Journal of Technology in Behavioral Science
https://doi.org/10.1007/s41347-024-00394-x

Virtual Reality Relaxation for Stress in Young Adults: A Remotely Delivered Pilot Study in Participants' Homes

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Received: 28 November 2023 / Revised: 26 January 2024 / Accepted: 31 January 2024

Abstract

High stress levels experienced by young adults were exacerbated by COVID-19 and traditional stress management techniques can be challenging. Virtual reality (VR) relaxation appears promising and is accessible remotely; however, research on young adults is limited, especially in naturalistic settings. This remotely delivered and controlled mixed-methods study investigated feasibility and acceptability of VR relaxation for young adults ($N = 23$, mean age = 22.96) at home during the pandemic. VR participants ($N = 11$) were asked to complete daily VR relaxation sessions (scenes of virtual beaches, mountains, the sea, and more) for a 14-day intervention period, alongside visual analogue scales (VAS) of psychological well-being pre- and post-VR sessions. Post-intervention, VR participants completed semi-structured interviews. Control participants ($N = 12$) received no intervention. Both groups completed outcome measures of psychological well-being pre- and post-intervention periods to evaluate feasibility of remote data collection. VAS results indicated acceptability of daily VR, with significant short-term increases in relaxation, happiness, and connectedness to nature, and decreases in stress, anxiety, and sadness within VR participants. VR usage and 100% completion of outcome measures indicated feasibility of VR relaxation and remote data collection. Qualitative findings suggest participants found the VR relaxing, but interest diminished over time and technical issues hindered user experience. This suggests a more informal, less prescriptive frequency of VR use may be more appealing for young adults, although adherence may relate to technical issues. Greater interactivity and remote technical assistance within VR could increase engagement. Future research should investigate optimal frequency of use, longer-term impact, and technical issues with a larger sample.

Keywords VR · Digital mental health · Mood · Anxiety · Trauma · COVID-19

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Published online: 28 March 2024

Introduction

Young adults experience life stressors which contribute to poor mental health and well-being (Truskauskaite-Kuneviciene et al., 2022). COVID-19 exacerbated psychological distress, causing increased anxiety and depression (Emery et al., 2021; Kwong et al., 2021). Studies indicate that younger people are more vulnerable to mental health problems and adjusted poorly to the pandemic (Varma et al., 2021). Stress management practices, including meditation, mindfulness, and yoga, have been shown to increase relaxation and reduce stress (Varvogli & Darviri 2011), but adherence to these practices is inconsistent, especially among young people (Danilewitz et al., 2018; Erogul et al., 2014; Gard et al., 2012). This highlights the need for acceptable, engaging, and effective self-management interventions that improve well-being for young adults.

Virtual reality (VR) is a simulated digital three-dimensional experience that can be accessed using a head-mounted display (HMD). VR shows promising results for stress management and well-being (Best et al., 2022; Freeman et al., 2017; Imperatori et al., 2020). Unlike traditional relaxation techniques involving memory and imagination, VR immerses users into virtual environments, facilitating a more realistic experience with less effortful engagement (Bohil et al., 2011). Studies show that nature-based virtual environments, including beaches, forests, and water scenes, increase relaxation and decrease stress (Anderson et al., 2017; Soyka et al., 2016; Van Houwelingen-Snippe et al., 2021). Systematic reviews indicate that VR relaxation has high user satisfaction and decreases stress for both clinical and non-clinical samples (Riches et al., 2021; Riches et al., 2023a, b, c). A recent study shows that exposure to a virtual forest reduces stress and negative affect in young adults after two supervised laboratory sessions (Chan et al., 2021). Decrease in heart rate and reduced psychological stress are reported in another study where young adults are exposed to virtual environment of a beach scene during a single 15-min laboratory-based VR session (McGarry et al., 2023). The incorporation of waterfall sounds into a virtual forest was also found to relieve anxiety states in university students (Hsieh et al., 2023). This body of research indicates that VR relaxation has the potential to support young adults coping with stress; however, existing VR relaxation studies are limited by lack of unassisted VR use in naturalistic, non-laboratory-based settings and limited qualitative data on participants' subjective experience of VR.

This mixed-methods study investigated VR relaxation for young adults during COVID-19. A remotely delivered pilot study of home-based VR relaxation was designed, which adhered to social distancing and infection control protocols for COVID-19 and contrasted with laboratory-based VR studies (Mottelson et al., 2021). The aims were to test feasibility and acceptability of delivering HMDs to participants' homes, of participants using HMDs unsupervised for relaxation and self-management of stress, and of remote data collection (Ma et al., 2018; Mottelson & Hornbæk, 2017; Steed et al., 2016).

Materials and Methods

The study gained ethical approval from King's College London (HR-19/20–19650). Young adults, aged 18–30, based in London, UK, with no reported mental health or neurological conditions, were recruited using social media to participate in a VR relaxation study. Participants were assigned to a VR relaxation group, who received an HMD for daily self-use, or a control group, who received no intervention. The aim was to recruit 10–12 participants for each group, as recommended for pilot studies (Julious, 2005; Lewis et al., 2021). Group allocation was based on geographical feasibility of researchers delivering HMDs to participants' homes. It was not possible for researchers to match groups for demographic characteristics. Participants provided informed consent via an online form. No financial incentives were offered.

Oculus Go wireless HMDs programmed with the VRelax app (https://vrelax.com/en/home-us/) were delivered by researchers to VR participants' homes in London from May to July 2021, when the UK was coming out of a lockdown but when there were still significant restrictions on travel and socialising. VR participants were loaned HMDs for a 14-day intervention period. Participants were encouraged to carry out at least one VR session per day. There was no requirement to complete a certain number of sessions because the study aimed to investigate the feasibility and acceptability of participants engaging in this intervention. In line with COVID-19 safety measures, HMDs were thoroughly cleaned, re-boxed, and quarantined for a week between deliveries to participants. VR sessions were unsupervised and conducted by participants in their own homes. Participants chose the time and duration of each session. Data collection for the control group occurred concurrently with VR group data collection to reduce risk of confounders.

Contacts between researchers and participants were conducted remotely. VR participants received a pre-intervention video call briefing and a VR training session from a researcher. Written instructions on using HMDs were emailed to VR participants. The VR environment comprised 360° nature scenes with audio, including beaches, swimming with dolphins, meadows, mountains, meditation exercises, and interactive games (Table 1 and Fig. 1) (Veling et al., 2021). On day 14, VR participants were debriefed by video call.

Measures

All data were collected anonymously using Qualtrics online surveys that participants accessed remotely using weblinks emailed to them by researchers.

Fig. 1 Impression of virtual reality relaxation environments from VRelax app

Pre- and Post-Intervention

On day 1 of the intervention period, all participants provided demographic information on age, gender, ethnicity, occupation, and impact of COVID-19 (Table 1), and completed the following psychological well-being measures: Generalised Anxiety Disorder scale (Spitzer et al., 2006); Patient Health Questionnaire (Kroenke et al., 2003), which measures depression symptoms; Trauma Screening Questionnaire (Brewin et al., 2002), which measures posttraumatic stress disorder symptoms;

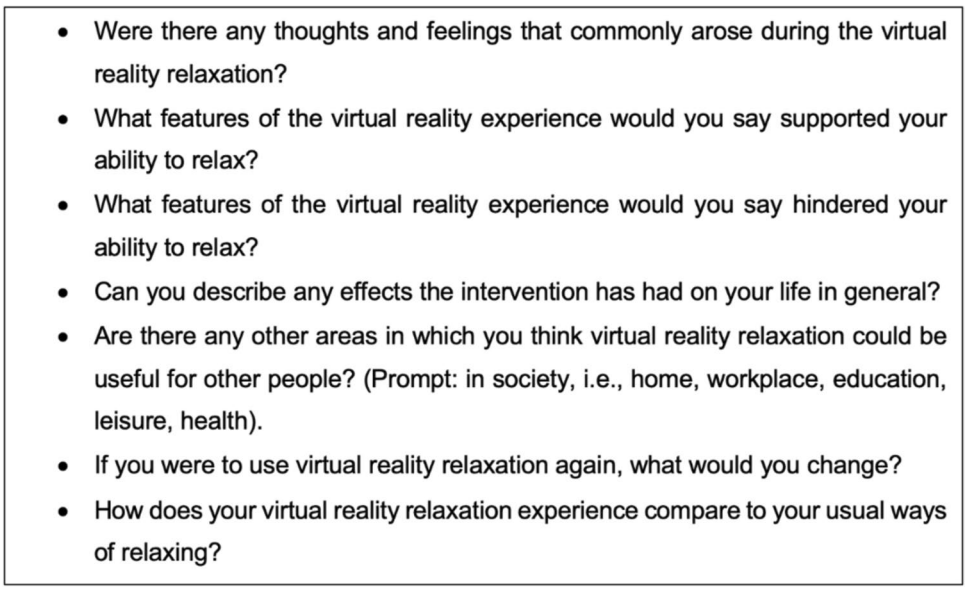

Fig. 2 Post-intervention interview questions assessing virtual reality participants' experience of virtual reality relaxation

Perceived Stress Scale (Cohen et al., 1983); and Interpersonal Sensitivity Measure (Boyce & Parker, 1989). All scales have high validity and reliability for adults (Dekkers et al., 2010; Denovan et al., 2019; Kroenke et al., 2003; Spitzer et al., 2006). The day after the intervention period ended, participants repeated all well-being measures (Table 2). VR participants also completed the Sense of Presence Scale (Slater et al., 1994), which measures immersion in VR; and a video call-based semi-structured interview investigated their experience of the VR (Fig. 2).

Pre- and Post-VR Sessions

VR participants completed visual analogue scales (VAS) evaluating their mood states, relaxation, and connectedness to nature on a scale of 0 ("not at all") to 10 ("very") immediately pre- and post-VR sessions. VAS of helpfulness of, and immersion in, the VR were completed post-sessions. See Table 3 for full VAS. Participants could also provide written feedback post-sessions.

Analysis

SPSSv27 was used to analyse quantitative data. Demographic data was reported to convey participant characteristics and contextual stress levels associated with COVID-19. Fisher's exact test was used to determine differences between VR and control groups in demographic characteristics and experiences of COVID-19.

Feasibility was measured by HMD delivery and collection, remote data collection, completion rate of outcome measures, intervention adherence, number of daily VR sessions, drop-out rates, and participants' feedback. Post hoc power analysis using G*Power showed insufficient power to compare pre- and post-intervention well-being outcomes between the two groups due to small sample sizes, so they were not carried out. Instead, data from these measures was reported solely to evaluate feasibility of participants completing measures remotely. Control participants' demographic characteristics were reported and compared to the VR group to investigate the possibility of recruiting and collecting data from appropriate controls.

Acceptability was measured by calculating changes in pre- and post-session VAS scores and investigating any adverse VR effects. Wilcoxon matched-pairs signed-rank tests compared mood, relaxation, and connectedness to nature VAS scores pre- and post-VR sessions, given small samples and normality violations. For each VAS, data were pooled for all sessions of all VR participants.

VR participants were divided into two subgroups to investigate novelty bias: participants who completed ≤ 7 sessions and participants who completed ≥ 8 sessions. This cutoff was selected to determine whether participants used VR more or less than half the time of the intervention. Wilcoxon matched-pairs signed-rank tests compared pre- and post-session VAS for subgroups.

Post-session and post-intervention qualitative data were pooled for all VR participants, and thematic analysis was conducted in NVivo12 to assess acceptability and user experience. One researcher (IK) carried out the analysis including data familiarisation, coding, and theme development. A second researcher (SN) subsequently reviewed the data and the identified themes and provided suggestions for refinement. The overall thematic analysis was regularly discussed with the lead researcher (SR) throughout the study. Thematic analysis was organised by researchers into categories of Feedback on VR Experience, Recommendations, and Future Applications. Themes listed under each of these categories were included if they were endorsed by ≥ 4 participants.

Results

There were 23 participants (11 VR, 12 controls). Table 1 reports full participant demographic characteristics and impact of COVID-19. Participants were mostly female, of White ethnicity, and in their early 20s. Approximately half were full-time employed, and a quarter were students. Nearly half had experienced stress or adverse life events due

Table 1 Demographic characteristics and impact of COVID-19 pandemic on participants ($N = 23$)

Demographics	Total sample ($N = 23$) *N* (%)	VR group ($N = 11$) *N* (%)	Control group ($N = 12$) *N* (%)	Test of difference between VR and control groups
Mean age (*SD*, range)	22.96 (2.21, 21–29)	23.64 (2.80, 21–29)	22.33 (1.30, 21–25)	$p = 0.181$
Gender				$p = 1.000$
Male	8 (34.8)	4 (36.4)	4 (33.3)	
Female	15 (65.2)	7 (63.6)	8 (66.7)	
Other	0 (0)	0 (0)	0 (0)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
Ethnicity				$p = 0.014$
Asian	4 (17.4)	0 (0)	4 (33.3)	
Black	0 (0)	0 (0)	0 (0)	
White	17 (73.9)	11 (100)	6 (50.0)	
Mixed/multiple ethnic groups	2 (8.7)	0 (0)	2 (16.7)	
Other	0 (0)	0 (0)	0 (0)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
Occupation				$p = 0.848$
Student	6 (26.1)	2 (18.2)	4 (33.3)	
Full-time employed	12 (52.2)	6 (54.5)	6 (50.0)	
Part-time employed	1 (4.3)	1 (9.1)	0 (0)	
Unemployed	4 (17.4)	2 (18.2)	2 (16.7)	
Other	0 (0)	0 (0)	0 (0)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
Occupation groupings				$p = 0.848$
Employed	13 (56.5)	7 (63.3)	6 (50.0)	
Other employment status	10 (43.5)	4 (36.4)	6 (50.0)	
Recently experienced stress or adverse life events as a result of COVID-19				$p = 0.684$
Yes	11 (47.8)	6 (54.5)	5 (41.7)	
No	12 (52.2)	5 (45.5)	7 (58.3)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
Negative impact of COVID-19				
Fallen ill physically	5 (21.7)	1 (9.1)	4 (33.3)	$p = 0.317$
Hospitalised	0 (0)	0 (0)	0 (0)	-
Self-quarantined	14 (60.9)	8 (72.7)	6 (50.0)	$p = 0.400$
Told to shield for 12 weeks	0 (0)	0 (0)	0 (0)	-
Lost job	4 (17.4)	2 (18.2)	2 (16.7)	$p = 1.000$
Reduced ability to earn money	8 (34.8)	3 (27.3)	5 (41.7)	$p = 0.667$
None of the above	5 (21.7)	2 (18.2)	3 (25.0)	$p = 1.000$
Prefer not to say	1 (4.3)	0 (0)	1 (8.3)	$p = 1.000$
Negative impact of COVID-19 on family members or close friends				
Fallen ill physically	12 (52.2)	5 (45.5)	7 (58.3)	$p = 0.684$
Hospitalised	3 (13.0)	2 (18.2)	1 (8.3)	$p = 0.590$
Self-quarantined	15 (65.2)	8 (72.7)	7 (58.3)	$p = 0.667$
Told to shield for 12 weeks	2 (8.7)	2 (18.2)	0 (0)	$p = 0.217$
Lost job	9 (39.1)	5 (45.5)	4 (33.3)	$p = 0.680$
Reduced ability to earn money	10 (43.5)	4 (36.4)	6 (50.0)	$p = 0.680$
Passed away	7 (30.4)	4 (36.4)	3 (25.0)	$p = 0.667$
None of the above	2 (8.7)	1 (9.1)	1 (8.3)	$p = 1.000$

Table 1 (continued)

Demographics	Total sample ($N = 23$) N (%)	VR group ($N = 11$) N (%)	Control group ($N = 12$) N (%)	Test of difference between VR and control groups
Prefer not to say	0 (0)	0 (0)	0 (0)	-
Feelings during the COVID-19 pandemic				
Tense and anxious				$p = 0.182$
Yes	10 (43.5)	7 (63.6)	2 (25.0)	
Somewhat	8 (34.8)	3 (27.3)	5 (41.7)	
Sad and depressed				$p = 1.000$
Yes	7 (30.4)	4 (36.4)	3 (25.0)	
Somewhat	9 (39.1)	4 (36.4)	5 (41.7)	
Connected to family				$p = 1.000$
Yes	9 (39.1)	4 (36.4)	5 (41.7)	
Somewhat	9 (39.1)	4 (36.4)	5 (41.7)	
Lonely				$p = 0.859$
Yes	9 (39.1)	5 (45.5)	4 (33.3)	
Somewhat	4 (17.4)	2 (18.2)	2 (16.7)	
The COVID-19 outbreak has been disruptive to my daily routines				$p = 1.000$
Yes	15 (65.2)	7 (63.6)	8 (66.7)	
Somewhat	8 (34.8)	4 (36.4)	4 (33.3)	
No	0 (0)	0 (0)	0 (0)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
Being at a greater risk of catching COVID-19 compared to most people				$p = 1.000$
Yes	3 (13.0)	1 (9.1)	2 (16.7)	
No	19 (82.6)	9 (81.8)	10 (83.3)	
Prefer not to say	1 (4.3)	1 (9.1)	0 (0)	
Being at a greater risk of developing severe illness from COVID-19 compared to most people				$p = 0.217$
Yes	1 (4.3)	1 (9.1)	0 (0)	
No	21 (91.3)	9 (81.8)	12 (100)	
Prefer not to say	1 (4.3)	1 (9.1)	0 (0)	
Been infected with the COVID-19 virus				$p = 0.525$
Yes	4 (17.4)	2 (18.2)	2 (16.7)	
Suspected	2 (8.7)	0 (0)	2 (16.7)	
No	17 (73.9)	9 (81.8)	8 (66.7)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
Fully recovered from the COVID-19 virus				-
Yes	4 (17.4)	2 (18.2)	2 (16.7)	
No	0 (0)	0 (0)	0 (0)	
Prefer not to say	0 (0)	0 (0)	0 (0)	
VR environments visited				
Start position		84 (100)		
Quiet beach		47 (56.0)		
Scuba diving with dolphins		31 (36.9)		
Tibetan sound therapy		27 (32.1)		
Quiet beach with rocks		23 (27.4)		
Coral reef		22 (26.2)		
Beach with interactive exercises		21 (25.0)		
Mountain scene without animals		18 (21.4)		
Sea view from cliff		17 (20.2)		
Mountain meadow with cows		11 (13.1)		

Tests: independent samples *t*-test for age and Fisher's exact test for other demographic characteristics and experiences of COVID-19

VR virtual reality, *SD* standard deviation

Table 2 Pre- and post-intervention outcome measures for virtual reality and control groups ($N=23$)

Measure	Timepoint	VR group ($N=11$) mean (*SD*)	Control group ($N=12$) mean (*SD*)
GAD-7	Pre-VR	8.27 (5.24)	7.00 (4.82)
	Post-VR	6.18 (4.73)	5.42 (3.42)
PHQ-2	Pre-VR	1.55 (1.29)	2.08 (1.44)
	Post-VR	1.36 (1.43)	1.92 (2.19)
TSQ	Pre-VR	3.73 (2.69)	3.42 (3.18)
	Post-VR	3.27 (2.45)	3.25 (2.93)
PSS	Pre-VR	17.36 (7.74)	19.67 (6.02)
	Post-VR	16.55 (7.01)	17.67 (5.12)
IPSM	Pre-VR	92.64 (18.77)	95.92 (11.96)
	Post-VR	92.45 (11.12)	98.25 (9.59)

VR virtual reality, *SD* standard deviation, *GAD-7* Generalised Anxiety Disorder scale, *PHQ-2* Patient Health Questionnaire (depression scale), *TSQ* Trauma Screening Questionnaire, *PSS* Perceived Stress Scale, *IPSM* Interpersonal Sensitivity Measure

to COVID-19. Most had self-quarantined, a fifth had been physically ill (although fully recovered), a third reported reduced ability to earn money, and a fifth had lost their jobs. More than half had a family member or friend who had been ill and nearly a third had one who had died. Although participants acknowledged that they were a lower risk group, most reported feeling tense, anxious, sad, and depressed during COVID-19. There were no significant differences between the two groups on demographic factors or impact of COVID-19, apart from a significant difference in ethnicity (Table 1), with greater ethnic diversity in the control group.

All participants completed all pre- and post-intervention well-being measures (Table 2). All HMDs were delivered to VR participants' homes and collected as scheduled. VR participants successfully learned to use HMDs with remote training. There was a technical issue with one HMD, but this was quickly resolved by a technician.

Participants carried out a total of 84 sessions. Mean number of sessions during the intervention period was 7.64 ($SD=2.16$, range 3–11). Mean VR session duration was 22.89 min ($SD=9.83$, range 11–59). Table 1 reports the VR environments visited by participants. Post-VR sessions, there were significant increases in relaxation, happiness, and

Table 3 Pre- and post-session measures of mood, relaxation, and virtual reality experience ($N=11$)

Visual analogue scale	Pre-VR mean (*SD*)	Post-VR mean (*SD*)	Test	*p*	Effect size (r)
How relaxed you feel right now					
Total group ($N=11$)	4.83 (2.53)	6.21 (2.17)	−5.04	**<0.001**	−0.39
Participants who did the VR ≤ 7 times ($N=3$)	4.87 (2.20)	6.07 (1.79)	−2.83	**0.005**	−0.52
Participants who did the VR ≥ 8 times ($N=8$)	4.83 (2.61)	6.25 (2.25)	−4.39	**<0.001**	−0.37
How stressed you feel right now					
Total group ($N=11$)	2.63 (2.32)	1.57 (1.74)	−4.95	**<0.001**	−0.38
Participants who did the VR ≤ 7 times ($N=3$)	2.40 (3.22)	1.67 (2.77)	−2.12	**0.034**	−0.39
Participants who did the VR ≥ 8 times ($N=8$)	2.68 (2.10)	1.55 (1.45)	−4.50	**<0.001**	−0.38
How anxious you feel right now					
Total group ($N=11$)	2.08 (2.03)	1.37 (1.66)	−4.26	**<0.001**	−0.33
Participants who did the VR ≤ 7 times ($N=3$)	1.53 (2.20)	1.20 (2.51)	−1.39	0.166	−0.25
Participants who did the VR ≥ 8 times ($N=8$)	2.20 (1.99)	1.41 (1.44)	−3.96	**<0.001**	−0.34
How happy you feel right now					
Total group ($N=11$)	5.04 (2.21)	5.80 (2.09)	−4.19	**<0.001**	−0.32
Participants who did the VR ≤ 7 times ($N=3$)	5.47 (2.50)	6.00 (1.93)	−1.55	0.120	−0.28
Participants who did the VR ≥ 8 times ($N=8$)	4.94 (2.15)	5.75 (2.13)	−3.89	**<0.001**	−0.33
How sad you feel right now					
Total group ($N=11$)	1.69 (1.88)	1.19 (1.46)	−3.47	**<0.001**	−0.27
Participants who did the VR ≤ 7 times ($N=3$)	1.13 (1.13)	0.73 (0.80)	−1.17	0.244	−0.21
Participants who did the VR ≥ 8 times ($N=8$)	1.81 (1.99)	1.29 (1.55)	−3.30	**0.001**	−0.28
How connected you feel to nature right now					
Total group ($N=11$)	2.98 (2.25)	5.10 (1.83)	−6.40	**<0.001**	−0.49
Participants who did the VR ≤ 7 times ($N=3$)	3.13 (1.55)	5.13 (1.30)	−3.11	**0.002**	−0.57
Participants who did the VR ≥ 8 times ($N=8$)	2.94 (2.39)	5.09 (1.93)	−5.64	**<0.001**	−0.48
How helpful you found the virtual reality experience					
Total group ($N=11$)	-	4.71 (2.26)	-	-	-
Participants who did the VR ≤ 7 times ($N=3$)	-	6.07 (1.44)	-	-	-
Participants who did the VR ≥ 8 times ($N=8$)	-	4.42 (2.30)	-	-	-
To what extent you felt you were actually in the relaxing environment					
Total group ($N=11$)	-	4.44 (2.32)	-	-	-
Participants who did the VR ≤ 7 times ($N=3$)	-	6.60 (2.41)	-	-	-
Participants who did the VR ≥ 8 times ($N=8$)	-	3.97 (2.03)	-	-	-

Participants carried out a total of 84 sessions. There was a total of 15 sessions for the three participants who did the VR ≤ 7 times. There was a total of 69 sessions for the eight participants who did the VR ≥ 8 times. Test = Wilcoxon signed-rank tests used for measures collected before and after sessions

VR virtual reality, *SD* standard deviation

Table 4 Thematic analysis of participants' experience of using virtual reality relaxation ($N = 11$)

Theme	Explanation	*N* (%)	Illustrative quotes
Feedback on VR experience			
Relaxing experience	Most participants reported that VR sessions helped them to relax, especially in times of necessity like moments of high anxiety, after stressful days at work, and before sleep. They described the VR sessions as enjoyable, useful, and holiday-like. Most participants described calming sounds and the bright colours of the environments as the most relaxing features of the VR experience	8 (73)	"The intervention really helped me relax and become at peace in moments with high anxiety, sometimes I used it after I finished work to calm down…I usually can't relax if I am by myself, so the VR headset helps me think I am not alone, I am somewhere else in a safe environment and it is more interactive than me trying to meditate by myself…I would say I benefit more from relaxing within a virtual environment because it's more pleasurable to think you are on a beach than just closing your eyes trying to meditate in your room." (#9) "Good relaxation…nice vibes…It was an enjoyable experience and one that I felt helped my relaxation…It is definitely something that is useful…it is an experience I would describe as holiday-like." (#10) "The first few days that I used the VR headset I really felt more relaxed and connected with nature, but at the same time I had stressful days at work, and I felt the urge to use the VR…I would recommend this VR experience as a form of relaxation for people that cannot access nature easily, but overall, I think it can help with relaxation after stressful days." (#2) "Works well as a momentary distraction so can be compared to playing games as a way to relax." (#3) "The images definitely helped me relax and the sounds as well, for example, sound of the waves, the bright colours of the environments." (#9) "The calming sound effects in every environment and the beautiful nature theme [supported my ability to relax]." (#7)
Technical issues	Most participants reported that technical difficulties such as glitches, poor resolution, time inconsistencies, discomfort while wearing the headset, and difficulty pointing the controller were the main factors hindering participants' relaxation. Dissatisfaction with the technology and the application set-up was the most frequently reported negative feedback	8 (73)	"I've actually started noticing some minor bugs and glitches in the app. occasionally, you can see a black spot while looking at the beach, which combined with the lack of an HD quality made me a bit annoyed… Whether it's the weight of the VR glasses or because the app was not as HD as mainstream TV today, I realised this is not really my thing." (#3) "[I had] Feelings of relaxation but the VR was a faff to setup and the controller didn't seem to be in sync which made it stressful to use!" (#8) "The views didn't have a good resolution and the 'begin' buttons were ruining the illusion. The meditation exercises were hard to do with the VR glasses on and I don't think they were timed correctly…Additionally, I didn't enjoy the video loop there and with the cows as one of them disappeared in thin air right in front of me…I would have enjoyed the lady with the sound relaxation if the camera was positioned at a lower angle, so it seems I am sitting in front of her instead of standing up and looking down on her. Especially when my body in real life is sitting down, it would have been more helpful with immersing when both my physical and visual scenes were 'experiencing' the same thing." (#1) "Most of the time was spent in the guided relaxation exercise. While trying to breathe through my legs, the lenses fogged up, so I carried on listening to the waves and the instructions with my eyes closed…the use of the remote also is something that distracted, but it is necessary to navigate with." (#10) "The low quality of the image, also small bugs in the videos like disappearing cows or random black circles appearing in front of you." (#2)

Table 4 (continued)

Theme	Explanation	*N* (%)	Illustrative quotes
Novelty effect	At the beginning of the intervention, participants expressed excitement about the experiment and the VR experience. This was mainly driven by their curiosity about the potential benefits of VR as well as the novelty of the experience, including exploring the different nature scenes for the first time. Participants reported that VR relaxation was most effective for the first few days of the intervention	5 (45)	"I was very excited to try the VR at the beginning. It was something new, promising and interesting to me. I was intrigued to see if it would work on me as I am an anxious person by nature and mediating and yoga have never worked for me." (#1) "Quite fun for a while, it drives your curiosity to explore more." (#4) "Quite exciting as a first try, looking forward to exploring more sceneries!" (#3) "The VR experience had the best effect on my first 3 days while I was using it after work to relax my muscles and clear my mind from a negative mindset." (#5)
Diminished interest over time	Some participants started to lose interest in the VR experience after several sessions due to repetitiveness and lack of interactivity. They reported that the scenes were monotonous which caused their initial excitement to diminish. Participants reported that the relaxing effect of the VR decreased over time	5 (45)	"After a week of using it, even when I wasn't anxious or stressed, it became kind of boring and tedious…I was progressively getting more bored with the sceneries and experiences. The meditation exercises, swimming with dolphins and the woman with the music were making me more anxious than calm." (#1) "The virtual reality relaxation provided a number of situations where I was able to relax my mind from the outside world. However, the longevity of the project made it less interesting and decreased my enthusiasm for enjoying it after the 5th day…the uniformity of all VR sessions caused repetitiveness and therefore lack of interest to continue doing the experiment." (#5) "Although I like the idea behind it, I feel like this app is great for receiving some form of instant gratification—it makes me happy and willing to explore for a while. However, this feeling disappears fairly quickly, probably because I don't actually create real memories that can bring me comfort when I'm stressed or anxious." (#3) "It felt relaxing and peaceful, but the scenes started to become too repetitive at some point…no interactivity, becomes a bit too silent and static at some point." (#4)
Enjoyment of beach and sea	Some participants reported that beach and sea scenes had the most calming and entertaining effect. The scuba diving scene seemed to be the most novel and desired experience	4 (36)	"The scuba diving with dolphins I found the most enjoyable, because it's something I want to do, I would say this is the setting that made me feel most connected to nature." (#10) "I'm pleasantly surprised at how much I enjoy the water sceneries, considering my fear of the ocean in real life—it's astonishing and very relaxing! Definitely my favourite part of the whole experience… it was quite nice to experience something we can't really do in real life for so long." (#3) "My favourite virtual experiences were the beaches, more particularly the splashing waves which relaxed me immediately especially when I closed my eyes as well in order to focus just on the sounds." (#5)
Positive impact on sleep	Some participants reported benefits to sleep, including improving sleep quality and getting in a "mindset to sleep"	4 (36)	"Definitely sleeping better than usual. Helping me clear my mind before going to the gym or doing an important task. Feeling more relaxed in general." (#7) "I used it mostly at night and I feel it helped me get in a mindset to sleep." (#10) "I find the sounds of waves very relaxing. Sometimes I close my eyes, as I typically do when I am on the beach, and I can catch myself falling asleep." (#5)

Table 4 (continued)

Theme	Explanation	*N* (%)	Illustrative quotes
Recommendations			
Increase interactivity	Most participants suggested increasing the interactivity of the VR application and the diversity of nature scenes and games. They proposed "opening up" new scenes and games over time and adding characters as a way of keeping them interested throughout the intervention	9 (82)	"I would definitely make it more interactive with a wider variety of views or even games to keep the person's attention which could definitely work for the younger target audience." (#5) "I would have enjoyed different sceneries opening up every few days or exploring new exercises and games. This would have kept me intrigued and would have taken me away from the 'real' word just like when I started using the VR set at the very beginning." (#1) "[I would change] the interactivity, will add more scenes to explore, maybe even add some 'characters'." (#3)
Improve user experience	Most participants recommended developing technical aspects of the application. Recommendations included improving video quality, reducing pixelation, making it easier to navigate through the application, including the option to change the background music, and adding headphones to minimise real-world distractions which seemed to hinder the immersion of the VR experience	8 (73)	"Perhaps including headphones to minimise environmental or surrounding noise would be more immersive. For this particular study I was not able to locate some of the places." (#10) "[I would change] definitely the video quality, option to change the background music, the app performance in general." (#4) "Make it easier to load the programme and quicker to start up and navigate." (#8) "I would put more instructions around with what you should expect and what exactly each environment experience contains rather than roaming around and exploring each one of them." (#9)
Future applications			
Workplaces	Nearly half of the participants recommended VR as a beneficial relaxation tool for workplaces, especially for high-stress or nature-limited professions	5 (45)	"I would definitely prefer to have VR relaxation experiences at my workplace… If I would have the headset at work that could help me also forget the environment I am in, relax and disengage with whatever upsets me. Having the idea of a comfortable environment even at work would definitely boost my wellbeing in a workplace." (#9) "I think it can be helpful for people working in high-stress jobs or people that do not have the chance of spending time in nature often." (#2)
Stressful environments	Some participants reported general mental health benefits of VR, including its potential application in various stressful environments such as hospitals, airports, and care homes. Impact on sleep was highlighted again by one participant	4 (36)	"[It would be useful] in environments which can be stressful but involve a lot of waiting like airports." (#8) "Maybe it could have some positive impact on people who are struggling to sleep well, anxious people, as well as people living in care homes- to disconnect from the reality." (#11)

connectedness to nature, and significant decreases in anxiety, stress, and sadness (medium effects—Table 3).

Three participants carried out ≤ 7 VR sessions, with a total of 15 sessions between them. Eight participants carried out ≥ 8 VR sessions, with a total of 69 sessions between them. Post-VR sessions, there were the same VAS findings for participants who completed ≥ 8 sessions as for the whole sample. For participants who completed ≤ 7 sessions, relaxation and connectedness to nature significantly increased, and stress significantly decreased. There were no significant changes on other VAS. Table 3 reports VAS scores and tests.

Table 4 reports full themes, explanations, and illustrative quotes from VR participants. Feedback on VR experience themes was that participants found it a *relaxing experience*, particularly when stressed, due to the calming sounds and images. There were *technical issues*, such as glitches and poor resolution, which hindered participants' experience. A *novelty effect* meant participants expressed initial excitement and curiosity about VR and its potential benefits; however, participants reported *diminished interest over time*, due to repetitiveness, limited interactivity, and monotony of the virtual environments. Participants reported an *enjoyment of the beach and sea* because they found these environments calming and entertaining. Participants also reported a *positive impact on sleep*. Recommendations were to *increase interactivity*, through more diverse environments and gamification, and *improve user experience*, by reducing technical problems. Future applications were to introduce VR relaxation in *workplaces* and *stressful environments*.

Discussion

This study investigated feasibility and acceptability of remotely delivered VR relaxation for stress in young adults. Remote delivery of HMDs to participants' homes, unsupervised VR relaxation, and data collection were feasible, suggesting that VR relaxation can be an accessible self-help intervention for young adults at home. Quantitative and qualitative findings, including lengthy duration of sessions, indicate participants found VR acceptable, with short-term benefits for relaxation and positive mood at a time of heightened stress.

Findings are consistent with research indicating VR relaxation can decrease stress among the general population (Riches et al., 2021) and young adults in isolated environments (Anderson et al., 2017), and suggest applications for young adults in other stressful or restrictive environments, such as in prison or in psychiatric hospitals, or where individuals' mobility issues hinder their ability to access real-world nature (Riches et al., 2023a, b, c). Positive feedback on sleep and relaxation was consistent with studies showing that VR can promote nighttime relaxation and improve sleep in young people (Yüksel et al., 2020). However, frequency of participants' VR sessions was lower than suggested by researchers, indicating daily use may be impractical or require further support. Although participants' interest diminished and technical problems hindered user experience, appraisals of these issues may have been exacerbated due to limited technical assistance, compared to that which they might receive in laboratory-based studies or through greater online support. Nevertheless, participants felt there were positive future applications for VR relaxation, including in the workplace and specific stressful environments (Nijland et al., 2021; Riches et al., 2023b, c; Riches & Smith, 2022).

This study reports an innovative methodology using entirely remote recruitment, participant consultation, and data collection for a VR-based psychosocial intervention. Previous "remote" VR studies have provided preliminary evidence, but have tended to either not be entirely remote, with participants collecting HMDs in-person (Mottelson & Hornbæk, 2017), or only recruiting participants who already owned an HMD (Ma et al., 2018). Further strengths of this study include use of a control group, qualitative feedback on the subjective experience of VR relaxation, and the naturalistic setting of participants' homes, which increased ecological validity. Limitations include the small homogenous sample and lack of physiological measures of stress. The fact that participant characteristics, number of sessions, and duration of sessions were self-reported is a potential limitation because there is no way to verify this data. It is also unclear how representative the demographic characteristics of the sample are compared to the general population, especially those that use VR interventions. Investigating such issues of representativeness fell outside of the remit of the present study.

Future research could investigate longer-term engagement and targeted use of VR relaxation for stressful circumstances with more representative and diverse samples (Riches et al., 2023a). Studies should also be adequately powered and compare intervention groups with control groups on the main outcome measures. To improve engagement and user experience, VR developers could design more diverse, interactive, gamified environments (Kaleva & Riches, 2023). VR relaxation could also be incorporated into videogames, social media, and virtual online communities in psychologically informed ways that target user well-being. Avatar-based technical support in the VR could provide instruction and troubleshooting to reduce technical problems.

In conclusion, remotely delivered VR relaxation in young adults' homes is feasible and appears to provide short-term stress relief, but further research should investigate optimal frequency of use with a larger sample to assess longer-term impact on psychological well-being.

Acknowledgements The authors thank the participants for their involvement in this study and the Health Innovation Network for supporting this project. We also would like to express our gratitude to the National Institute for Health Research (NIHR) Biomedical Research Centre for Mental Health at South London and Maudsley NHS Foundation Trust and King's College London.

Author Contribution All authors conceived the concept and the design of the study. Ina Kaleva conducted the data collection under the supervision of Simon Riches. Simon Riches, Ina Kaleva, Sarah L. Nicholson, and James Payne-Gill conducted the analysis. Simon Riches, Ina Kaleva, and Sarah L. Nicholson led on writing the manuscript. All authors contributed to and approved the final manuscript.

Funding This project was supported by an Innovation Grant from the Health Innovation Network, the Academic Health Science Network for South London, awarded to Simon Riches and Freya Rumball. Helen L. Fisher was supported by the Economic and Social Research Council (ESRC) Centre for Society and Mental Health at King's College London (ES/S012567/1).

Data Availability Ethical approval for this study did not permit the sharing of data.

Declarations

Ethics Approval The study gained ethical approval from King's College London (HR-19/20–19650).

Consent to Participate All individual participants included in the study provided informed consent for their participation.

Consent for Publication All individual participants included in the study provided informed consent for publication of their data.

Competing Interests Wim Veling is the cofounder of VRelax BV, the company that has developed the VR application in collaboration with University Medical Center Groningen, and holds shares in VRelax BV. There are no other conflicts of interest.

Disclaimer The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR, Department of Health, the ESRC, or King's College London.

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