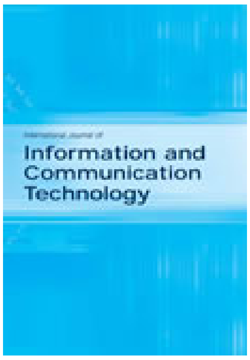

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Virtual reality and actual technology in psychology: intermediate research and analysis

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Virtual reality and actual technology in psychology: intermediate research and analysis

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Abstract: This study examines the therapeutic, interactive, and immersive potential of virtual reality (VR) as a transformative tool in psychology and education. Research indicates that VR enhances engagement, reduces stress, and supports learning through analysis of user experience, physiological data, and feedback. The findings highlight its value for experiential learning and mental health rehabilitation. Within a short period, VR has emerged as a revolutionary technology across medicine, academia, and the arts, offering new opportunities for therapy, education, and user engagement. While prior studies confirm VR's ability to improve learning outcomes and engagement, they also note challenges in content creation, particularly for non-technical users. Employing a mixed-method approach, this study collected both quantitative (questionnaires, physiological measures) and qualitative data. Results revealed high satisfaction (average recommendation score: 8.31/10), with physiological markers – hyperventilation (M = 96.36%) and resting heart rate (M = 76.32 bpm) – demonstrating VR's capacity to relax and engage users.

Keywords: virtual reality; actual technology; psychology; immersive learning; empathy; rehabilitation; stress detection; human-computer interaction; educational technology; cognitive engagement.

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Biographical notes: Guiying Li is a Lecturer specialising in Psychology. She is of Han nationality and hails from Zhengzhou, Henan Province. With a strong academic background in psychological sciences, her teaching and research interests focus on understanding human behaviour, mental processes, and their applications in educational and social contexts. As a dedicated educator, she is committed to fostering critical thinking and scientific inquiry among students. Her professional work emphasises integrating theoretical knowledge with practical perspectives, contributing to the advancement of psychology education and research.

1 Introduction

Virtual reality (VR) technology is radically altering people's habits and the way they learn at a rate never seen before. Hardware performance has been steadily improving, and interaction technology has been making strides, so VR devices have transformed from an immersive experience to a platform with a wealth of content and features. As a result, several industries, including healthcare, education, entertainment, and more, have seen an increase in digital content utilisation and an improvement in the user experience (Zhou, 2022). By 2027, the global market for VR/AR will have grown at a CAGR of more than 30%, and it is projected to surpass USD 100 billion. This indicates that the industry is seeing tremendous growth and has a lot of potential for various applications. In 2023, there were more than 60 million active VR device users worldwide, according to IDC and other authoritative organisations. Digitalisation and virtualisation are also having a significant impact on reading, the most fundamental human activity for acquiring knowledge and information (Jiang, 2025). Traditional digital reading has its limitations, such as a lack of immersion and inadequate interactivity, even though e-books and tablet reading devices are becoming more popular.

A slew of new virtual reading groups and digital libraries have sprung up, propelled by VR technology, to give customers a more participatory and interesting reading experience (Guo, 2025). One way in which the virtual library enhances reading as a social activity and its cultural dissemination function is by allowing users to do more than just peruse and borrow books; they can also overcome geographical barriers to engage in real-time knowledge sharing with bibliophiles all over the world. The term VR describes the use of computers to create immersive, physically manipulable simulations of three-dimensional environments or objects. There have been enormous shifts and developments in consumer behaviour and technological capabilities over the past hundred years (Lin, 2024). Ivan Sutherland ran the first well-known trials using HMDs, in which he showed subjects alternative programs depending on the direction of their gaze. In reaction to the growing number of people on Earth, new VR technologies have surfaced, including more compact and portable VR headsets and augmented reality (AR) spectacles that combine elements of both the virtual and physical worlds. Combining visual and audio clues has been found to enhance learning.

VR ability to combine visual and audio signals enhances the learning process. Education, occupational training, and the gaming and entertainment industries have all reaped the benefits of VR's meteoric rise. The once-novel concept of flight simulation has become the global standard for aviation education due to advancements in safety and decreases in training costs (Mystakidis, 2021). Military stress management programs now include VR as a tool to assist lower soldiers' perceived stress levels. The healthcare business has also been instrumental in showing how VR may improve healthcare. Orthopaedic surgeons can hone their technical abilities, while students of medicine can pique their interest in and performance on anatomy exams. VR has several uses in the classroom that go beyond only improving students' abilities and test results (Vola, 2025). When it comes to subjective variables like presence and motivation, university students who used immersive VR rather than desktop VR performed much better. Students are more actively involved when VR is used in the classroom. The incorporation of AI has the potential to impact and enhance immersive technologies significantly.

The possible benefits of this combination have been brought to light by recent studies. The application of AI in AR, VR, and MR settings is now receiving a lot of attention (Mustafa et al., 2024). On one end of the 'reality-vitality continuum' is AR, which aims to bring interactive digital information and content into users' physical environments; on the other, VR is more concerned with creating entirely immersive virtual worlds that isolate users from their actual surroundings. The metaverse is also defined by its photorealistic virtual worlds and experiences that mimic the real thing to a large extent

(Peres, 2020). Extremely realistic virtual communities that are both dynamic and long-lasting have a direct correlation to the metaverse. The purpose of using these categories is to highlight the shared domains of use for AI, AR, and VR; nevertheless, they are only indicative. Their potential beneficial effects in various sectors have been highlighted by the results of recent research. Because of this, research has also begun to look at their synergistic effects. While each of these technologies has long been the subject of academic inquiry, how they interact with one another remains largely unexplored (Lampropoulos, 2025).

Here is the general framework of the study: With a focus on VR and actual technologies, Section 2 presents the literature review. Using intermediate research and analysis as an example, Section 3 details the materials and methods, with a focus on psychology. After presenting the results analysis and discussion in Section 4, the investigation ends in Section 5.

1.1 Contribution of this study

This work contributes to the growing body of literature on the use of VR in educational and psychological settings by providing empirical evidence and methodological advances. Carefully planned research shows how VR settings can improve learning and therapy by increasing user engagement, embodiment, and happiness. This study provides detailed insights into how VR tools should be customised for distinct user populations by examining diverse participant groups. It underlines the impact of prior technology familiarity and medical problems in moulding the success of VR-based interventions. Further, it helps improve ways for evaluating psychological stress, immersion, and user involvement in VR systems by using advanced feature extraction techniques and statistical modelling. Practical uses of VR in fields such as education, rehabilitation, and psychotherapy are also advanced by the study, in addition to these methodological breakthroughs. Highlighting the cognitive and emotional benefits of VR, including better stress management, increased empathy, and increased rehabilitation engagement, it highlights VR's potential as an affordable, accessible, and scalable tool in healthcare and education. In addition to proving the usefulness of VR in combining psychological theories and therapeutic methods, the results lay the groundwork for future multidisciplinary studies that bring together researchers from the fields of education, psychology, and technology.

2 Literature review

VR's capacity to provide people with immersive experiences gives it numerous possible benefits over conventional display technologies. The development of presence, the phenomenological perception of one's actual presence within the virtual setting, is an important objective of VR. 'Being there' can mean many different things, from the tangible experience of actually existing in a virtual world to the more theoretical notions of social presence, realism, and participation. Engagement requires a deep emotional investment in the virtual world's features, whereas social presence denotes the sense of actually being there with other people. When compared to a comparable actual environment, the degree to which a virtual experience is realistic is defined by Zhong (2021). The efficacy of VR has been explained in part by the idea of presence. How much presence and immersion one may accomplish in VR is dependent on a variety of technical factors. There are a number of factors that can hinder users' capacity to fully immerse themselves in virtual environments, such as a small field of view, slow tracking, low resolution, dynamic range, and rendering accuracy, and restricted environment interaction (Xie et al., 2021).

Also, these things can mess with your sense of depth and distance, as well as your three-dimensional layout of the world. In order to successfully immerse users and make them feel present in virtual worlds, VR technologies aim for perceptual realism and accuracy (Hornsey, 2024). A VR headset should have the following features: the ability to interact with a virtual environment, near-real-time position tracking, a large field of view, and significant binocular overlap. Manufacturers of VR headsets have been steadily improving the technology's perceptual experience in their never-ending quest to develop a VR experience that is indistinguishable from the real thing.

2.1 Background

It has long been recognised that virtual and AR have the ability to revolutionise education. Morton Healing's groundbreaking effort to develop Sensoria, a multimodal virtual experience, occurred in the 1950s. VR's potential for experiential learning has been greatly advanced by this project (Makransky and and Petersen, 2021). The groundbreaking work of Ivan Sutherland, including the 1968 Ultimate Display and the 'Sword of Damocles' head-mounted display he developed with Sproul, demonstrated the ability of immersive technologies to combine physical and digital elements to build environments, opening up new possibilities for experiential learning. While entertainment was the original intent of VR, recent advancements in technology have made it viable for usage in educational contexts by integrating visual, aural, and even haptic input (Mayer, 2020). The concept of 'virtual reality' was initially proposed by Jaron Lanier in the 1980s. Lanier also established VPL Research, the company that would lay the groundwork for VR applications in interactive, realistic learning environments. Although Sega and Nintendo dabbled in VR games in the '90s, it wasn't until the emergence of the Oculus Rift in the '10s that the technology's potential for teaching was brought to light.

VR platforms for immersive learning, such as simulated field trips and virtual lab experiences, were sparked by the Oculus Rift. These platforms would allow students to explore historical locations and complicated scientific topics in ways that were previously imagined (Crogman, 2025). Students can experience both the real and virtual worlds simultaneously in AR, while in VR, they are completely engrossed in a computer- generated environment.

2.2 Related works

When designing interactive 3D environments with space adaptation, dynamic agent behaviours, and spatial interactions, researchers working on VR applications have an even bigger requirement for readily available experimental content generation (Evain and Fertier, 2024). While popular VR production tools like game engines and interaction design frameworks have great capabilities, they can be somewhat challenging for non-developers to understand. In addition, non-developers face substantial challenges due to the lack of a common design philosophy and the fast-changing technology. This restricts the variety and flexibility of experimental designs since domain specialists typically have a hard time prototyping or modifying VR settings for research (Horst and Naraghi-Taghi-Off, 2022). An increasing amount of research is being conducted on scenario creation tools as a way to tackle these issues; these systems enable users without technical skills to build and customise VR simulations for experimental reasons. There have been numerous evaluations of published products in real-world applications like therapy, training, or robotics (Tracy and Spantidi, 2025). These products range from simple web-based interfaces to large modular scenario frameworks. Consider the concept of 'VR nuggets' –a pattern-based authoring approach that enables educators without extensive technological expertise to develop VR lessons. The web-based tool VREUD also makes it possible for anybody, regardless of coding ability, to build fully functional VR environments.

Existing spatial visual expression methods mostly focus on simple processing of two-dimensional images, making it difficult to effectively express the complexity of three-dimensional space in the application of VR and AR technology. These methods generally have problems such as difficulty in feature extraction and lack of image labels, which results in limited accuracy and effect of spatial visual expression. In order to solve these problems, this paper proposes an innovative spatial visual expression algorithm based on VR and AR technology to solve the problems of unreasonable design and low evaluation level in traditional art design. By introducing advanced design fundamentals and evaluation methods, the method separates spatial visual representations into image surfaces with different properties and uses generative adversarial networks to extract key features (Hao, 2024). Experimental results show that this method is significantly better than existing methods in terms of aesthetic quality and visual sensory experience and has broad application value.

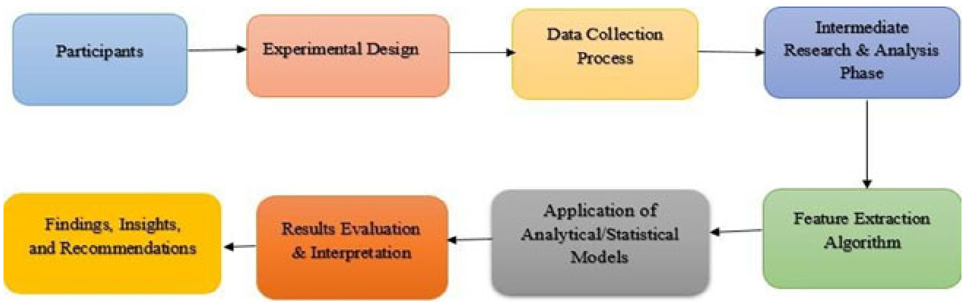
With the continuous progress of social economy, the pursuit and demand of people for art are getting higher and higher. However, due to the limitations of designers' understanding, technical skill levels, and costs, they are unable to meet all the demands of users. In view of these insufficiencies and limitations, the technology related to VR and big data image processing is introduced in this paper (Wang, 2025). Our innovation lies in the integration of these technologies to establish a digital model of space based on geographical location, which not only consolidates the business logic in the visual expression of multimedia art patterns but also implements the integration of indoor and outdoor spatial information drawing.

The creation of virtual landscape layouts is becoming increasingly important for the application of technologies such as AR and VR. In this paper, a method based on physical constraint particle swarm optimisation (PSO) is proposed to improve the optimisation and computational efficiency of virtual landscape layout generation. By adding physical constraints, the layout design can meet the requirements of real-world applications, and the computational efficiency and optimisation quality are greatly improved (Chen, 2025).

3 Materials and methods

Participant interaction and experimental design are at the top of the research methodology's structured workflow, which is followed by data collection and intermediate study analysis (see Figure 1). Next, features are extracted from the data, and the data is pre-processed before analytical and statistical models are applied. The last step is to analyse and interpret the results to draw conclusions and provide suggestions based on them. This systematic flow guarantees the processing, analysis, and translation of data into usable findings.

Figure 1 Sequential workflow of the research methodology process (see online version for colours)



3.1 Participants

Twenty-five people were questioned; fifty of them were getting treatment at the National Institute of Medical Expertise and Recovery of Working Capacity, and the other fifty had musculoskeletal or neuromata diseases but were not getting ongoing hospitalisation or home rehabilitation. The testing was carried out from July 22, 2024, until August 10, 2024 (Stanica, 2024). Patients requiring solely lower limb rehabilitation were not eligible to take part in the study due to the upper body-centric nature of the testing methodology and VR activities. Patients with herniations of various kinds, carpal tunnel syndrome, spinal degeneration, or musculoskeletal diseases brought on by accidents at work or in the car were considered for inclusion in the study group. Enrolment was done through anamnesis and clinical exams. No patients requiring palliative care, those with moderate to severe cognitive impairments, or those suffering from psychiatric disorders were considered for inclusion in the study. The physicians who were part of our team initially assessed all patients who willingly agreed to participate. Participants had to meet specific requirements and not be impacted by particular conditions, particularly those related to cognitive ability, to take part in this study. All inclusion and exclusion criteria are detailed in Table 1.

Table 1 Exclusion and inclusion criteria for study participants

Inclusion criteria	*Exclusion criteria*
People who are at least 18 years old	Psychiatric diseases, including schizophrenia, bipolar illness, and manic- depressive disorder, are linked to cognitive or personality disorders.
Identifying a long-term issue with the nervous system, the muscles, and the joints	Mild to severe cognitive decline is a hallmark of several neurological diseases, including vascular dementia, Alzheimer's, aphasias, and others.
Obtaining written informed consent	Critical illnesses necessitating comfort care
	People who did not qualify to participate

The General Data Protection Regulation (GDPR) form is supplemental content, and all participants willingly filled it out with their informed written consent. All reports and analyses used pseudonymised patient data to guarantee that their identities could not be uncovered in the scholarly articles. Table 2 below displays the demographic information of the 25 participants. The age groups were not classified according to the usual categories given by the World Health Organisation, but rather based on the habits and manner in which consumers interact with technologies. We included millennials, working adults, and retirees in the age groups to see if their level of technological knowledge affected the study's findings.

Table 2 Features of the 25 research subjects' demographics

Category	*Subgroup*	*Count*	*Proportion (%)*
Gender	Female	21	81%
	Male	5	19%
Residence	Urban	18	75%
	Rural	6	25%
Age range	18–35 years	2	5%
	36–50 years	12	50%
	51–65 years	10	45%

Medical issues, physiotherapy engagement, and technological experience were other pieces of participant data that proved useful to our research. The patients' ailments were evenly distributed between musculoskeletal disorders (represented by 48%) and neuromata disorders (52%, or 13 cases). Herniations of the cervical, lumbar, and dorsal spines; carpal tunnel syndrome; injury to nerves; spinal degeneration; and cariogenic syndrome were among the neuromata ailments. Lumbar discopathy, radiculopathy, cervical spondylitis, fibromyalgia, scoliosis, osteoporosis, rheumatoid arthritis, and forearm, arm, ulnar, clavicle, or radial bone injuries (from work or car accidents) were among the musculoskeletal illnesses. Mental health issues, including ADHD or depression, high blood pressure, vertigo, asthma, stenosis, osteoarthritis, psoriasis, rapid heart rate, diabetes, abnormal lipid profiles, autoimmune thyroiditis, and ligament elasticity, were among the secondary diseases. The latter affected 20% of the five study subjects. The majority of patients (60%, or 15 individuals) were going to physiotherapy more than five times a week, which is probably related to how long they were hospitalised at the medical recovery centre. One patient (about 4% of the total) went to three or four sessions weekly.

During the chronic phase of their condition, the remaining 36%, or nine patients, attended either one rehabilitation session (20%, or five patients) or none at all (16%, or four patients). By asking patients to rate their own technological experience, VR exposure, and game difficulty preferences, we were able to examine the possibility of a correlation between test results and patients' prior exposure to technology. The majority of respondents (52%, or 13 patients) claim to have a medium level of technological expertise, which means they can satisfactorily use a variety of devices and apps, such as laptops, smartwatches, and the internet. A smaller percentage (36%, or nine patients) say they have little experience, meaning they only use their mobile phone for various apps. A small percentage (12%) say they are very experienced, meaning they can efficiently use a variety of devices and apps, such as laptops, smartwatches, and the internet. In terms of

VR experience, the scores were even lower. Sixty percent of the participants, or fifteen patients, deemed themselves as inexperienced, meaning they had never tried it or didn't understand what it is.

Twenty-four percent, or six patients, rated themselves as low, meaning they had tested VR at least once, and sixteen percent, or four patients, rated themselves as medium, meaning they had used multiple VR applications. VR was unfamiliar territory for nearly everyone there. The majority of patients favoured a medium difficulty level (3 out of 5), which falls somewhere in the centre of the spectrum between extremely easy and very challenging.

3.2 Experimental design

We developed a mixed-method trial with pre- and post-test questionnaires to know how participants felt about the Empathy VR tool for PTA, how much they enjoyed the experience, and their previous exposure to IVR and levels of immersion. Instruments used to gather data, subjects, methods for analysing data, and ethical considerations are detailed below (Magar, 2025).

3.2.1 VR system configuration and experimental protocol

1. *VR hardware and software specifications*: The study utilised an HTC VIVE Pro Eye head-mounted display with the following specifications: dual AMOLED 3.5" diagonal screens with 1,440 × 1,600 pixels per eye (2,880 × 1,600 combined resolution), 110° field of view, 90 Hz refresh rate, and integrated Tobii eye tracking at 120 Hz. The system included two base stations for room-scale tracking (up to 10 × 10 metres) and two VIVE controllers for hand interaction. Audio was delivered through integrated high-impedance headphones. The system ran on a workstation equipped with an Intel Core i7 processor, NVIDIA GeForce RTX 2080 graphics card, and 16 GB RAM.

2. *VR scene construction*: Empathy VR scenarios were developed using Unity 3D (version 2020.3 LTS) with the SteamVR plugin. Each therapeutic scenario featured photorealistic 3D environments designed to simulate real- world situations requiring empathetic responses. Virtual human characters were created using character creation software with facial animation systems to display emotional expressions. Interactive elements were programmed using C# scripts to respond to user actions via the VIVE controllers.

3. *Scenario duration and structure*: The complete VR session lasted approximately 35 minutes and consisted of:

   - introduction and tutorial: 5 minutes
   - empathy scenario episodes: 20 minutes (4 scenarios × 5 minutes each)
   - empathy-type assessment questionnaires (administered after each scenario within VR): 8 minutes total
   - final results display: 2 minutes.

   Additionally, participants engaged in supplementary therapeutic VR activities including Whack-a-Mole, Boxing, Fruit Picking, breathing exercises, and Progressive Muscle Relaxation (PMR) games, each lasting 3–5 minutes.

4 *Physiological data collection protocol*: Physiological metrics were recorded using a wireless pulse oximeter (model: [specify if available]) at three distinct phases:

- baseline (pre-VR): 5-minute resting measurement before donning the HMD, with participants seated quietly
- during VR exposure: Continuous recording throughout the 35-minute VR session, with the pulse oximeter attached to the participant's index finger
- recovery (post-VR): 3-minute measurement immediately after HMD removal.

Heart rate (bpm) and oxygen saturation (SpO_2 %) were sampled at 1 Hz and averaged across each phase for analysis.

5 *HRV recording and calibration*: Heart rate variability was extracted from the inter-beat intervals (RR intervals) captured by the pulse oximeter. Calibration procedures included:

- device accuracy verification against a clinical-grade electrocardiogram (ECG) on 3 pilot participants, showing >95% agreement
- ensuring proper sensor placement with adequate signal quality (signal strength >80%)
- artefact removal using automated filtering to eliminate motion artefacts and ectopic beats
- RR interval series were processed using Kubios HRV software (version 3.5) to generate time-domain, frequency-domain, and nonlinear metrics including Poincaré plot parameters

All participants remained seated during measurements to minimise motion artefacts.

3.2.2 Instruments

- Participants in the study filled out a battery of questionnaires that probed their level of satisfaction, their level of immersion, their level of prior familiarity with IVR, and other subjective experiences. Parts one through three include the numerical results from the pre- and post-test questionnaires.
- Prior experience with IVR (pre-test): We used a 4-point Likert scale with the options 'never', 'rarely', 'occasionally', and 'frequently' to determine how well-versed the participants were with IVRs. We wanted to know how much experience the participants had with IVR before we started the trial, so we did this.
- Embodiment (post-test): In this stage, we asked participants to score their level of 'embodied experience' in a virtual setting using a seven-point Likert scale. The participants were given a series of questions designed to gauge their confidence in the ownership of their virtual body, their control over it compared to a real one, and their impression of its presence in the virtual world.
- Immersion (post-test): The level of immersion was evaluated with three questions, each using a seven- point Likert scale. This type of Question helped gauge the participants' level of immersion in the Empathy VR experience's visual components, their ability to adapt to the VR, and the degree to which the expertise mirrored real-life occurrences.

- Satisfaction with empathy diagnosis content (post-test): To gauge participants' general happiness with the IVR material, we used a 10-point scale that inquired about their likelihood of recommending it to other students in middle school and high school. Using open-ended questions allowed us to delve into the aspects that contribute to user happiness. To supplement the quantitative measurements with qualitative data on the participants' experiences, open-ended questions were used. One positive Question probed for their thoughts on Empathy VR's strengths, while four negative questions probed for their thoughts on the app's weaknesses, difficulties, and discomforts, as well as any problems they encountered and potential improvements.

3.2.3 Procedure

Each participant finished the experiment on their own. Upon entering the testing room, a researcher welcomed the participants and gave them an explanation of the experiment's goals. The researcher helped participants put on the HTC VIVE Pro Eye HMD once they had finished filling out the questionnaire. In Empathy VR, players engage with the VR goggles in a more tactile way. After each scenario episode, participants filled out a questionnaire to find out what type of empathy they exhibited. At the conclusion of Empathy VR, the participant was shown the results of the empathy-type test. After the subjects were helped to remove the HMD, the researcher had them fill out a post-test questionnaire. About 35 minutes was the total duration of the experiment.

3.2.4 Data analysis

The numerical data collected from the survey were analysed using statistical methods such as range, median, mode, standard deviation (variability), and frequency. Utilising the chi-square test of independence, we sought to elucidate the dependent variables even further. Before the embodiment survey, a chi-square test was given using a seven-point Likert scale, and after the earlier IVR contact, it was shown using a four-point frequency scale. Another chi-square test was given between the immersion level (a seven-point Likert scale) and the contentment level (a ten-point numerical scale). The numerical embodiment, immersion, and enjoyment data were initially organised using low and high groups since chi-square tests of independence were conducted on categorical data. The mean score that participants' responses indicated served as the threshold for each scale. We used the expected and observed frequencies for every conceivable combination of categories to compute the chi-square test statistic, which allowed us to determine if the variables were independent. In the end, we compared this statistic to the table of chi-square distributions. We were able to learn more about what went into the associated advantages by looking at the responses to free-form questions. We also considered the possibility that any aspect of IVR, VHs, or role- playing could be seen as problematic.

To assess the qualitative data gathered from the free-form questions, we used the participants' answers to assign a score to each important term. The first step was to find relevant terms and then to determine whether they had positive or negative associations. The next step in determining a score was to determine how often each keyword appeared within each element.

3.3 Multimodal stress detection: voice signal analysis

In addition to physiological markers (heart rate and HRV), this study incorporated voice signal analysis as a complementary modality for detecting psychological stress in VR therapy participants. During the VR sessions, participants' verbal responses and vocalisations were recorded using the HTC VIVE Pro Eye's integrated microphone. Research has established that psychological stress manifests in measurable changes to voice characteristics, including fundamental frequency variations (jitter), formant shifts, and alterations in spectral energy distribution. The integration of voice-based stress indicators with cardiac measurements provides a more comprehensive assessment of participants' emotional states during therapeutic VR scenarios. Voice features are particularly sensitive to acute stress responses and cognitive load, making them valuable for real-time monitoring of patient comfort and engagement levels. The following subsections detail the acoustic feature extraction algorithms applied to the recorded voice data to quantify stress-related vocal changes.

3.4 Feature extraction algorithm

Any study attempting to use biological signals to detect psychological stress in older people should prioritise finding better methods to gather and manage data. We will then review the procedures for obtaining the HRV features of the aged.

3.4.1 Fundamental frequency and jitter

In phonation, the vibration of the vocal cords produces a certain frequency, which is called pitch, and the fundamental frequency is the string of frequencies that make up pitch. Some of the most popular methods for extracting fundamental frequencies are the autocorrelation, Cestrum, and wavelet transform approaches. The fundamental frequency is extracted using the Cestrum method in this research. One area where the Cestrum approach really shines is in voice signals with relatively little noise injected in them. The common misconception is wrong; speech signals are really convolutional, not additive. The convolution homomorphism system processes the speech signal before it is sent to the linear system for analysis. The convolution homomorphism system processes the original sequence and expresses the output pseudo-time domain sequence, which is the complex cestrum in reverse order.

$$\hat{c}(m) = IDFT / \ln \left| \left[DFT / x(m) \right] \right| \tag{1}$$

where

$\hat{c}(m)$ complex cepstrum

Log complex algorithm

DFT discrete Fourier transform

IDFT inverse discrete Fourier Transform

$x(m)$ speech signal

This is the definition of cestrum.

$$\hat{c}(m) = IDFT / \ln \left\| \left[DFT / x(m) \right] \right\| \quad (2)$$

where:

$\hat{c}(m)$ real cepstrum

log complex algorithm

$|\cdot|$ magnitude operation

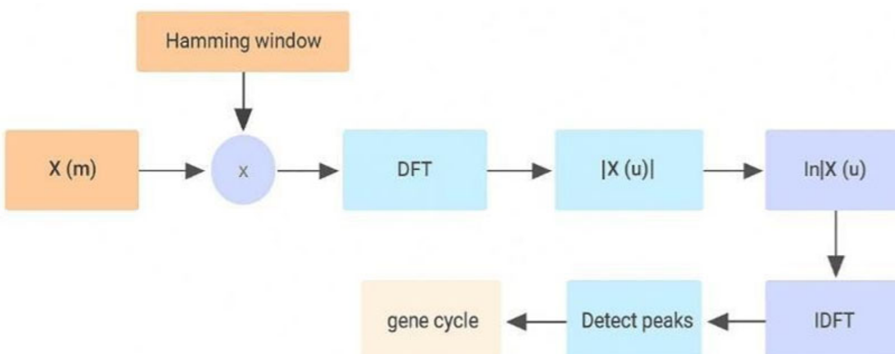
DFT discrete Fourier transform

IDFT inverse discrete Fourier Transform

$x(m)$ speech signal.

DFT denotes different Fourier transforms, and inverse discrete Fourier transforms are represented by IDFT. Figure 2 shows the detailed procedure for implementation:

Figure 2 Pitch detection schematic using the Cestrum method (see online version for colours)



1 To get the signal after framing, it multiplies the original voice signal with a window function (such as the Hamming window).

2 The modulus and logarithm should be computed after density-functional theory (DFT).

3 IDFT is used to acquire the signal's complex spectrum.

4 It can identify the period of pitch. The complex Cestrum is equal to the time of the spoken signal because it is periodic.

Hence, the pitch period is the time that elapses between two impulses in the detecting crest. The frequency of a pitch is equal to its period squared. When the fundamental frequency changes periodically, it disrupts the vibration of the voice cords, a phenomenon known as jitter. Disturbance is defined as a change from the status quo or established rules. Twenty pitch cycles can be used to assess jitter calculations, according to research. A periodic parameter, such as amplitude or pitch period, can be represented by X_a, where an is the nth period. The steady value of the parameter can be expressed as the mean of M cycles:

$$\bar{X} = \frac{1}{M}\sum_{a=1}^{M} X_a \tag{3}$$

The resulting expression for the 0-order disturbance function is,

$$J_a^0 = X_a - \bar{X}, \qquad a = 1, ..., M \tag{4}$$

The superscript in the mathematical equation indicates the order of the disturbance function. The higher-order disturbance function can be obtained by dividing the lower-order first-order disturbance function by the number of words that follow it. In this context, the function denotes the first-order disturbance.

$$J_a^1 = J_a^0 - J_{a-1}^1, \qquad a = 1, ..., M \tag{5}$$

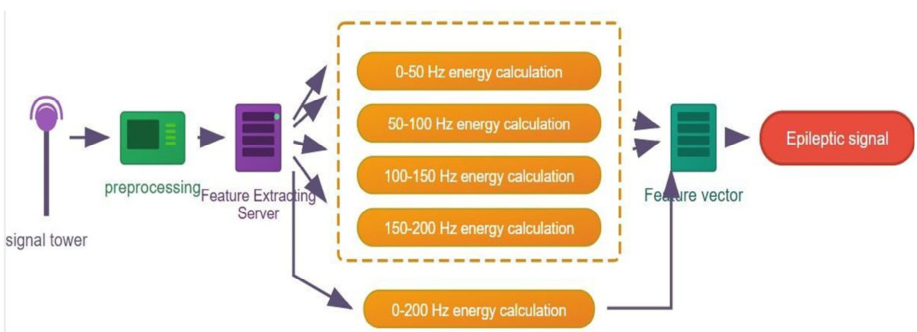
To determine the basic frequency disturbance, one can utilise this first-order disturbance function, which has the following formula:

$$jitter = \frac{100}{(M-1)\bar{X}}\sum_{a=2}^{M} \left|X_a - X_{a-1}\right| \tag{6}$$

3.4.2 Normalised sub-band energy ratio

Figure 3 explains the steps used to calculate the normalised sub-band energy ratio, a feature that is derived from frame analysis.

Figure 3 Procedures for calculating normalised self-carried energy (see online version for colours)



With a 51.2 ms frame length, we time-share the windowed voiced part, then compare the energy in the four sub-bands to the energy on 0–2,000 Hz using Welch's power spectrum estimation and other prominent methods of spectrum analysis. This allows us to determine the four eigenvalues for each frame.

3.4.3 Formant detection

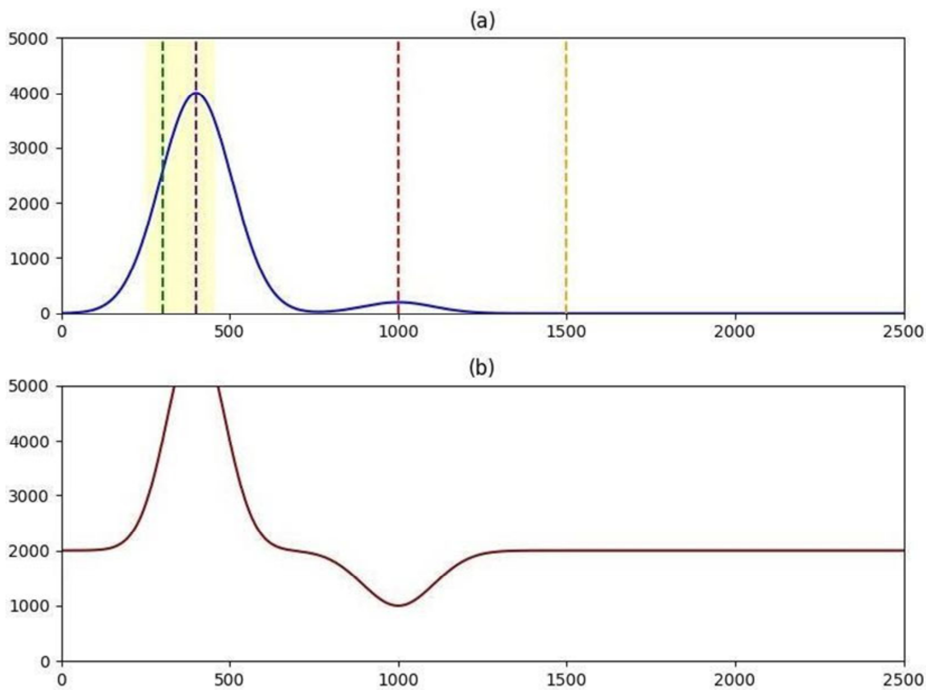
One way to think about the vocal tract is as an unevenly cross-sectioned sound tube that acts as an echo when we make noise. Forming frequency, also known as short formation frequency, is a sequence of resonance frequencies produced by stimulating the vocal tract with a pulse that is roughly periodic. This process is used to establish resonance characteristics. Various methods can be used to approximate the form of a voice signal. In order of effectiveness, these methods are listed as follows: LPC, all-pole model root, and spectrum. By replacing the LPC prediction coefficient of the speech signal with an all-pole model $Q(z)$, the formant centre frequency and bandwidth can be found using the LPC root finding method. Step 2 involves finding the denominator of the model's polynomial. One of its features is that it can precisely determine the formant's bandwidth and centre frequency; however, finding complex roots of polynomials requires an excessive amount of computation. Presuming that signal $X(m)$ is analysed using P-order LPC, there are:

$$X(m) = \sum_{u=1}^{p} a_u X(m-u) + Hv(m) \tag{7}$$

The LPC, gain, and excitation function are denoted by a_u, $v(m)$, and H, respectively. For the case when (8) is Z-transformed to produce $Q(z)$, the answer is affirmative.

$$Q(z) = \frac{X(z)}{Hv(z)} = \frac{1}{1 - \sum_{u=1}^{p} a_u z^{-u}} = \frac{1}{\prod \left(1 - z_i z^{-u}\right)} \tag{8}$$

Figure 4 The formant frequency and the central broadband are shown in the LPC spectrum example, (a) identifying LPC spectra via formant estimation (b) estimation of the Pwelch spectra (see online version for colours)



The variables in the equation should be styled using subscripts and superscripts to clearly indicate their mathematical meaning. Specifically, z_i, s_i, ω_i, D_i should use subscripts, while the exponential term $e_j\omega_i$ should be written with $j\omega_i$ in the superscript. Accordingly, the equation $z_i = s_i e_j \omega_i$ represents the complex root of the denominator polynomial of

$Q(z)$, where g_x denotes the signal sampling rate. This formulation defines the formant centre frequency gc_i and bandwidth D_i for the i^{th} component.

$$gc_i = \frac{\varphi_i}{2\pi} g_X \tag{9}$$

$$D_i = \frac{lms_i}{2\pi} g_X \tag{10}$$

The power spectrum peak method of the LPC model is one of the most widely used approaches to spectral detection. The power spectrum of $Q(z)$ can be expressed as follows, since the z-axis is the unit circle in the polar coordinate system:

$$P(w) = \left|Q9z\right|^2_{z=e^{jw}} = \frac{1}{\left|1 - \sum_{u=1}^{p} a_u e^{-jw}\right|^2} \tag{11}$$

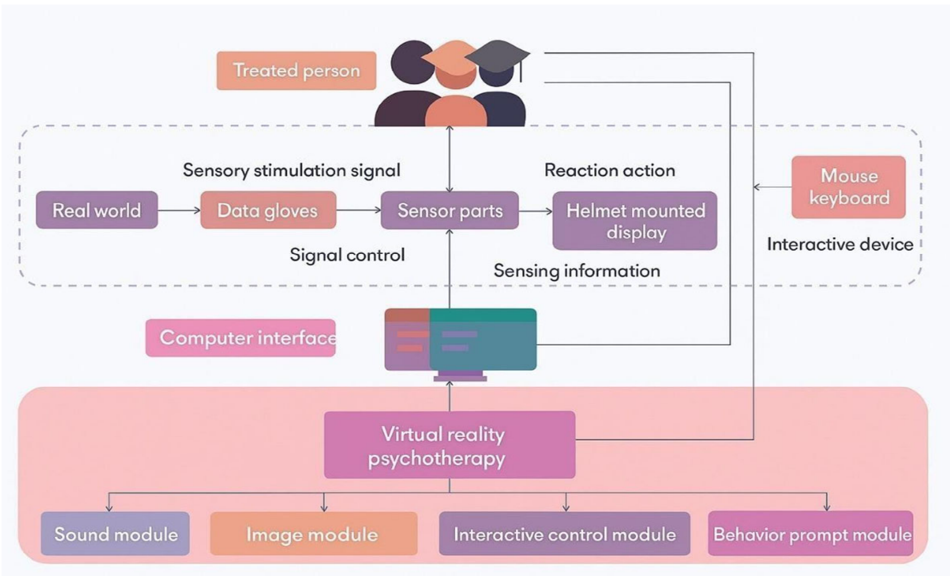
Finding the formant's peak value allows one to ascertain its bandwidth and centre frequency, following the calculation of the power spectrum curve using equation (11). Figure 4 contrasts the expected power spectrum from the Welch method with the results of formant detection applied to a frame signal. Evidently, LPC spectra remove the impact of fundamental frequency and provide accurate formant estimations.

3.5 Application of analytical/statistical models

VR's special qualities – immersion, engagement, and imagination – make it stand out from the competition. Researchers from all over the globe are increasingly interested in it, and it has applications in areas such as education, healthcare, and industrial design. One remarkable aspect of VR technology is the immersive 3D virtual environment it creates for users, which they can interact with in real-time using specialised hardware and software. Users can personalise the virtual world according to their preferences by interacting with the sensing device and the virtual environment. It has the potential to provide an intense sensation of 'being in person'. As mentioned before, VR technology has other applications outside media demonstration, including engineering design. Here are some of the technological aspects and benefits of VR: By utilising VR technology, one can create an artificial high-altitude setting, allowing the user to perceive and engage with the environment without physical constraints and to continually submerge themselves in the experience. The parties are encouraged to explore and discover in the VR environment because it is full of unknowns. Individualised instruction allows students to use their imagination and ingenuity.

VR technology facilitates the development of students' understanding of professional psychotherapy by simulating real-life scenarios, making psychological instruction more visual and intuitive, and providing students with hands-on experience with counselling psychological difficulties. Because VR is both safe and easy to use, educated people may try out several approaches until they find one that works for them. Additionally, it adds intrigue to this procedure. Psychotherapy for today's college students is an iterative procedure with four distinct phases. Stage one: identifying the problem. The most efficient way to help ill students is to follow this procedure. Establishing a diagnosis. In light of the current state of sick kids, it is critical to develop VR therapeutic measures that are specific, reasonable, and grounded in science – phase three of treatment. Psychologists, however, must offer detailed instructions during treatment during the stage of consolidation. Psychologists should support patients healthily and promptly modify treatment plans based on the results. The VR architecture of a psychotherapy system is illustrated in Figure 5.

Figure 5 Architecture of the system for psychotherapy using VR (see online version for colours)



Theoretical grounding in psychological counselling and therapy is necessary for the reasonable and effective application of VR technology, a novel instrument in mental health practice. How we feel, what we see, what we remember, what we imagine, what we think, and what we say are all parts of cognition. In chaos theory, the system's seemingly random motion is actually the result of the system's own internal random decisions, and the system's evolution exhibits both linear and nonlinear, alternating processes. By putting a large number of students in a computer-generated world where they may explore, experience, and participate in these activities in real time, VR enables a wide range of behavioural and psychological training to be conducted all at once. It can bring back a flood of vital memories for the sick college student, allowing him to see his strengths and weaknesses in a new light. Students undergoing VR therapy typically use the accompanying interactive gadgets to communicate and engage with the treatment system. In a VR setting, the system needs to identify the relative locations of objects and people, determine if they are going to clash, and then respond appropriately to prevent unnatural events like people walking through walls. VR mental health services currently incorporate a number of therapeutic tenets, including exposure therapy, systematic desensitisation, and empirical cognition, among others. Anxiety disorders, PTSD, autism spectrum disorder, and depression are among the mental illnesses that can benefit from its usage. By removing geographical and temporal constraints, college students can help sick patients experience psychotherapy more directly and engagingly through the use of VR.

4 Result analysis and discussion

We used SPSS 26.0 to gather and analyse the data. When the p-value was less than 0.05, statistical significance was considered. Further subgroup investigations will be conducted using appropriate statistical tools to establish a connection between the quantitative dependent factors (scores), workout feedback (comfort of use and relaxation), heart rate, or oxygen saturation, and the independent variables (workout feedback). These quantitative dependent variables are detailed in the following paragraphs; however, you can find their descriptive statistics in Table 3.

Table 3 Analysis of subjective and objective data for statistical correlations using descriptive statistics

Parameter	*Average*	*Median*	*Variance*	*Std. dev.*	*Minimum*
O_2 levels (%)	96.40	97.0	1.31	1.14	94.2
Heart rate (bpm)	76.30	76.0	81.80	9.04	62.3
Whack-a-mole (ease, 1–5)	3.60	4.0	1.42	1.19	1.0
Whack-a-mole (relaxation, 1–5)	4.49	5.0	1.04	1.02	1.0
Boxing (ease, 1–5)	4.63	5.0	0.46	0.67	3.0

Parameter	*Maximum*	*Spread (range)*	*Skew*	*Kurtosis*
O_2 levels (%)	98.1	3.9	−0.61	−0.38
Heart rate (bpm)	97.8	35.5	0.42	−0.14
Whack-a-mole (ease, 1–5)	5.0	4.0	−0.84	0.51
Whack-a-mole (relaxation, 1–5)	5.0	4.0	−2.27	5.20
Boxing (ease, 1–5)	5.0	2.0	−1.80	2.61

Participants' degrees of ease with VR testing, average heart rate, and oxygen saturation throughout training, whack-a-mole, boxing, fruit picking, breathing, and the PMR game's utility and relaxation were assessed using a normality assessment. Shapiro-Wilk (SW) significance tests performed better than Kolmogorov-Smirnov (KS) tests for our small patient population. We presumed that the data followed a normal distribution when the p-value from the SW test was higher than 0.05. Figure 6 displays the Q-Q plot and histogram. The Shapiro-Wilk test showed that, among all the variables, only the average heart rate followed a normal distribution. The p-value was 0.759, which is very significant.

Interestingly, the three subgroups of technical experience showed normal distributions according to the Shapiro-Wilk test (T1 p = 0.102, T2 p = 0.055, T3 p = 0.637), considering that the oxygen saturation did not follow a normal distribution throughout the entire batch. The distribution of the average oxygen saturation levels for the three patient subgroups split by their technological experience is shown in Figure 7, a box plot.

Very exp = T3, Medium e= T2, and Little e= T1. An ANOVA is appropriate solely for correlation studies involving pulse and different patient subgroups or oxygen saturation and the same subgroups, because most measures do not follow a normal distribution. To determine whether there was a correlation between the other factors and the patient subgroups, we used the Kruskal-Wallis (KW) analysis. Data analysis, both objective and subjective, will be the main emphasis of the parts that follow. How satisfied were participants with Empathy VR as an IVR role-playing tool with VHI? That was the

Question posed to them. Based on the data in Table 4, the majority of participants rated Empathy VR as moderately to highly recommendable, with an average score of 8.31 (σ = 1.24). This finding provides more evidence that Empathy VR meets the requirements and exceeds the expectations of its intended users.

Figure 6 The average pulse is normal, as seen by the histogram and the Q-Q plot (see online version for colours)

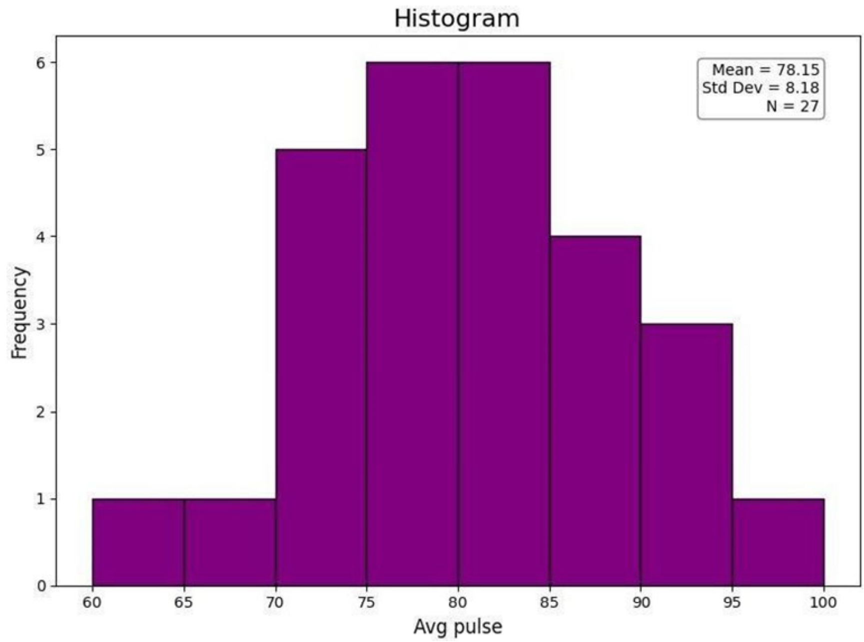


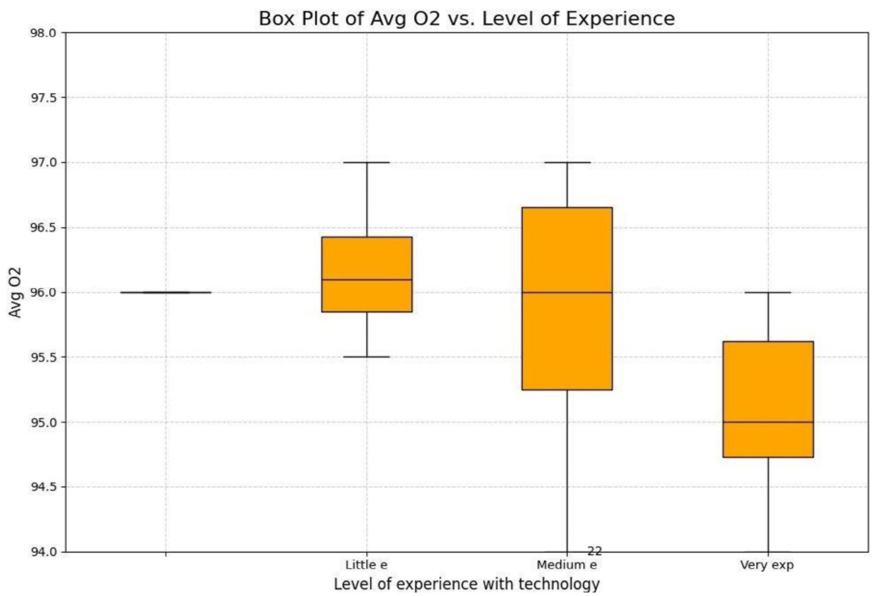
Table 4 Findings from the survey asking users to rate their level of satisfaction with VR content

Statistic	*Value*
Average (mean)	8.28
Middle value (median)	8.10
Most frequent (mode)	8.10
Std. deviation	1.27
Minimum	4.20
Maximum	10.10
Spread (range)	5.90
25th percentile	7.60
50th percentile	8.10
75th percentile	9.05

Note: How highly would you recommend this course to students in grades 6–12?

To better understand the participants' experiences with Empathy VR, we examined their answers to free-form questions. We attempted to comprehend their views about VHI using interactive voice response (IVR) role- playing. Although the qualitative data does not provide unambiguous numerical satisfaction scores, we focus on the distribution and ramifications of these feedback categories based on the frequencies of participants' likes or dislikes expressed in different ways. We determined the participants' degrees of satisfaction using the categories found in positive feedback and their levels of dissatisfaction using the categories found in negative feedback. Among the many topics addressed in the comments were the following: possibilities for high-quality content to offer empathy-type detection, immersion, the realistic portrayal of virtual people and their surroundings, the ease of use of hardware and software, and interest stemming from both entertainment and instructional value.

Figure 7 According to their degree of technical competence, the patients' average oxygen saturation values are shown in the following three groups in the boxplot (see online version for colours)



After extracting relevant keywords, the relevant comments were sorted according to their meaning. What follows are the last groupings with descriptions of each.

- *immersive*: expressions that suggest being somewhere at the same time
- *realistic virtual humans and environment*: words that describe a realistic depiction that is close to reality
- *usability – hardware*: expressions indicating the gadgets' utility
- *usability – software*: terms suggesting that the intended purpose of the content was met
- *interesting and enjoyable*: expressions implying that the read was entertaining
- *interesting and educational*: expressions describing interesting and helpful material for detecting and learning empathy

- *opportunity providing*: expressions showing how the material provided a foundation for growth and empathy detection while also promoting insight into new topics.

To find out how common good and bad experiences were, we gave each positive and negative meaning of the word one point. Using this method, we were able to measure how people felt about the open-ended questions systematically. The characteristics of Empathy VR are shown in Figure 8, where the frequency of participants' favourable and negative remarks on the specified categories can be seen. You may find more specifics on the good and bad reactions to VHs and the surroundings in Figure 9.

Figure 8 The post-test asked participants to rate the VR content on two dimensions: what they liked and what they did not (see online version for colours)

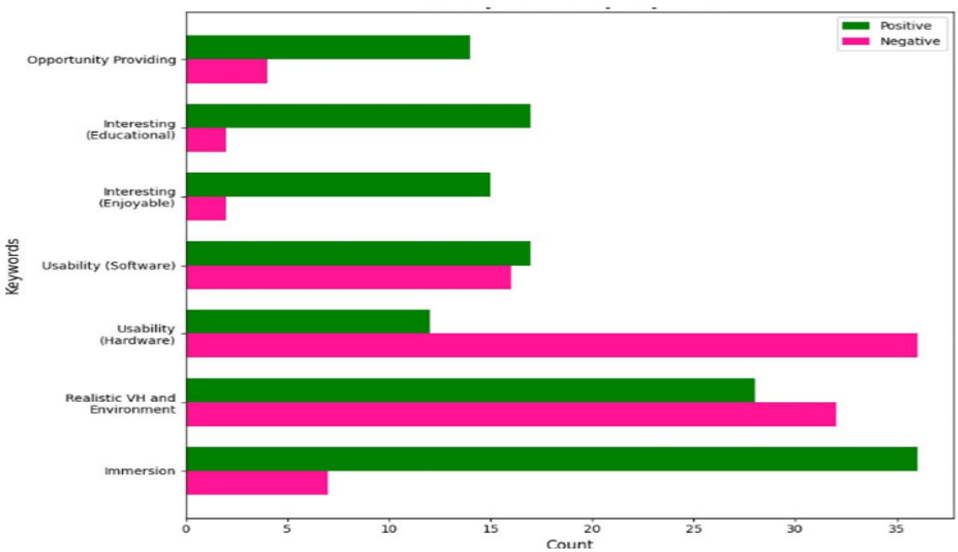
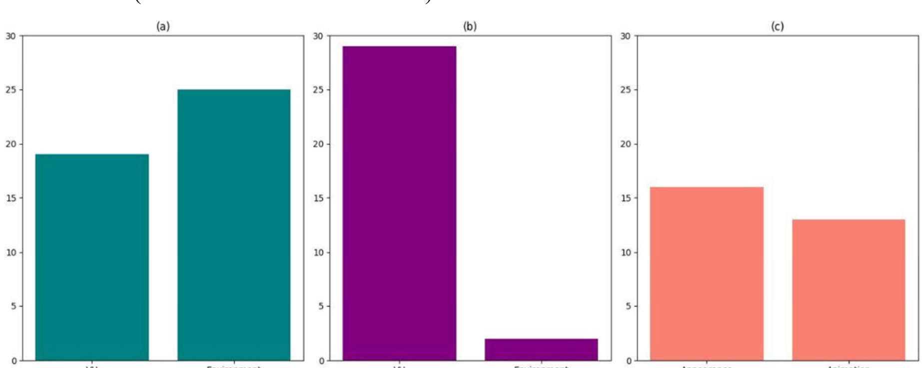


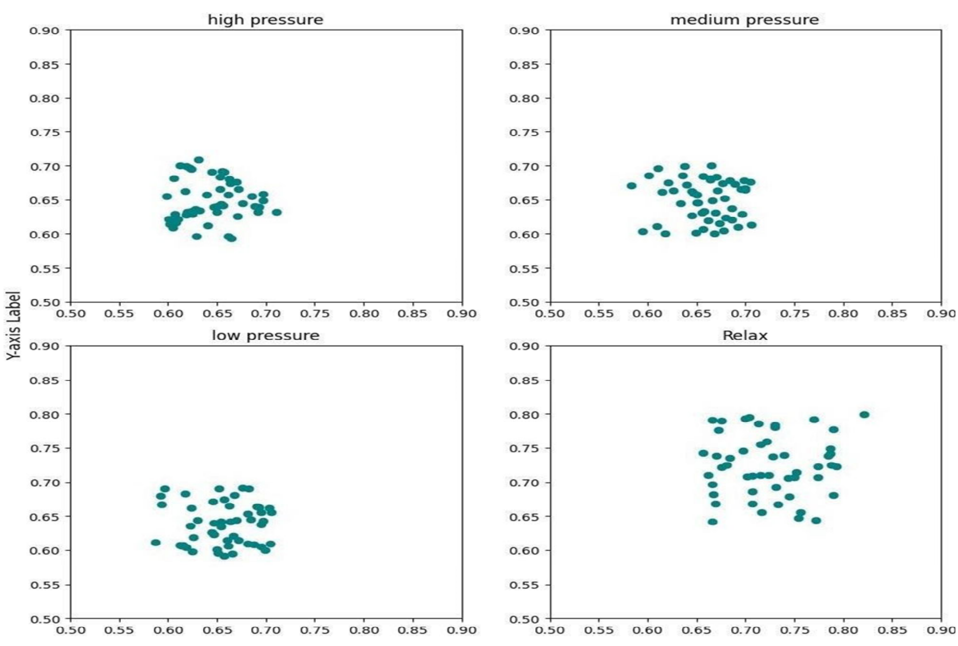
Figure 9 The following are the results of the responses: (a) participants' positive reactions to the 'What did you like about the VR content?' question on the VH and environment post-test; (b) participants' negative responses to the question asking, 'What were some negative aspects of the virtual reality content?' placed on the identical exam; and (c) people's unfavourable opinions about the visual quality and animation expressed on VH (see online version for colours)



The realistic atmosphere was emphasised by participants in good comments, while in negative responses, they voiced concerns about the realism of VR headsets. Poincare scatter plots go by several names: Lorenz scatter plots, RR interval scatter plots, and so on. These names stem from the fact that they display the RR interval as coordinates and track it over time. Using a rectangular coordinate system, Poincaré scatter diagrams show spots at each neighbouring RR interval. One kind of distribution diagram is the one that includes these. To put it simply, it encapsulates HRV in a way that everybody can grasp. The reflection of the immediate change in heart rate, beat by beat, may also reveal the nonlinear law of HRV (Gao, 2022). In both experimental and clinical settings, it is a typical tool for nonlinear analysis. The characteristics of HRV are examined and extracted in this work using a Poincaré scatter diagram. After keeping track of RR intervals for a specific duration, create a Poincaré scatter plot in rectangular coordinates with the starting RR interval value as the axis. Finding the first RR interval's location is as simple as using the value of the second RR interval as the ordinate. Going down to the abscissa of the second RR interval from the ordinate of the third RR interval yields the second point.

This study used a Poincaré scatter plot to show the heart rate variability (HRV) of elderly individuals subjected to varying degrees of stress. The data reveal that under four different pressure settings – high, medium, low, and relaxation – 80% of patients experience a shift from concentration to dispersion (Figure 10).

Figure 10 Pie chart showing the distribution of HRV under varying pressure conditions (see online version for colours)



A considerable number of the HRV data points in the Poincaré scatter plot represent various forms of psychological stress, and these points show regular fluctuations. This research analyses the visual components of the Poincaré scatter plot into two common indicators: the vector angle index and the vector length index. The goal is to automatically assess the HRV feature set's impact on psychological stress. When plotted on a 45° line, the *VAI* quantifies the dispersion of the Poincaré scatter plot. The precise formula is as follows:

$$VAI = \frac{\sum_{a=1} \left| \theta_a - 45 \right|}{M} \tag{12}$$

M is the number of points in a Poincaré scatter plot, and the angle covers both the line from the scatter point to the coordinate origin and the X-axis. The dispersion along the length axis can be quantified in a Poincaré scatter plot using the vector length index (VLI). Let me give you the formula:

$$VLI = \sqrt{\frac{\sum_{a=1} \left(K_a - K \right)^2}{M - 1}} \tag{13}$$

The vector length at point *A* is the most crucial variable in this particular equation because it is utilised to get the average of the vector lengths at locations *A* and *M*. This chapter uses data mining techniques applied to the 2021 university student survey. Due to its multifaceted nature, mental health does not have a single definition or standard measure.

5 Conclusions

The research shows that VR has a lot of potential for use in therapeutic settings, classroom instruction, and mental health assessments. The results show that immersive settings open up new avenues for training, experiential learning, and therapy by increasing engagement and motivation. VR apps provide more interactive, individualised, and effective treatments than conventional methods; this was demonstrated through rigorous experimentation and analysis. In addition to highlighting VR's influence on technical performance, the results show that it can significantly improve user happiness, empathy, and social presence. While VR technology is booming, there are still obstacles to overcome in terms of usability, accessibility, and the authenticity of VR experiences, according to the study. Improving virtual human interactions, lowering technical limits, and making sure people with different tech skills can all use it should be the goals of future development. VR could revolutionise the field of psychology and related fields by tackling these issues and providing novel, adaptable, and scalable answers to people's complicated problems. In the end, this study adds to the increasing amount of evidence that VR may be used as a tool for therapy and education, which opens the door for its widespread use in a variety of fields.

Declarations

All authors declare that they have no conflicts of interest.

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