical populations generally present impairments in well-being, and positive interventions developed within the positive psychology perspective were found to be effective in addressing those impairments (Sin & Lyubomirsky, 2009; Weiss et al., 2016). Owing to its flexibility and capacity to engage participants, VR interventions might play a crucial role in promoting better mental health in the population, including clinical samples. Considering the large number of private and public investments in digital technologies for mental health, this review suggests further research to develop existing VR software and treatments to align them with the modern positive mental health approach.

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Chapter 3: Effectiveness of a Virtual Reality program in treating psychological distress and promoting positive mental health: A pilot feasibility study.

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Abstract

Introduction: Virtual reality (VR) has been recently used for the treatment of mental health conditions. While research shows symptom reduction, further investigation is required to ascertain the impact of VR on well-being indicators. This pilot study aims to assess the effectiveness of a new VR software, H.O.M.E (How to Observe and Modify Emotion) Positivity, in promoting positive mental health, which implies addressing both psychological distress and well-being.

Methods: A sample of 16 healthy college students participated in a six-session intervention involving individual interviews and VR experiences using H.O.M.E delivered at the university of Bologna. They were assessed before and after intervention and at 3-month follow-up with indicators of negative symptoms (i.e., Depression Anxiety Stress Scales (DASS) and the Negative affect scale of (PANAS) and of well-being (i.e., Mental Health Continuum (MHC) and the Positive Affect (PA) subscale of the PANAS). Moreover, they were asked to report their satisfaction and comments on the experience of the VR software.

Results: Following the intervention, participants reported significantly lower scores at DASS and higher scores at MHC and PA. In contrast, NA subscale score did not change significantly after the intervention or at three months follow-up.

Conclusion: The results provide support to the use of H.O.M.E_Positivity for the promotion of positive mental health. Participants reported a reduction of psychological distress and improvement in well-being, and they were all highly satisfied and engaged while using the VR software. These findings indicate the potential value of this intervention, particularly in an increasingly digital society.

Keywords: positive mental health; well-being; virtual reality; positive emotions; college counselling

1. Introduction

Virtual reality (VR) refers to a simulated experience similar to or completely different from the real world. It is typically generated by computer technology and allows users to interact with a three-dimensional environment, through specialized equipment such as headsets and gloves. VR allows the generation of artificial experiences in real-time, delivering a sense of immersion to users and enabling them to interact within these simulated worlds as if they were genuine physical environments. In mental health settings, VR has emerged as an innovative tool to provide effective psychotherapies, especially in treating phobias and anxiety disorders (e.g. Botella et al., 2017; Riva, 2005; Valmaggia et al., 2016). During the last decades, several software and interventions with VR therapies have been developed and tested, demonstrating their capacity to elicit a greater degree of participant engagement and interest. Thus, VR therapies can be employed to deliver more intense and effective interventions compared to the traditional ones (e.g. Bouchard et al., 2017; Côté & Bouchard, 2005). However, there is considerable heterogeneity in the type of software and hardware used and a significant proportion of these tools focused typically on specific symptomatology (i.e., fear of flying, fear of animals, public speaking, etc.), with very few VR programs targeted at enhancing well-being (Li Pira et al., 2023). For instance, in the context of anxiety (Kampmann et al., 2016) and phobias (Lindner et al., 2020), VR is employed as a tool to facilitate traditional exposure therapy. Empirical evidence suggests that this approach is effective in alleviating the symptoms associated with anxiety disorders (Rowland et al., 2021). Nevertheless, the available evidence concerning the enhancement of well-being is not definitive. Similarly, there are various VR interventions to address depressive symptomatology: some targeted specific positive domains such as self-compassion and the cultivation of positive experiences, demonstrating the potential to diminish the severity of depressive symptoms (Falconer et al., 2016; Habak et al., 2020).

The current understanding of mental well-being, which is rooted in the principles of positive psychology, comprises two interconnected aspects: (i) the presence/absence of symptoms or psychopathological conditions and (ii) the presence/absence of well-being (Keyes, 2002; Ruini, 2017). This framework posits that psychopathology and well-being exist on a dual continuum, with mental illness and languishing on one axe, and flourishing mental health on the other axe (Keyes, 2002). Moderate mental health represents the most frequent condition as documented by various epidemiological studies (Keyes,

2003). According to this complete perspective on mental health, the promotion of well-being and optimal human functioning should receive the same emphasis as the treatment of symptoms and psychopathology. Consequently, modern interventions in mental health should be equipped to address both aspects (Sin & Lyubomirsky, 2009).

With the recent development of digitalization, modern technologies (such as computer, software, apps, virtual reality devices, etc.) can be considered innovative and promising methods to enhance the overall quality of individual experiences The fundamental theoretical foundation of this approach has been labeled as “positive technologies” (Riva, 2005).

1.1 The software H.O.M.E.

On the wake of the positive technology approach (Riva et al., 2012), a new VR software was developed at the University of Bologna, under the acronym of H.O.M.E (How to Observe and Modify Emotion). It consists of a four-room virtual house equipped with various objects and stimuli, which enables user interaction. This interaction allows the user to associate an object present in the house with an emotional label that represents the user’s frequent reaction when dealing with that specific object (i.e., food, drinks, computer, books, paintings, mirrors, etc.). The rationale behind this selection is twofold. Firstly, the use of a house setting allows the clinician to extend the applicability of the software to a wide range of daily situations, providing a flexible tool that can be continuously integrated and modified with additional stimuli, based on the users' needs. This flexibility enables the customization of experiences, making the VR environment adaptable to various emotional and situational triggers relevant to each user’s personal life. Secondly, the ability to interact with objects within the virtual environment allows the clinician to observe the participant's emotional reactions in real-time, and in a realistic context. (for an illustration of interaction with the software, see **Fig.1**). This feature is particularly valuable for working on emotion regulation and psychoeducation (Gardini et al., 2023). As participants engage with different scenarios, clinicians can guide them through strategies for recognizing, managing, and adjusting emotional responses. This real-time feedback loop supports the development of emotional awareness and self-regulation skills, allowing participants to learn and practice these techniques in a safe, controlled setting. Through such interactions, the software serves as a practical tool for

psychoeducation, helping users understand the nature of their emotions and offering insights into how different coping strategies can be applied in daily life (Ruini et al., 2024).

Figure 1: Example of interaction with an object in the H.O.M.E. virtual environments. a) emotional labeling of an object b) selection of resources from the box.

By incorporating VR in this way, clinicians can create a dynamic therapeutic environment that not only provides immediate feedback, but it also facilitates the transfer of emotional regulation skills to real-world situations, thereby enhancing the therapeutic impact of the intervention. Moreover, VR allows clinicians to observe and analyze emotional and cognitive reactions in real-time, offering immediate insights that traditional retrospective methods cannot provide. This supports more effective, tailored interventions and enhances understanding of clients' emotional responses, fostering improved therapeutic outcomes (Gaggioli et al., 2014).

The advantage of using this type of virtual environment is that it can be administered transdiagnostically across several psychiatric conditions, overcoming the limitation of a disorder-specific approach (Freeman et al., 2017; Ioannou et al., 2020; Colombo et al., 2021). Gardini and colleagues (2023b) published a recent research protocol where they describe the use of H.O.M.E software to reduce unhealthy lifestyles and behaviors, offering a structured framework for its implementation and evaluation.

With the present research we aim at expanding the application of H.O.M.E. software to the promotion of well-being (i.e. HOME_Positivity). In fact, each room in the virtual house has been equipped with a box containing items representing multiple psychological resources (e.g. gratitude, environmental

mastery, self-efficacy, positive interpersonal relationships, etc.). The theoretical foundations of the resource box are based on the principles of hedonic and eudaimonic well-being (Seligman, 2011;Ryff, 2014; Ryand & Deci, 2000) and the concept of positive technologies (Riva, 2005). The resource box allows the selection of items aimed at discovering and cultivating various domains of well-being . The virtual environment is used to induce positive and pleasurable experiences; to foster engagement and self-realization; and to support connection and interpersonal relationships (Botella et al., 2012b). The resources contained in the virtual environment are gradually discovered by the users, who can select and engage in exercises with the clinician, aimed at training that specific dimension of well-being in a virtual scenario. Through the use of H.O.M.E_Positivity, the final objective is not only to alleviate negative symptoms experienced by the participants but also to enhance and bolster their positive mental health and the resources they possess or they wish to develop.

1.2 The present study

Given the novelty of H.O.M.E._Positivity, its feasibility still needs to be verified, as well as its beneficial effect in promoting positive mental health (i.e., addressing distress and promoting well-being).

Using a single arm longitudinal design study, the present study aims to verify the feasibility of our digital intervention and to assess whether our intervention is able to decrease psychological distress as well as to promote well-being and positive mental health. The targeted population consists of young college students, presenting moderate to severe psychological distress. Moreover, this target population is also likely familiar with the use of digital technologies (Davies et al., 2014).

1.3 Hypothesis

We hypothesized that the intervention will be feasible and accessible to the participants. Moreover, given the existing data regarding the efficacy of digital interventions, we hypothesize a decrease in depression, stress, and anxiety symptoms along with an increase in well-being in the participants who will take part in our intervention and that improvements will be maintained at three-month follow-up.

2. Methods

2.1 Sample and recruitment

Participants were recruited in a medium size university campus in Northern Italy through digital channels, newsletters, and social networks. The VR intervention was also presented during academic classes, and students were invited to enroll on a voluntarily basis. Before enrollment in the project, all participants were screened online through the Qualtrics digital platform, using a screening procedure that was designed with the purpose of selecting participants devoid of severe psychiatric conditions and presenting impairments in well-being dimensions according to specific psychometric instruments (MHC\DASS\PANAS) (see section below). All participants were requested to sign an informed consent form before participation. The research project was approved by the ethical board of the University of Bologna.

Inclusion criteria: Participants had to meet at least one of the following criteria to be included in the project. : 1) presence of moderate to severe psychological distress (DASS score ranging from 31- to 60) 2) presence of impairments in well-being; (participant belonging to the moderate mental health category of MHC) 3) absence of clinical condition which would compromise the use of a virtual reality device (i.e., neurological disorders, or motion-sickness conditions).

The exclusion criteria were: 1) the presence of high psychological distress (DASS score over 60); 2) the presence of a psychiatric diagnosis of bipolar disorder, schizophrenia, psychotic disorder, personality disorder (as reported by participants during the online screening); 3) presence of neurological disorder, 4) refusal to sign the informed consent or 5) presence of difficulties in comprehension and production of the Italian language.

Participants who met eligibility criteria were contacted by phone or email and invited to take part in the study. A final sample of 16 college students (mean age = 23.2; SD=2.9; F=14) participated in the study. None of them reported current or past psychiatric disorders.

2.2 Instruments

An online form was created for the collection of socio-demographic, anamnestic, and clinical data relative to mental health. The screening and assessment have been carried out using the following psychometric questionnaires:

- Depression Anxiety Stress Scale (DASS-21) (Henry & Crawford, 2005), consists of 21 items (7 items per subscale: depression, anxiety, and stress). Participants were asked to score every item on a Likert scale from 0 (did not apply to me at all) to 3 (applied to me very much). According to previous clinical investigation a total score of higher of 60 can be used as a cut off for high psychological distress (Melaku et al., 2021). The Chronbach'α of the DASS-21 (total score) is .926 in this sample.
- Mental Health Continuum short-form (MHC) (Keyes et al., 2008a), consists of 14 items that measure the frequency of 3 domains of well-being: 3 items for emotional well-being (EWB); 6 items for psychological well-being (PWB); and 5 items for social well-being (SWB); according to a Likert scale ranging from 0 'never' to 5 'every day'. A total well-being score was calculated with a Cronbach'α value of .924 in this sample. The MHC can provide a categorical diagnosis of languishing, flourishing and moderate mental health. To be flourishing, individuals must report that they experience "everyday" or "almost every day" at least seven of the symptoms, where one of the symptoms is from the hedonic cluster (i.e., happy, interested in life or satisfied). To be languishing, individuals must report that they "never" or "once or twice" experienced at least seven of the symptoms, where one of the symptoms is from the hedonic cluster. Individuals who do not fit the criteria for flourishing or languishing are categorized as moderately mentally healthy(Keyes, 2006; Keyes et al., 2008b).
- Positive and Negative affect scale (PANAS) (Watson et al., 1988), measures two distinct and independent dimensions: positive affect (PA, 10 items), and negative affect (NA, 10 items) for a total of 20 items. The PA subscale reflects the degree to which a person feels enthusiastic, active, and determined. The NA subscale refers to unpleasant emotional states such as anger, guilt, and fear. Respondents had to evaluate the frequency of positive or negative emotions using a 5-point Likert scale. The Cronbach' α for this sample is .865 for PA and .838 for NA

In order to collect qualitative data on the feasibility and acceptability of the new software, at the end of the intervention participants were interviewed with few questions regarding their personal experience with the software and some additional comments/suggestions for improving it. (e.g. How did you find the overall experience? What did you like and what would you improve in the software?)

2.3 Materials

Hardware: The software was displayed via an HTC Vive Pro (display resolution of 1440 × 1600 pixels per eye and 90 Hz refresh rate) head-mounted display (HTC Corporation, 2021), running on a Dell Alienware (Windows 10 Pro 64 bit, intel i7-9750H 2.6 GHz CPU, NVIDIA RTX 2070 GPU, 16 GB RAM).

2.4 Procedure

The intervention was delivered at the University of Bologna Virtual Reality Lab, by a junior researcher, who was trained and supervised by one of the senior authors of the manuscript. The training was focused on traditional counselling skills, integrated with positive psychology methodologies for promoting hedonic and eudaimonic well-being (Ruini, 2017). Supervision was provided in case of specific problems/difficulties during the delivery of the individual sessions.

The VR intervention comprised six individual sessions lasting approximately 50 minutes each. For each session, the initial 30 minutes were dedicated to conducting an individual psychological interview, while the remaining 20 minutes were allocated to the HOME VR training. The interview aimed to explore and discuss with the clinician the specific theme brought by each participant and its evolution during the course of the intervention. Thus, this initial phase of the session was conceived as a tailored preparation for the VR phase. For example, a participant could have reported difficulties in concentrating while trying to study or difficulties in waking up on time for attending classes. Accordingly, we would recreate the same situations within the virtual environments (e.g. studio, bedroom) and monitor the progress made throughout the intervention in each session of the intervention.

Within the virtual environment, the topics that emerged during the interview were thoroughly discussed and elaborated, with participants being encouraged to utilize objects and various virtual spaces to articulate their emotions and even re-enact the experiences they shared.

The first three sessions were primarily focused on conveying the purpose of the treatment and providing an explanation of how the software operates, as well as exploring the issues raised by the participants in the virtual environment to foster a deeper understanding of their emotional state (psychoeducation with the use of the VR software).

The last three sessions were dedicated to introduce the participant to the virtual resource box, which was present in each room of the house within the virtual environment. The participant was encouraged to enhance the application of the selected resources, to elucidate why they were chosen, and to outline their plans for utilizing these strategies in real-life scenarios. During these last sessions, the interview was also used to assess the progress of each participant's daily exercises aimed at enhancing their strength and resources. This comprehensive approach ensured that the sessions had a tangible impact on participants' growth and well-being beyond the virtual world.

2.5 Analysis

In this experimental design, we conducted a single-arm study where all participants received the individual VR treatment. We measured negative symptoms and positive mental health at three-time points: before the treatment (T0), immediately after the treatment (T1), and three months post-treatment (T2).

For the analysis of normally distributed data, we used repeated measures MANOVA with time (T0, T1, T2) as a within-subject factor. To further investigate specific effects within each dependent variable (Positive Affect (PA) and Mental Health Continuum (MHC), we performed one-way ANOVA for each variable and pairwise comparisons adjusted using the Bonferroni method.

For the non-normally distributed data, specifically the Depression Anxiety Stress Scales (DASS) and the Negative Affect (NA) subscale, we applied the Friedmann non-parametric test to compare the mean scores before and after the intervention.

This approach allowed us to comprehensively analyze both normally and non-normally distributed data to understand the impact of VR treatment on various psychological measures.

The raw data for this project **are** available in a public repository on the Open Science Framework (OSF) through the following link: https://osf.io/fdq7s/?view_only=c016047dfba540c7b1c902e9faa7ad91.

3. Results

The analysis was implemented to assess the effect of time on the variables PA and MHC. The multivariate results revealed a significant effect of time on the combined dependent variables, as indicated by Wilks' Lambda ($\lambda = 0.477$, $F = 2.802$, $p = 0.012$, $\eta^2 = .310$). These findings suggest that the intervention had a moderate to large effect on the measured variables.

Further examination through univariate analysis allowed for a more detailed understanding of the effects of time on each variable. Pairwise comparisons between different time points (T0, T1, and T2) were conducted to elucidate specific differences (see **Table 1** and **Table 2**). There was a significant increase between T0 and T2 (mean difference = 6.467, $p = 0.007$) in PA, and MHC (mean difference = 7.000, $p = 0.038$); suggesting that the intervention effectively improved the participant's well-being. The effect sizes, measured by Cohen's d, were $d = 0.96$ for PA and $d = 0.74$ for MHC, indicating a large effect for PA and a medium effect for MHC, respectively.

The Friedman test results showed significant differences in the distributions of DASS scores across different time points ($p = .002$) with a moderate effect size (Kendall's $W = 0.37$). Subsequent pairwise comparisons using the Wilcoxon signed-rank test for DASS scores across different time points revealed significant differences between T2 and T0, with a large effect size ($r = 0.538$, $p = 0.008$), and a marginal significant difference between T1 and T0, with a moderate effect size ($r = 0.341$, $p = 0.056$). However, no significant difference was observed between T2 and T1.

Finally, the Friedman test results for the NA scores indicated no significant differences in distributions across different time points (p=.063). See Figure 2 for a summary of the results.

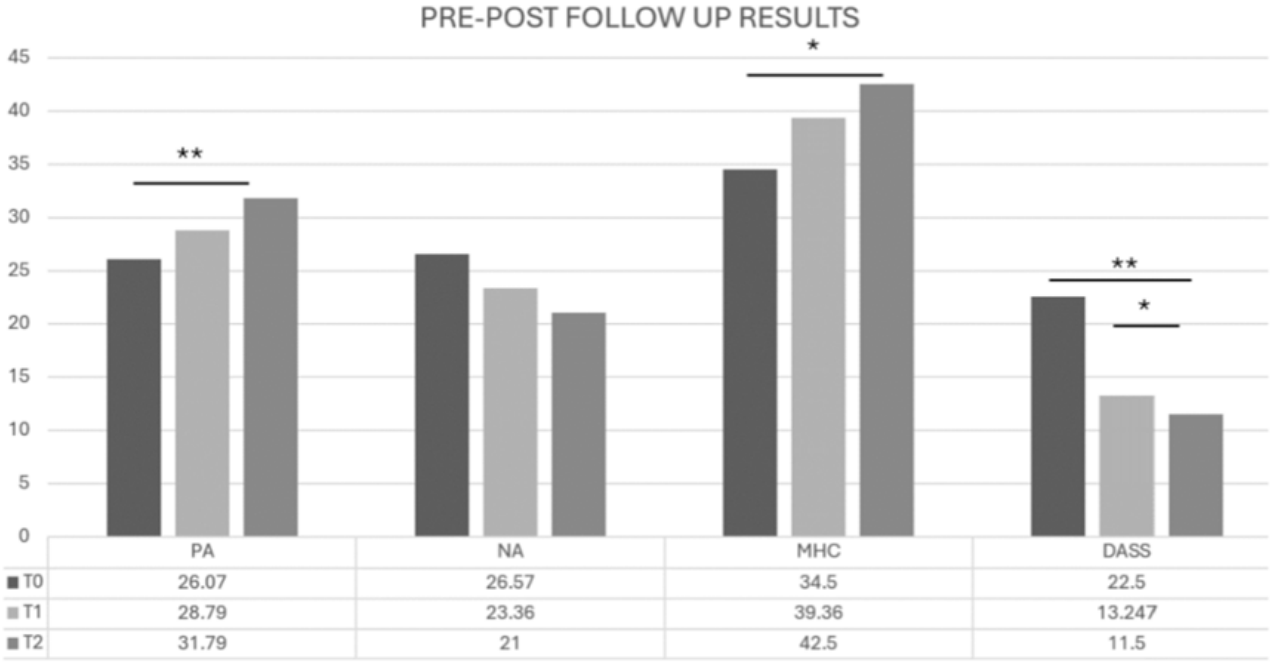

Figure 2: Bar plot of the scores of the different dependent variables: Positive Affect (PA), Negative Affect (NA), Mental Health Continuum (MHC), Difficulties in Emotional Regulation Strategies (DERS), and Depression, Anxiety, and Stress (DASS) at three time points (T0 "baseline", T1 "post-intervention", T2 "follow-up"). * p<.05, **p<.01

Table 1: Pairwise comparison between PA and MHC. The mean difference is significant at .05 level.*

Measure	(I)TIME	(J)TIME	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
PA	T0	T1	-2.333	2.337	1.000	-8.686	4.019
		T2	-6.467*	1.740	0.007	-11.195	-1.738
	T1	T0	2.333	2.337	1.000	-4.019	8.686
		T2	-4.133	1.927	0.150	-9.370	1.104
	T2	T0	6.467*	1.740	0.007	1.738	11.195
		T1	4.133	1.927	0.150	-1.104	9.370
MHC	T0	T1	-3.333	2.220	0.467	-9.368	2.701
		3	-7.000*	2.453	0.038	-13.668	-0.332
	T1	T0	3.333	2.220	0.467	-2.701	9.368
		T2	-3.667	1.748	0.164	-8.416	1.083
	T2	T0	7.000*	2.453	0.038	0.332	13.668

Table 2: Pairwise comparison between each time point of DASS total scores. The mean difference is significant at .05 level.*

Pairwise Comparisons

	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
T0 DASS-T1 DASS	0.781	0.354	2.210	0.027	0.081
T2 DASS	1.188	0.354	3.359	0.001	0.002
T1 DASS-T2 DASS	0.406	0.354	1.149	0.251	0.752

In order to collect data on the feasibility and acceptability of the new software, the most relevant comments provided by participants are summarized and reported in Box 1. We categorized them in 5 main areas.

Participants opinions about the VE

Participants comments can be summarized into 5 main categories. The following are selected examples of participants' comments collected after the six sessions of the intervention:

1. **Easier Expression of Emotions:**

   "Wearing the headset somehow made it easier to open up. It felt like a safe space where I could express myself without judgment. The virtual environment helped me detach from the real world and delve into my emotions more freely."

2. **Engaging and Immersive Experience:**

   "I was skeptical at first, but the technology blew me away. It was way more engaging and immersive than I could have imagined. The virtual reality was so similar to the situation I was describing that it helped me remember and express my thoughts and feelings, making the whole therapeutic process much more impactful for me. I would have liked an avatar to make things even more realistic."

3. **Excitement about Resource Box:**

   "The resource box was my favorite thing! Having tangible tools in the virtual world helped me understand and practice my personal strengths. It was like a treasure trove of self-discovery, and I left each session with practical skills to apply in my daily life."

4. **Useful Intervention but Desired More Sessions:**

   "The intervention was helpful, no doubt. But I felt like there was so much more we could explore. I wanted more sessions to dive deeper into certain aspects. It was like scratching the surface of a profound experience, and I craved more time to explore it fully."

5. **Enhanced imagination through VR:**

   "I thought imagination was powerful, but this technology took things to a whole new level. It wasn't just in my mind; it was all around me. It made the whole process feel real and impactful. I found myself fully engaged, and it pushed me to confront things I might have avoided otherwise. Something I would have liked though, is the possibility to save the changes made in the environment at each session."

Box 1: Exemple of the most common feedback received from the participants after the intervention

4. Discussion

The results of the pilot study give support the beneficial effect of a digital intervention for promoting positive mental health in university students. Following a brief psychological intervention delivered with the use of a new software of VR, we obtained a reduction in psychological distress (measured with the DASS questionnaire) and an increase in participant's well-being (measured with MHC and PANAS).

These results suggest that the positive effects of VR interventions in reducing psychological distress previously documented in the literature (e.g. Falconer et al., 2016; Habak et al., 2020), can be generalized to our new software. This finding is particularly promising, as these symptoms are often associated with various mental health challenges and can significantly impair an individual's daily functioning, interpersonal relationships and overall quality of life. For example, previous research by Lindner and colleagues (Lindner et al., 2020), highlighted the effectiveness of Virtual Reality Exposure Therapy (VRET) in treating specific phobia. Additionally, a recent review of the literature (Li Pira et al. 2023) emphasize that VR was found to be effective in improve negative symptoms but not necessarily positive mental health. Conversely our pilot study also demonstrated an improvement in well-being and positive mental health among the participants. Specifically, there was a significant improvement in the total score of the Mental Health Continuum (MHC) and positive affect (PA), indicating an enhancement in the participants' overall emotional and psychological well-being. Even though our participants were devoid of severe psychiatric conditions, these outcomes suggest that the intervention may not only yield a reduction of negative symptoms, but it may also promote the cultivation of positive emotions and psychological resources. To date the apport of digital technologies in promoting well-being and positive mental health is still debated (Babbage et al., 2022; Li Pira et al., 2023; Thangavel et al., 2022) and the results of this pilot study, although preliminary, support the possibilities to use this kind of tool to promote resilience and positive mental health. This promising result could be due to the specific use of the VR. Firstly, re-experiencing daily episodes with the use of the VR software may result in a better memory recall and acceptance of negative life experiences (Colombo et al., 2024) as well as possible beneficial effect on memory bias (Visser et al., 2020). Secondly, VR could be considered a useful tool for building a therapeutic alliance between participants and the therapist because it introduces a gamification component within the sessions, and it allows a better agreement on treatment goals and activities to be performed in between sessions. Even though research on therapeutic alliance in digital

psychotherapeutic interventions is still debated, VR was found to improve participants engagement and self-realization (Botella et al., 2012b). Finally, another benefit of our VR software was provided by the resource box which contains the visual representations of hedonic and eudaimonic well-being dimensions (i.e., positive interpersonal relationships, forgiveness, self-esteem and self-acceptance, relaxation, gratitude, etc). These dimensions could be considered difficult to understand because of their abstract nature (Fattore et al., 2019). However, in our VE they can be visualized inside the resource box and can be freely explored by participants and then discussed with the clinician during the session. After the virtual training, the participants are specifically invited to use the selected well-being dimensions in real world contexts. The experience of well-being in participants' real life may have determined the maintenance of the beneficial effects of the digital intervention also during the follow up.

On the other hand, the unexpected finding of no significant difference in negative affect (NA) after the intervention or during the follow-up period, despite the decrease in DASS scores post-intervention, raises interesting questions about the mechanisms underlying the intervention's effects. While it is possible that the intervention indirectly influenced negative affect through other pathways not captured by the measures used in this study, further investigation is warranted to better understand these dynamics.

Regarding the feasibility and acceptability of the new VR software, users' feedbacks revealed several key benefits and areas for improvements (see Box 1). Torous and colleagues (2021) emphasized that VR can provide users with a sense of safety, making it easier for them to express their emotions without fear of judgment, which is crucial for effective therapeutic interventions. Our results align with these findings, and highlights VR's potential to facilitate deeper self-disclosure compared to traditional methods. In the framework of positive technologies, Riva (2005) documented that the use of interactive elements within VR scenario could enhance users' engagement and learning. According to participants' comments, this fact emerged also for our new HOME software, particularly referring to the resource box (see BOX 1).

In fact, the resource box placed in each virtual environment was particularly well-received by participants, offering them practical tools for self-discovery, skill development and application in real life contexts. These results confirm the possibility to foster mental wellbeing through the use of positive

technology (Riva 2005). The results are encouraging given the lack of empirical data on the topic (Li Pira et al., 2023).

Finally, the feedback indicating a need for more sessions suggests that while VR interventions are impactful, their duration may need to be extended to fully realize their benefits. The present literature on the topic is very heterogeneous with VR-based therapies ranging from one-session treatment to twenty sessions of VR and duration of the intervention ranging from 5 minutes to 120 minutes. (Rowland et al., 2022). Similarly, the debate on the optimal duration of positive psychology interventions is still open, with studies underlying the necessity to address various components of well-being (and therefore needing more sessions) and other studies emphasizing the hedonic treadmill phenomena, which calls for shorter interventions to prevent well-being adaptation (Rusk et al., 2018; Sheldon & Lyubomirsky, 2012). Overall, while VR offers significant advantages, further research is needed to understand if it can be used to deliver shorter interventions and if so, what would the best duration be according to participant clinical status and readiness to self-awareness.

Therefore, it is crucial for future studies to explore the mechanisms behind VR and positive interventions, considering factors such as the type of technology used (e.g., VR vs. non-VR), the resources selected, and the treatment dose effects. (e.g., the number of sessions required to achieve significant improvement).

5. Limitations and Strengths

Limitations of the study included a small sample size, which affects the generalizability of the findings to broader populations and the statistical power of our results . Indeed, observations from 16 participants do not allow to draw inferences regarding the robustness of the intervention outcomes. Additionally, a single-arm design without a control group makes it challenging to attribute changes solely to the intervention, as other factors could have contributed to the observed outcomes, such as screening and assessment performed during exam period or other stressful academic moments. Moreover, the improvement in well-being dimensions could have resulted as a consequence of an effective treatment alliance fostered by the VR. Unfortunately, we have not assessed therapeutic alliance in the present study. Future studies are needed to further explore this possibility. It should also be noted that the relatively short duration of the

intervention may not have been sufficient to produce significant changes in certain outcomes, such as negative affect, which may require longer-term interventions for noticeable improvements.

Another notable point is the potential enhancement of user experience through personalization. The desire for the presence of avatars suggests that incorporating such elements could further improve user engagement. Future developments should consider including an avatar in the environment, in line with Freeman and colleagues (1999), who reported that even the mere presence of a human avatar, without interaction, can enhance the sense of immersion experienced by users.

Despite these limitations, the study provides promising insights into the potential of this new VR intervention for improving psychological well-being and positive mental health, while highlighting areas for further research and refinement.

6. Conclusions

In conclusion, while this pilot study provides promising evidence of the intervention's effectiveness in improving psychological well-being and positive mental health, it also highlights areas for refinement and further investigation. Future research could explore the long-term effects of the intervention, as well as the specific mechanisms through which it operates. Additionally, considering individual differences in response to the intervention and potential moderators or mediators of its effects could enhance our understanding of its efficacy and inform tailored interventions for different populations.

Given the brief duration of the intervention and the utilization of newly developed trans-diagnostic software, these results are promising and underscore the value of HOME_Positivity software to be easily integrated in traditional counselling. This integration is line with the swift transition of our society toward increased digitalization, also when delivering mental health interventions.

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Chapter 4: General discussion

4.1 Summary

This dissertation investigated the role of digital technologies in healthcare and mental health settings, with a particular focus on the use of VR. The first two chapters of this work focused on systematic reviews of the literature to identify the state of the art and literature gap regarding the use of digital technologies—especially VR—within healthcare and mental health settings. The first chapter showed that digital technologies can play a pivotal role in fostering empathy among healthcare professionals, including both medical students and experienced healthcare workers. However, challenges remain, such as the lack of a consistent definition of empathy across studies, which complicates the creation of effective training programs. Wearable devices, particularly VR, show promising potential by immersing users in patients' experiences. This feature facilitates perspective taking, allowing for deeper empathetic response. The chapter highlights the importance of integrating digital empathy training into medical education but underscores the need for tailoring these programs to users' specific needs.

Expanding beyond empathy and focusing more on enhancing eudaimonic well-being, Chapter 2 shifts attention to VR's role in promoting positive mental health, particularly its potential to cultivate well-being and positive mood states. This review of the literature confirms that VR has a well-established effect on alleviating negative symptoms, such as depression, anxiety, and stress. However, a similar conclusion cannot be drawn for the positive dimensions of mental health, such as well-being, positive emotions, and personal flourishing. These aspects remain underexplored in current research, highlighting a significant gap in the literature.

According to Keyes' definition (2002), mental health is a multidimensional construct consisting of two related but distinguishable components: the absence of mental illness (negative symptoms) and the presence of positive psychological functioning. The latter includes factors such as emotional well-being, psychological well-being, and social well-being, reflecting a state of flourishing rather than merely the lack of distress.

While many VR interventions focus on symptom reduction, there is limited exploration of how VR can actively enhance positive mental health outcomes (Li Pira et al., 2023). For example, studies rarely

evaluate the potential of VR to cultivate joy, gratitude, or meaningful social connections, despite its immersive and engaging nature, which seems well-suited for fostering such experiences. Moreover, most of the intervention present in the literature do not directly target those components. Expanding research efforts to assess these positive dimensions could align VR applications more closely with the principles of positive psychology and provide a more comprehensive understanding of VR's potential in promoting mental health and well-being.

Building on the insights from these initial chapters, Chapter 3 explores the practical applications of VR interventions, focusing on their implementation in clinical settings and their potential to support patient care, enhance well-being, and reduce psychological distress.

The pilot study presented indicates that the VR intervention delivered through our software, HOME_Positivity, had a positive effect on university students' mental health. Specifically, it demonstrated a decrease in psychological distress (measured by the DASS) and an increase in well-being (measured by the MHC and PANAS). These findings align with prior research highlighting VR's benefits for mental health while also demonstrating the unique capability of addressing both the reduction of distress and the enhancement of well-being simultaneously.

What sets our software apart is its specific focus on targeting key dimensions of mental health and well-being, particularly through the cultivation of personal strengths and resources, incorporating elements designed to foster resilience, self-efficacy, and positive emotional experiences, such as the resource box. This dual approach underscores the potential of tailored VR interventions to provide holistic mental health benefits, addressing both the alleviation of negative states and the enhancement of positive mental health.

4.2 Interpretations of main findings

4.2.1 Opportunities to explore

Chapter 1 investigated the effectiveness of empathy training and whether those training are more beneficial for medical students or established healthcare workers. The findings aim to guide the development of targeted interventions to enhance empathy in healthcare settings, ultimately improving patient care.

The studies employed two main types of digital technologies: wearable and non-wearable devices. Wearable devices, such as VR head-mounted displays (VR-HMD) and the SymPulse™ armband, offered a more immersive experience. Non-wearable technologies included mobile apps, computer-based training, and the Kinect motion sensor. These tools differed in levels of interactivity and in perspective—some oriented toward the doctor's view, others toward the patient's. This variation impacted participants' sense of immersion and presence, factors that influenced the effectiveness of empathy training.

In line with this view, most technologies effectively promoted empathy in participants, with the exception of three studies. Each of these exceptions utilized less immersive, non-wearable technologies (Hess et al., 2022; Yao et al., 2022; Tong et al., 2017).

This immersive quality positions VR as an "enhanced imaginal system" (Vincelli, 1999; Vincelli et al., 2001), uniquely capable of facilitating transformative experiences that strengthen empathy and perspective-taking. The compelling nature of VR supports its role as an effective tool for empathy development, with research affirming its value across various contexts, including patient-clinician relationships and mental health applications (Riva et al., 2016; Lacle-Melendez et al., 2024).

Regarding the mental health applications, the findings from Chapter 3 highlight VR's general effectiveness in reducing negative symptoms across a variety of mental health disorders, such as depression (Falconer et al., 2016; Habak et al., 2020), anxiety (Geraets et al., 2019; Lindner et al., 2020; Rus-Calafell et al., 2013), and stress (Gaggioli et al., 2014; Matsumoto et al., 2021; Richesin et al., 2021). These results are consistent with existing literature emphasizing VR's potential to leverage immersive environments to foster emotional engagement and behavioral modification (Riva et al., 2016; Botella et al., 2012; Baños et al., 2012).

However, while VR interventions demonstrate efficacy in symptom reduction, evidence of their impact on positive functioning were encouraging but remains limited. In clinical practice and research, there remains an evident emphasis on symptom reduction rather than the enhancement of well-being, which may reflect an imbalance favoring traditional clinical frameworks over the positive psychology perspective (Sin & Lyubomirsky, 2009; Wood & Tarrier, 2010).

To address this research gap, we designed a pilot study, informed by the theoretical insights outlined in Chapter 2 and 3, to examine the feasibility and effectiveness of a VR intervention through the HOME software. This study aimed to promote positive functioning and well-being, aligning with positive psychology principles.

4.2.2 Promoting Eudaimonic well-being using technology

The development of our VR software intervention was informed by the framework of Positive Technology (PT), as outlined by Botella and colleagues (2012). PT emphasizes the use of digital tools to enhance quality of life, focusing on both hedonic and eudaimonic dimensions of well-being. This framework, rooted in Positive Psychology, advocates for the application of technology to increase wellness and build resilience by enhancing the user's emotional and psychological experiences. Key aspects of PT, such as immersion, interactivity, and positive content guided our software design to stimulate positive emotions and foster a sense of well-being. By leveraging immersive VR environments, we aimed to create experiences that align with the principles of subjective well-being—specifically the induction of positive emotions. As stated in the introduction of the present work, most of the VR software and interventions developed to date focus on inducing a positive mood guided by MIP principles or exposure therapies. Fewer studies (e.g. Kosa and Johnson, 2023; Chen et al., 2022; Huang et al., 2024) have specifically targeted the eudaimonic well-being.

Kosa and Johnson (2023) showed that interactivity, immersion, and meaningfulness each have cumulative, additive effects that contribute to reducing stress and enhancing emotional regulation. Their findings underscore the potential benefits of eudaimonic VR and point to the importance of integrating these qualities into software design.

In our pilot study, we applied these design principles to create a VR environment within the HOME_Positivity software to address symptoms reduction and promote positive functioning.

Eudaimonic well-being involves fostering a sense of fulfillment and connection to values (Ryff, 2017), which aligns well with interactive VR's capacity to simulate purposeful experiences and scenarios that promote introspection and growth. In developing the HOME software, several features have been designed with this dual emphasis on hedonic and eudaimonic well-being. For instance, interactive tasks within the VR environment encourage users to engage in activities that resonate with both enjoyment and self-reflective

growth, thereby integrating elements of positive psychology to support a more comprehensive model of mental health.

The *resource boxes* in the HOME software are designed as interactive modules that support both hedonic and eudaimonic well-being, facilitating emotional regulation, personal growth, and self-reflection within the VR environment. Each resource box serves as a repository, providing a variety of tools and resources that participants can explore. The therapist assigns specific guided activities or exercises based on the resource chosen by the participant. These resource boxes are carefully crafted to incorporate elements of positive psychology and gamification, inviting users to engage with resources grounded in the PERMA model—Positive Emotion, Engagement, Relationships, Meaning, and Achievement (M. Seligman, 2018).

Gamification introduces interactive and reward-based mechanics that not only make interventions more engaging but also foster sustained motivation and adherence. This aspect is particularly beneficial for youth populations, who are not only more familiar with but also more inclined toward using digital technologies in their daily lives (Bell et al., 2024).

Integrating VR within the HOME_Positivity software demonstrates a promising approach to addressing symptoms and promoting both hedonic and eudaimonic well-being. By aligning with positive psychology principles and leveraging the immersive potential of VR, the design fosters an engaging, purpose-driven environment that supports emotional regulation, personal growth, and introspection.

The unique opportunities of VR—its ability to create controlled, immersive, and adaptable environments—enable users to explore meaningful activities, build resilience, and connect with values in a way that traditional therapeutic methods often cannot. This convergence of technology and psychology presents exciting prospects for transforming mental health care, offering scalable, engaging, and impactful solutions for diverse populations.

In conclusion, the data from the pilot study suggests that VR interventions can effectively reduce psychological distress and simultaneously promote positive mental health, as indicated by improvements in the Mental Health Continuum and Positive Affect scores. These findings echo prior studies, which documented the efficacy of VR in decreasing psychological distress (see Riva et al., 2019 for a meta-review on the topic). However, in addition to that, our pilot study demonstrated a notable increase in well-being

indicators. These results contribute to the scientific debate on well-being promotion through positive technology (Li Pira et al., 2023), highlighting VR's potential as a tool not just for alleviating distress, but for actively fostering psychological strengths and resilience.

4.2.3 Challenges to address

The first chapter aimed to consolidate knowledge on the theoretical framework underscoring digital empathy training for healthcare professionals. To achieve this, we examined how empathy is defined and measured, which components are targeted, and the comparative effectiveness of various digital tools.

A primary finding from the review is the lack of a clear consensus on the definition of empathy as a construct. Many studies concentrate on technological applications but often lack a robust theoretical framework. This observation is consistent across psychological research involving VR. For instance, Freeman et al. (2017) noted that, while VR holds promise for treating mental health disorders, the field faces significant challenges, particularly methodological inconsistency and generally low-quality studies. Practical applications frequently take precedence over developing a unified theoretical foundation, leading to a fragmented research landscape. Similarly, Vasser and Aru (Vasser & Aru, 2020) further emphasized that inconsistencies in VR hardware and software within psychological research hinder the establishment of reliable and theoretically grounded findings.

These perspectives align with the results presented in Chapter 2, which highlighted the heterogeneous nature of studies encompassing diverse populations, including both clinical and nonclinical groups, treated with various VR protocols and assessed using different outcome measures. Together, these findings underscore the need for enhanced methodological rigor and theoretical integration in VR research to foster more robust and replicable outcomes.

The variety of measurement tools for constructs like empathy and positive functioning mirrors a central issue in psychological research on VR, namely substantial heterogeneity due to inconsistencies in measurement. As noted by Linden and Hönekopp (2021) this problem is common not only on VR research but more in general in psychological research. The authors argue that this heterogeneity reflects a lack of theoretical coherence and methodological alignment in the field. This is heterogeneity was also found in Chapter 2 and 3, with the scarcity of consensus on tools for measuring empathy (Chapter 2) and positive

functioning (Chapter 3) This diversity complicates comparisons and may fragment our understanding of empathy by focusing on different dimensions of the construct.

Another significant challenge lies in elucidating the mechanisms underlying the efficacy of virtual reality (VR). While immersion and a sense of presence have been widely recognized and documented in the literature, many studies lack appropriate controls, such as active control groups or comparisons between VR and other media. Consequently, even though a substantial body of research supports the effectiveness of VR interventions, important questions remain unanswered. For example: In what contexts should VR be preferred over traditional therapies? Does the sense of presence elicited by VR exceed that provided by other media and technologies? When is it more appropriate to use one approach over the other?

The novelty and expectations surrounding VR may lead participants to perceive greater benefits, inflating reports of improvement. In this sense Rosen and Davison (2003) highlight the importance of considering these effects to disentangle its genuine therapeutic benefits from those driven by novelty.

Crucially, ethical considerations and potential unintended consequences must also be addressed. While VR holds transformative promise, it may also pose psychological risks, such as derealization and depersonalization, especially in vulnerable populations. Accessibility barriers—such as cost, digital literacy, and equitable access—must be carefully considered to avoid deepening health disparities. Additionally, the highly immersive nature of VR raises important concerns about user data privacy, consent, and long-term cognitive impacts.

Madary and Metzinger (2016) propose a detailed framework for ethical VR use in both research and clinical settings. They highlight potential harms such as the blurring of real and virtual experiences, emotional overstimulation, and the long-term consequences of repeated immersive exposure. Their framework stresses the need for anticipatory ethics—guidelines that evolve alongside the technology—to ensure user safety and well-being (Madary & Metzinger, 2016).

Slater and Sanchez-Vives (2020) further emphasize that the sense of “presence” in VR can lead to real emotional and behavioral consequences, and therefore must be treated with the same ethical seriousness as real-life interventions. They advocate for establishing safeguards to protect users from harm, ensuring informed consent processes explicitly address the psychological intensity of immersive environments, and

developing transparent protocols around data collection and usage (Slater & Sanchez-Vives, 2020).Despite these challenges, VR offers more opportunities than drawbacks, making its rigorous study crucial—not only for clinical psychology but also for the ecological understanding and investigation of a wide range of psychological processes.

4.5 Limitations

A significant limitation of this study, consistent with prior research, is the high degree of heterogeneity in both intervention protocols and assessment measures. This variability complicates direct comparisons across studies, particularly due to the use of diverse methods for evaluating outcomes such as empathy and positive functioning. Furthermore, the inclusion of varied populations, spanning both clinical and nonclinical groups, exacerbates these challenges, hindering the ability to draw consistent conclusions or perform robust meta-analyses. This underscores the pressing need for standardized assessment tools and protocols to enhance comparability and facilitate more reliable synthesis of findings across future studies as highlighted above. Beyond these methodological issues, it is also important to consider broader critiques of VR as a tool for fostering empathy. As highlighted by Sora-Domenjó, C. (2022), while VR has the potential to evoke emotional responses, it may also lead to superficial or short-lived emotional engagement rather than deep, sustained empathic understanding. Ethical concerns—including the risk of manipulation or emotional exploitation—further complicate the use of VR in this context. Moreover, sustaining long-term empathic change through VR remains a significant challenge, particularly in the absence of standardized and validated assessment tools that can reliably track such outcomes over time (Sora-Domenjó, 2022). These considerations underscore the pressing need for not only methodological standardization but also critical reflection on the technological and ethical dimensions of empathy-focused VR interventions.

Finally, the last pilot investigation is subjected to several limitations. First, the small sample size limits the generalizability of the findings and increases the potential for type II errors, where significant effects might go undetected. Additionally, the lack of a control group restricts our ability to draw causal inferences about the intervention's effectiveness. However, this pilot gave us the opportunity to collect valuable qualitative feedback from the participants, in order to refine and improve the software. This step serves as an initial phase within a broader investigation, where the VR software will be tested on a larger

sample and compared to a control condition. This subsequent phase will allow for a more rigorous assessment of VR's specific contributions, providing insights into how it supports behavioral and emotional shifts in therapeutic contexts.

4.6 Future directions

4.6.1 Addressing challenges and limitations

In order to further enhance the field of empathy training and virtual psychological interventions, it is important to thoughtfully address existing methodological limitations and design challenges that may impact the robustness and applicability of current research findings.

To advance the development of effective empathy training and psychological interventions, future research could adopt a more theory-driven approach. This entails clearly defining the constructs and components central to the examined construct, explicitly detailing the methods and tools used to address each component, and providing a robust theoretical rationale for these choices. A unified theoretical framework would not only streamline the development of digital empathy training or virtual psychological intervention but also enhance cross-study comparability, allowing for more reliable and replicable findings. By prioritizing theoretical coherence and methodological alignment, researchers can reduce the field's current fragmentation, establish clearer operational definitions, and build a more cohesive body of knowledge.

Moreover, different methodological and design improvements could be implemented. The standardization of assessment tools and interventions should be prioritized across studies. The diversity of protocols and measurement tools used in existing research on empathy and VR interventions has complicated comparisons and limited the ability to conduct meta-analyses. By adopting standardized, validated measures for assessing empathy, positive functioning, and psychological outcomes, researchers can improve the comparability of findings and build a more cohesive evidence base that facilitates stronger conclusions about the efficacy of these interventions.

Moreover, there is a critical need for mechanism-based investigations. Most studies focus primarily on outcome measures without probing the underlying mechanisms that drive the effectiveness of VR and

empathy training. Future research should prioritize exploring these mechanisms of change to gain insights into how VR, for instance, promotes therapeutic benefits. Experimental designs that involve control conditions using non-immersive technology or immersive experiences with and without therapeutic intent would be valuable. Such comparisons could help to separate therapeutic effects unique to VR from placebo effects linked to the novelty or appeal of VR technology. Expanding sample sizes to include a broader range of participants with varying professional backgrounds, clinical needs, and age groups would improve the generalizability of findings. Additionally, by implementing longer intervention periods, researchers could assess the durability of changes in outcomes, such as negative affect or behavioral adjustments, which may require sustained engagement for meaningful impact.

4.6.2 Synergy between academia and industry

Finally, a key consideration for future research is addressing the cost and sustainability of VR intervention development. Building on the synergies between industry and academia offers a promising pathway to creating affordable, scalable VR tools that can be adopted widely in clinical practice. Thanks to the experiences and insights gained throughout the course of this PhD program, where I collaborated closely with a technology company, I realized how essential it is to merge the theoretical insights generated in university settings with the practical, application-oriented knowledge held by industry professionals. This collaboration not only helps bridge the research-to-practice gap but also ensures that the tools developed are grounded in solid evidence while being optimized for real-world use.

One of the significant challenges currently facing VR research in mental health is the proliferation of experimental software that, while innovative, often fails to meet the standards required for broad market adoption. Many prototypes remain confined to research labs or limited clinical trials, lacking the refinement, regulatory approval, and distribution channels necessary for implementation in mainstream clinical settings. This issue highlights the need for research teams to work closely with industry partners from the beginning stages of development, ensuring that each tool is designed not just for efficacy but also for scalability and ease of integration into diverse healthcare systems.

Moreover, fostering these collaborations aligns closely with the European agenda, which prioritizes initiatives that bridge academic and industry expertise. Many European grants are structured to incentivize

and support projects that emphasize such synergies, recognizing their potential to drive innovation while addressing societal challenges. These funding opportunities create a fertile ground for partnerships that combine cutting-edge academic research with the resources, technical expertise, and market insights of industry players. By tapping into these collaborative frameworks, researchers can access the necessary support to develop VR tools that meet the dual goals of scientific rigor and real-world applicability.

In moving forward, fostering partnerships between academia and industry could help VR intervention development, creating a pipeline that transitions from experimental prototypes to commercially viable, evidence-based products accessible to clinicians worldwide. This approach also opens up the possibility of integrating user feedback loops, enabling continuous improvement of VR tools based on insights from actual users—both clinicians and patients. Additionally, such collaborations can ensure compliance with regulatory standards, enhance dissemination strategies, and reduce the time required for innovative tools to reach the market. By aligning the goals of academic research with industry capabilities, the field can make significant strides toward transforming VR-based mental health interventions into practical, scalable solutions for global healthcare systems.

5.Conclusion

This dissertation explored the transformative potential of digital technologies, particularly VR, in healthcare and mental health settings, with a focus on fostering empathy and promoting psychological well-being. Through systematic reviews and pilot studies, the research highlighted the promising role of VR in addressing both negative and positive dimensions of mental health. While VR has demonstrated considerable success in reducing psychological distress, this work underscored the underexplored opportunities for leveraging VR to actively enhance eudaimonic well-being and foster positive functioning.

The findings emphasize the importance of integrating theoretical frameworks, methodological rigor, and interdisciplinary collaboration to advance the development of VR interventions. Key challenges identified include the lack of standardized definitions and measurement tools, limited understanding of underlying mechanisms, and the difficulty of translating experimental prototypes into scalable solutions. Addressing these gaps is essential to build a cohesive and replicable evidence base.

Moreover, this dissertation underscores the critical role of academia-industry partnerships in bridging the research-to-practice gap. By leveraging such opportunities, future research can create scalable, cost-effective VR tools that enhance accessibility and impact.

In conclusion, the research presented in this dissertation contributes to the growing body of evidence supporting the efficacy of VR in mental health care and advocates for a balanced approach that combines reducing distress with actively promoting well-being.

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