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Acceptability and effects on mental health of a music-based virtual reality intervention in geriatric outpatients: results from a pilot randomized controlled trial

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Background: Although the benefits of music on mental health are well established, few studies have investigated the impact of delivering it through virtual reality (VR) technologies. VR offers immersive experiences that can enhance mental health benefits in geriatric patients. However, accessibility to VR music-based interventions for geriatric outpatients remains uncertain. This study aimed to evaluate the acceptability and effects of a music-based VR intervention on emotion, wellbeing and mood in geriatric outpatients living in Montreal (Quebec, Canada).

Methods: A single-center randomized controlled trial (RCT) with two parallel arms (i.e., control *versus* intervention) was conducted at the Montreal Geriatric University Institute (Quebec, Canada). A total of 41 outpatients from the geriatric and memory clinics were recruited and randomly assigned in the control group (n = 20; music listening *via* headphones) and in the intervention group (n = 21; VR-based music experience). The primary outcome was the acceptability of the intervention assessed using three complementary criteria: adoption defined as a retention rate ≥80%, satisfaction defined as willingness to reuse the intervention and perceived mental health benefits, and tolerance using the Simulator Sickness Questionnaire [SSQ] score (high tolerance defined by a score ≤9). Secondary outcomes were the effect on emotional state assessed with the Positive and Negative Affect Schedule (PANAS), on wellbeing assessed with the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) and on mood states assessed with the Visual Analog Mood Scale (VAMS).

Results: High retention (95.2%), satisfaction (85.0%) and tolerance (95%) rates were observed in the intervention group. The PANAS positive score significantly improved in the VR group (β = 15.9, 95% CI [6.8, 25.1], p = 0.001). No significant intergroup differences were observed for wellbeing and mood.

Interpretation: This study demonstrates that a music-based VR intervention was highly acceptable and led to a significant improvement in positive emotional state among older adults in geriatric outpatients.

Clinical trial registration: NCT06296199; https://clinicaltrials.gov/study/NCT06296199.

KEYWORDS

virtual reality, emotion, mental health, acceptability, art-based activities, music

Introduction

Art-based activities have significant mental health benefits among adults of all ages (Fancourt and Finn, 2019). These activities include listening to music, which is widely practiced across diverse populations and countries (Tymoszuk et al., 2021; National Endowment for the Arts, 2023). For instance, the National Endowment for the Arts' 2022 Survey of Public Participation in the Arts revealed that more than half of US adults engaged in some form of art-based activities, with music listening as a key component (National Endowment for the Arts, 2023). Listening to music not only enhances wellbeing in older adults, but also helps reduce anxiety, ease depression and boost both mood and cognitive performance (Chabot et al., 2019; Ma and Ma, 2023). These mental health benefits are primarily attributed to positive emotions elicited by music (Koelsch, 2014). Music has demonstrated mental health benefits for older adults with cognitive impairments, showing efficacy in reducing neuropsychiatric symptoms and enhancing emotional wellbeing (Leggieri et al., 2019). However, the delivery methods of music-based interventions, particularly those involving emerging technologies, remain relatively underexplored (Rodwin et al., 2022). However, optimizing these methods is essential to ensuring accessibility and efficacy, particularly for older adults (Särkämö et al., 2014). Thus, there is a need to identify the most effective formats and technologies for maximizing the benefits of music-based interventions in mental healthcare.

Music-based interventions are typically delivered in person through group workshops or one-on-one sessions (Schroeder et al., 2018; Veal et al., 2022). However, these traditional methods face certain limitations when applied to older adults, particularly geriatric patients with morbidities and functional impairments (Platel and Groussard, 2020). Mobility and sensory impairments, like hearing loss or low vision, may hinder accessibility and reduce engagement in geriatric patients (J. Kim et al., 2023). Additionally, cognitive impairment may complicate participation by making it difficult for these patients to follow instructions or keep pace with group activities (Hanson et al., 1996). These limitations emphasizes the need to reconsider and adapt intervention delivery methods to better suit the specific needs of geriatric patients and expand access to music-based interventions (Tjasink et al., 2023).

Virtual reality (VR) has emerged as a promising tool for enhancing music-based interventions. By providing immersive experiences, VR can evoke positive emotions and improve quality of life and wellbeing, similar to in-person music listening intervention (Anttonen and Surakka, 2007; Bailenson, 2018; Huber et al., 2021; J. Kim et al., 2023; Park et al., 2024). Additionally, VR sessions presenting film sequences or music for older adults have shown promise in reducing symptoms of depression (Pavic et al., 2022; Yang J. et al., 2025). Advances in VR technology, such as improved VR headsets and higher display resolutions, make VR even more immersive compared to other virtual environments (Marougkas et al., 2023). These highly immersive VR environments have been found to elicit more positive emotions and greater arousal than lower-immersion environments (Pavic et al., 2023). However, despite promising results, research on VR interventions for older adults remains limited, especially compared to younger populations (Skurla et al., 2022). Many existing studies face methodological limitations including small sample sizes, non-representative populations and the lack of randomization (Skurla et al., 2022; Appel et al., 2019). While several studies have investigated immersive VR for improving cognitive or emotional outcomes in older adults (Restout et al., 2023; Yu et al., 2024), most have used non-musical content (e.g., nature, relaxation) and lacked a focus on outpatient settings. To our knowledge, the present study is the first randomized trial to assess the acceptability and emotional impact of a music-based VR intervention in community-dwelling geriatric outpatients. This dual focus on immersive musical content and real-world clinical implementation offers a novel contribution to the field. Furthermore, the effectiveness of VR experiences in older populations has not been sufficiently explored (Miller et al., 2014; Brown, 2019), nor have their acceptability for geriatric outpatients been well studied (Dermody et al., 2020). Given the potential benefits of VR for geriatric patients, further research is needed to assess its acceptability and effectiveness within this population.

Building on the potential benefits of music and VR for the geriatric population, we developed a music-based VR intervention consisting of watching and listening to a classical music performance with a VR headset. We hypothesized that this VR intervention would be both acceptable for geriatric outpatients and could enhance their mental health by enhancing their positive emotional state and, thus, their wellbeing and mood. To test the hypothesis, we designed a pilot two-arm, parallel, open label randomized controlled trial (RCT) that assessed the acceptability and the mental health effects (*i.e.,* emotional state, wellbeing and mood) of a one-on-one in-person music-based VR intervention by comparing an intervention group which received the music-based VR session with a control group engaged in traditional music listening within geriatric outpatient population.

Methods

Design and population

This pilot study was a single center RCT conducted at the Montreal Geriatric University Institute in Quebec, Montreal. It employed a two-arm parallel, open-label design with participants assigned to either an intervention or control group. The intervention group engaged in an in-person, music-based VR experience using a VR headset (MetaQuest Pro from Facebook Technologies LLC, equipped with advanced optical technology, featuring a high-resolution display with a combined pixel count of 3664 × 1920 - 1832 × 1920 per eye - LCD panels, a 90Hz refresh rate and light blockers and integrated speakers with spatial audio (Meta Platforms, Inc, 2024). The control group participated in traditional music listening with a standard MP3 headphones (Innioasis, 2024) and Sennheiser HD569 wired supra-aural headphones with sound isolation (Sennheiser, 2024). Participants were randomly assigned to their respective groups using Participants were randomly allocated into intervention and control groups, each participant having a 50% chance of being assigned to either group, thanks to a pre-established randomization list. The randomization list was established using the N'Query randomization software. This method was chosen to ensure equal group sizes and maintain balance in sample distribution over time. Although neither the participants nor the investigators were blinded to the intervention, randomization results were disclosed to participants and other research team members only after the initial assessment (i.e., before the intervention) to minimize bias. This RCT is registered on the ClinicalTrials.gov website (Project Number NCT06296199) and adheres to the CONSORT guidelines for randomized controlled trials (Moher et al., 2012).

The study was conducted at the memory and geriatric outpatient clinics of the Montreal Geriatric University Institute (Quebec, Canada). Inclusion criteria required participants to be 1) community-dwelling, 2) older adults aged 60 and above, 3) who receive care at the memory or geriatric outpatient clinics of the Montreal Geriatric University Institute. Participants with severe visual or hearing impairment or vestibular-origin balance disorders were excluded. Participants unable to provide informed consent or those diagnosed with severe-stage major neurocognitive or psycho-behavioral disorders were excluded. Eligible participants were recruited through open and rolling recruitment within the outpatient clinics. While participants were community-dwelling, this recruitment strategy specifically targeted individuals receiving specialized care in geriatric and memory clinics and was not intended to evaluate the effects on cognitive health in patients with neurocognitive disorders, nor to represent the broader older adult population.

Assessment

Eligible patients were pre-selected by their attending physician at the memory and geriatric outpatient clinics between August and October 2024. A research team member then contacted 108 pre-selected patients by phone to inform them about the new clinical research opportunity, conduct a final screening, obtain informed consent and schedule an appointment for the intervention at the research center. Of these 108 potential participants, 85 (78.7%) were reached by phone. Of these 85 reached participants, 41 (48.2%) declined to participate. Ultimately, 44 participants (51.8%) agreed to participate in the RCT but 3 (6.8%) of them withdrew their interest. Therefore, 41 participants (93.2%) were enrolled and were randomized into the intervention (n = 21) and control (n = 20) groups. Among them, 1 participant (2.4%) dropped out during the intervention phase (from the intervention group) because of major technical issue. A major technical issue is defined as a technical problem requiring the intervention to be interrupted with the removal of the VR headset and requiring the intervention of a member of the research team. The Figure 1 showed the CONSORT flow diagram detailing the selection of participants.

All participants completed assessments both before and after the intervention. Regardless of group assignment, information was collected on age, sex, body mass index (BMI), neurocognitive disorder diagnoses and preference for classical music. The presence of neurocognitive disorders was determined based on participants' clinical records and diagnostic assessments made by the referring geriatricians who used the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition) criteria for major neurocognitive disorders requiring the presence of multiple cognitive deficits, including memory impairment, and at least one other cognitive domain impairment (language, praxis, gnosis, or executive function), with significant functional decline. Additionally, assessments included the CARE scale (Beauchet et al., 2022a) which integrates the baseline clinical and functional parameters (age, ADL, IADL, depression, BMI and frailty). Participants' prior exposure to VR technology, educational background and prior musical training was not systematically collected, as the study focused primarily on the immediate acceptability and short-term emotional effects of the intervention even if these factors are known to influence emotional processing and engagement with music-based interventions (Hanna-Pladdy and Gajewski, 2012; Schellenberg, 2006).

Before and after the intervention, participants in both the intervention and control groups completed several questionnaires to assess emotional state (with Positive and Negative Affect Schedule scale (Watson et al., 1988), wellbeing (with Warwick-Edinburgh Mental Wellbeing Scale (Bass et al., 2016)) and mood (with Visual Analog Mood Scale (Visual Analogue Mood Scales, 2024).

The number of dropouts, linked or not to major technical incidents, was recorded to assess the acceptability of the VR intervention. Additionally, participants in the intervention group also completed two additional questionnaires (Acceptability Questionnaire, internally defined on a Likert scale model, and Simulator Sickness Questionnaire [SSQ] (Kennedy et al., 2019)) post-VR experience. Emotional state was assessed using the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988), a scale designed to evaluate both the valence and intensity of an individual's emotional state defined as momentary expressions within that broader affective experience. PANAS consists of two subscales: positive and negative emotional states, each containing 10 items,

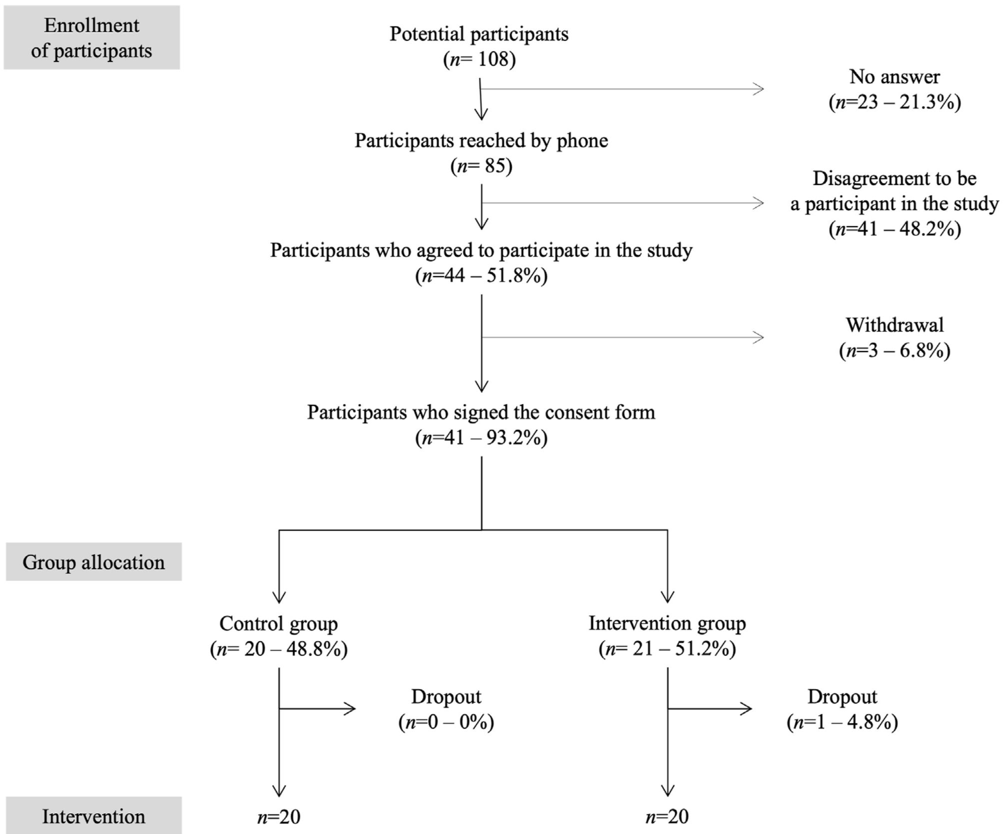

FIGURE 1
Consort flow diagram detailing selection and inclusion of participants in the RCT.

for a total of 20 items. The scale categorizes individuals into four emotional profiles, reflecting different interactions between positive and negative emotions. Scores for both subscales range from 10 to 50. A low negative emotional state score indicates minimal negative emotions, reflecting calm and serenity, whereas a high score suggests psychological distress with various unpleasant emotions. Conversely, a high positive emotional score reflects a strong presence of positive emotions, while a low score indicates reduced positive emotional state.

The self-administered Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) (Bass et al., 2016) was used to assess overall wellbeing. This scale consists of 14 positively worded items, with scores ranging from 14 (indicating "none of the time") to 70 (indicating "all of the time"), providing a comprehensive measure of mental wellbeing. The Visual Analog Mood Scale (VAMS) (Visual Analogue Mood Scales, 2024), was used to evaluate mood. This scale assesses eight mood states using ideogrammatic icons, including two positive mood states (happy and energetic) and six negative mood states (scared, confused, sad, angry, tired, tense). Each mood state is represented by a neutral face on a continuous line, where participants mark the point corresponding to their mood intensity. The score is determined by measuring the distance (in millimeters) from the neutral face to the marked point, greater distances indicate stronger mood. Higher scores for positive mood reflect a better mood, whereas higher scores for negative emotions indicate a worse mood.

Intervention

The intervention consisted of a 15-min experience in which participants in the intervention group listened to and watched classical musicians perform via a VR headset, while participants in the control group only listened to the same musical suite, defined here as a curated and thematically organized sequence of musical pieces, through an audio headset.

The 15-min single-session format was chosen for its suitability in geriatric care, where brief interventions can enhance feasibility, engagement, and emotional responsiveness, and are supported by theoretical models emphasizing the benefits of short, targeted affective experiences (Bannon et al., 2025) and minimum side-effects (Cinalioglu et al., 2023; Sekhon et al., 2024). All participants, regardless of group allocation, experienced the same pre-recorded musical suite performed by professional musicians with extensive experience in chamber music, ensuring a high level of artistry. A carefully curated selection of classical and popular music, chosen by the concerned professional artists in accordance with directives of the research team, was recorded and presented by a trio ensemble consisting of flute, violin, and cello. The repertoire featured both instrumental works and lyrical excerpts, offering a diversified listening experience. The performance was filmed in 360° during a live rehearsal session, emphasizing the authenticity and intimacy of in-the-moment performance while maintaining a high standard of musical interpretation.

The selected musical works included in the musical suite were, by chronological order, 1) *Romance for Violin and Orchestra No. 2 in F major*–Ludwig van Beethoven (1798), a gentle and lyrical piece, 2) *Suite No. 2 in B Minor, BWV 1067* – Johann Sebastian Bach (1738), an uplifting and structured Baroque composition, 3) *Lascia ch'io pianga (Almira)* – George Frideric Handel (1705), an aria expressing longing and introspection, 4) *La donna è mobile (Rigoletto)* – Giuseppe Verdi (1851), in its instrumental version, 5) *Por una cabeza*–Carlos Gardel (1935), in a classical arrangement of this well-known tango, 6) *El Choclo*–Ángel Villoldo (1903), another iconic tango, also in a classical arrangement, 7) *Quién quiero no me quiere*–Lucho Barrios (1964), Peruvian waltz, arranged for classical trio, and 8) *Petradaki Patradaki*–Nikos Xanthopoulos (2015), a contemporary Greek melody with strong folkloric undertones.

The selection of musical works was designed to span a wide range of musical eras and cultural contexts with the aim of stimulating affective responses, autobiographical memory and a sense of comfort in older adults. The combination of classical repertoire and popular melodies, reinterpreted in a chamber music format and enhanced by lyrical elements, enriched the sensory experience and intentionally reflected the diverse cultural backgrounds and musical preferences of older adult populations.

The intervention was conducted in a dedicated room under researcher supervision in a quiet clinical setting at the Research Centre of Montreal Geriatric University Institute (Quebec, Canada), where participants were seated comfortably in an armchair. Each session was conducted individually in a dedicated quiet room. Participants in the intervention group experienced a single 15-min VR session using the MetaQuest Pro headset. The control group listened to the same musical program through stereo headphones while seated comfortably. Before the intervention, participants completed the pre-intervention assessments and received an explanation of the standardized procedure and equipment and device adjustment. Volume levels were individually adjusted prior to each session to accommodate hearing differences among participants. During the intervention, the environment remained silent. No visual stimuli were presented in the control condition. Participants were not given explicit instructions regarding whether to keep their eyes open or closed, nor were they guided to imagine content. In both conditions, they were asked to remain silent during the session to avoid external influence on emotional experience. If any technical issues arose, participants could signal the research team member, who stayed in the room during the entire intervention.

Power calculation

Since it was not possible to determine the required sample size based on acceptability (assessed through descriptive criteria in the intervention group only) which is the primary outcome, the calculation was instead based on the change in the positive and negative affect schedule (PANAS) positive score before and after the intervention, using the formula: ((score M^{n+1} – score M^{n})/ ((score M^{n+1} + score M^{n})/2))x100. PANAS reflects immediate emotional state and is sensitive to short-term interventions (Watson et al., 1988). An expected intergroup difference of 8 points was chosen based on prior research reporting smaller but significant changes following brief VR or music interventions (Chan et al., 2011), combined with clinical judgment that a larger effect could be observed in an immersive VR context. A free online sample size calculator (http://www.sample-size.net/sample-size-means/) was used to determine the required sample size. To detect a significant absolute difference between the two groups (intervention and control) with an alpha level of 5% and a power of 90%, a minimum of 20 participants per group was required.

Outcomes

The primary outcome corresponded to the acceptability of the VR intervention. Considering that acceptability remains poorly defined and lacks a unified framework (Bucyibaruta et al., 2022), we decided to use three specific criteria to better define it (M. Sekhon et al., 2017). It included adoption (i.e., willingness to complete the entire study), satisfaction (i.e., user satisfaction, perceived effectiveness) and tolerance (i.e., cybersickness) (Sekhon et al., 2017). First, adoption was defined as the retention rate which was determined by calculating the proportion of participants who completed the entire study without dropout or withdrawal due to major technical incidents or for other reasons. Retention rate was expressed as a percentage, with a retention rate of ≥80% deemed acceptable (Walters et al., 2017). Second, satisfaction was determined by calculating the proportion of participants willing to repeat the VR experience (user satisfaction) and the proportion of participants who believed in its potential mental health benefits (perceived effectiveness). Both variables were assessed using 7-point Likert scales, where higher scores indicated stronger agreement (1 = strong disagreement, 7 = strong agreement). A score of ≥6 was considered indicative of very good agreement for the willingness to repeat the VR experience and score of ≥5 was considered indicative of very good agreement for the perceived effectiveness on health. A high level of perceived interest was defined as at least 80% of participants who completed the study scoring ≥6 on the will to reuse the intervention measure and ≥5 on belief in a potential mental health benefit (Anastasiadou et al., 2024). Lastly, tolerance was assessed by using the Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 2019). This questionnaire consists of 16 items evaluating symptoms such as fatigue, headache and nausea, each rated from 0 (no symptoms) to 3 (severe symptoms). The total SSQ score ranges from 0 (excellent tolerance) to 48 (poor tolerance), with ≤9 indicating very good tolerance (Lin et al., 2023). A high level of tolerance was defined as at least 80% of participants in the intervention group scoring ≤9 on the SSQ. The primary outcome was assessed based on participants randomized to the intervention group. For the adoption criterion, all randomized participants in intervention group were considered (n = 21), whereas satisfaction and tolerance were evaluated only among those who completed the full intervention (n = 20).

The second category of outcomes corresponded to the intervention's mental health effects. For this purpose, we looked after the mean value of scales assessing emotional state, wellbeing and mood; each scale being performed before and after intervention in the intervention group and the control group. In addition, we used the score variations for these scales between pre- (T0) and post-

TABLE 1 Baseline participant characteristics (n = 40).

Characteristic	Participants		p-value†
	Control (n = 20)	Intervention (n = 20)	
Age (years), *mean* ± *SD*	78.8 ± 6.1	80.9 ± 6.9	0.342
Female, n (%)	17 (85.0)	7 (35.0)	**0.003**
Body mass index (kg/m^2), *mean* ± *SD*	26.6 ± 6.5	26.6 ± 6.1	0.685
Neurocognitive disorder, n (%)	11 (55.0)	12 (60.0)	1.000
Like classical music*, n (%)	18 (90.0)	20 (100)	0.487
ADL score (/6)‡, *mean* ± *SD*	5.5 ± 1.2	5.3 ± 1.3	0.553
IADL score (/4)||, *mean* ± *SD*	3.6 ± 0.8	3.4 ± 0.9	0.461
GDS score (/15)§			
Mean ± *SD*	3.6 ± 2.1	4.6 ± 4.0	0.663
Score abnormal ≥5, n (%)	9 (45.0)	10 (50.0)	1.000
CARE score (/21)¶			
Mean ± *SD*	5.4 ± 3.1	5.9 ± 3.2	0.640
Frail (score >5), n (%)	10 (50.0)	10 (50.0)	1.000

SD: standard deviation; ADL: activities of daily living; IADL: instrumental activities of daily living; GDS: geriatric depression scale; CARE: CriblAge et Recommandations; * Participants' preference for classical music was assessed at baseline for descriptive and adjustment purposes. It was not an inclusion criterion; †: Comparison based on Mann-Whitney test or chi-squared, as appropriate; ‡: Ranging from 0 (dependent) to 6 (independent); ||: Ranging from 0 (non-autonomous) to 4 (autonomous); §: Ranging from 0 (no depression) to 15 (severe depression); ¶: Ranging from 0 (robust) to 21 (frail); Values in bold indicate statistical significance at p < 0.0045 after Bonferroni correction for multiple comparisons (n = 11).

(T1) intervention for control group and the intervention group using the formula: [(score T1) – (score T0)/n (score T1 + score T0)/2] X 100).

Standard protocol approvals, registrations, and patient consents

This study is conducted in accordance with the ethical standards set forth in the Helsinki Declaration (1983). Participants were included after giving written, informed consent for research. Data were anonymized and the study received was approved by the *CIUSSS Centre-Sud-de-l'Île-de-Montréal* (Quebec, Canada) Research Ethics Committee *Vieillissement et neuroimagerie* (# 2024-2064 – CÉR VN 23-24-40). This RCT was registered on ClinicalTrials.gov (project number NCT06296199) and adheres to the CONSORT guidelines for RCTs (Moher et al., 2012).

Statistical analysis

Analyses were conducted on an intention-to-treat basis. Missing data, which constituted less than 10% for each variable, were addressed using multiple imputation techniques. This method involved replacing missing values with the mean of the observed values for the respective variable within the corresponding allocated group (Mohamed et al., 2018). The imputed data represented 0.4% of the complete dataset.

Descriptive statistics (means, standard deviations [SD], frequencies, and percentages) were used to summarize participants' characteristics. Between-group comparisons of change scores (post–pre) were conducted using Mann-Whitney U tests, while within-group differences were analyzed using Wilcoxon signed-rank tests. Multiple linear regressions examined the association of the intervention (used as independent variable) with change (between after and before intervention) in mean values of scales assessing emotional state, wellbeing and mood (used as the dependent variable, separated model for each variable). In order to limit the risk of overfitting in this sample (n = 40) while still accounting for key baseline differences, the models were adjusted for four covariates selected *a priori* based on theoretical relevance and clinical comprehensiveness: music preference, sex, neurocognitive disorder status and the CARE score. Bonferroni corrections were applied where relevant: for baseline comparisons (n = 11), the adjusted threshold was $p < 0.0045$; for outcome comparisons across groups and time (n = 20), $p < 0.0025$ was used. For regression analyses, each model tested a separate hypothesis, and a conventional threshold of $p < 0.05$ was applied. All statistics were performed using SPSS (version 29.0.2.0; SPSS, Inc., Chicago, IL).

Results

Characteristics of the study population

As shown in the Table 1, participant ages ranged from 66 to 95 years (M = 79.8, SD = 6.5), with a BMI range of 16.3–44.3 kg/m^2

TABLE 2 Acceptability assessments for VR intervention group.

Acceptability measure	Value	[95% CI]
Retention rate, *n* (%)*	20 (95.2)	[-0.1; 0.2]
Willingness to repeat the VR experience, Score ≥6, *n* (%)†	17 (85.0)	[0.7; 1.0]
Perceived effectiveness on health, Score ≥5, *n* (%)‡	17 (85.0)	[0.7; 1.0]
SSQ Score ≤9, *n* (%) ‖	19 (95.0)	[-0.5; 0.2]

CI: confidence interval; VR: virtual reality; SSQ: simulator sickness questionnaire; *: calculation based on 21 participants; †: Ranging from 1 (strong disagreement) to 7 (strong agreement), with a score ≥6 indicating a very good agreement, calculation based on 20 participants with full intervention; ‡: Ranging from 1 (strong disagreement) to 7 (strong agreement), with a score ≥5 indicating a very good agreement, calculation based on 20 participants with full intervention; ||: Ranging from 0 (excellent tolerance, no symptoms) to 48 (poor tolerance, all symptoms present), with a score ≤9 indicating an excellent tolerance, calculation based on 20 participants with full intervention.

TABLE 3 Comparisons between control and intervention groups of mean values of scales assessing positive emotional state, negative emotional state, wellbeing, happy mood and sad mood (*n* = 40).

Outcome measure	Participants						*p*-value†	
	Control (*n* = 20)			Intervention (*n* = 20)			T0	T1
	T0	T1	*p*-value*	T0	T1	*p*-value*		
PANAS Positive score (/50)‡, *mean* ± *SD*	36.6 ± 6.6	36.6 ± 7.5	0.914	32.3 ± 10.0	34.4 ± 9.2	0.371	0.184	0.570
PANAS Negative score (/50) ‖, *mean* ± *SD*	23.0 ± 7.7	21.8 ± 7.9	0.456	17.7 ± 5.9	18.5 ± 7.4	0.860	0.032	0.113
Warwick-Edinburgh Wellbeing scale (/70)§, *mean* ± *SD*	52.1 ± 13.5	56.0 ± 8.2	0.409	55.1 ± 11.6	54.9 ± 12.9	0.924	0.542	0.860
VAMS happy (/100)¶, *mean* ± *SD*	61.2 ± 41.2	56.3 ± 40.3	0.596	77.1 ± 30.2	74.1 ± 33.1	0.643	0.280	0.265
VAMS sad (/100)¶, *mean* ± *SD*	8.6 ± 17.5	5.2 ± 13.4	0.122	7.4 ± 19.4	6.6 ± 14.7	0.977	0.061	0.805

T0: baseline assessment; T1: assessment after intervention; *SD*: standard deviation; PANAS: positive and negative affect schedule; VAMS: visual analog mood scale; *: Comparisons based on Wilcoxon test; †: Comparison based on Mann-Whitney test; ‡: Ranging from 10 (lowest level of positive emotional state) to 50 (highest level of positive emotional state); ||: Ranging from 10 (lowest level of negative emotional state) to 50 (highest level of negative emotional state); §: Ranging from 14 (i.e., none of the time) to 70 (i.e., all the time); ¶: Ranging from 0 (neutral) to 100 (highest level of the described mood); *p*-value significant fixed at 0.0025 because of multiple comparisons (n = 20; Bonferroni correction).

(*M* = 26.6, *SD* = 6.2). Participants were predominantly female (*n* = 24 [60.0%]), all were of Caucasian ethnicity (*n* = 41 [100%]), 23 [57.5%] had a neurocognitive disorder (NCD).

Most participants reported liking classical music (*n* = 38 [95.0%]) and 21 [52.5%] were not depressed. Additionally, 26 [65.0%] participants were independent in activities of daily living (ADL) and 28 [70.0%] in instrumental activities of daily living (IADL). Half of the participants were equally categorized as robust or frail (*n* = 20 [50.0%]).

No significant differences were observed between the intervention and control groups for demographic variables, except for sex. There were fewer females in the intervention group compared to the control group (*n* = 24, *p* = 0.003).

Acceptability

A descriptive analysis showed a high retention rate in the intervention group (Figure 1; Table 2, *n* = 20, 95.2%, 95% CI [−0.1; 0.2]) across 20 full VR sessions. It was also showed a high satisfaction with 85.0% of participants indicating a strong willingness to repeat the VR experience (Table 2, *n* = 17, 95% CI [0.7, 1.0]) and 85.0% agreeing that it could benefit their mental health (Table 2, *n* = 17, 95% CI [0.7, 1.0]). Tolerance to the intervention was also high with 95.0% (Table 2, *n* = 19, 95% CI [-0.5; 0.2]) of participants scoring below 9 on the SSQ.

Mental health effects of the intervention

Intra-group comparisons (pre-post) using Wilcoxon signed-rank tests revealed no significant changes in any outcome for either the intervention or control group (Table 3). Inter-group comparisons of change scores (post-pre), performed using Mann-Whitney U tests, also showed that there was no statistically significant difference (Table 3). However, trends favoring the intervention group were observed in the PANAS positive score ($U = 136.5$, $p = 0.072$) and the WEMWBS wellbeing score ($U = 133.5$, $p = 0.086$) (Figure 2).

Multiple linear regression analyses further indicated a significant increase in the PANAS positive score in the intervention group ($\beta = 15.9$, 95% CI [6.9, 25.1], $p = 0.001$; *adjusted* $R^2 = 0.32$), after adjusting for baseline characteristics. No other outcome was significantly associated with the intervention, and the adjusted R^2 values for these models ranged from −0.02 to 0.13, indicating minimal variance explained. Cohen's *d* values were also computed to complement regression estimates and assess the magnitude of between-group differences. A moderate effect size was observed for the PANAS

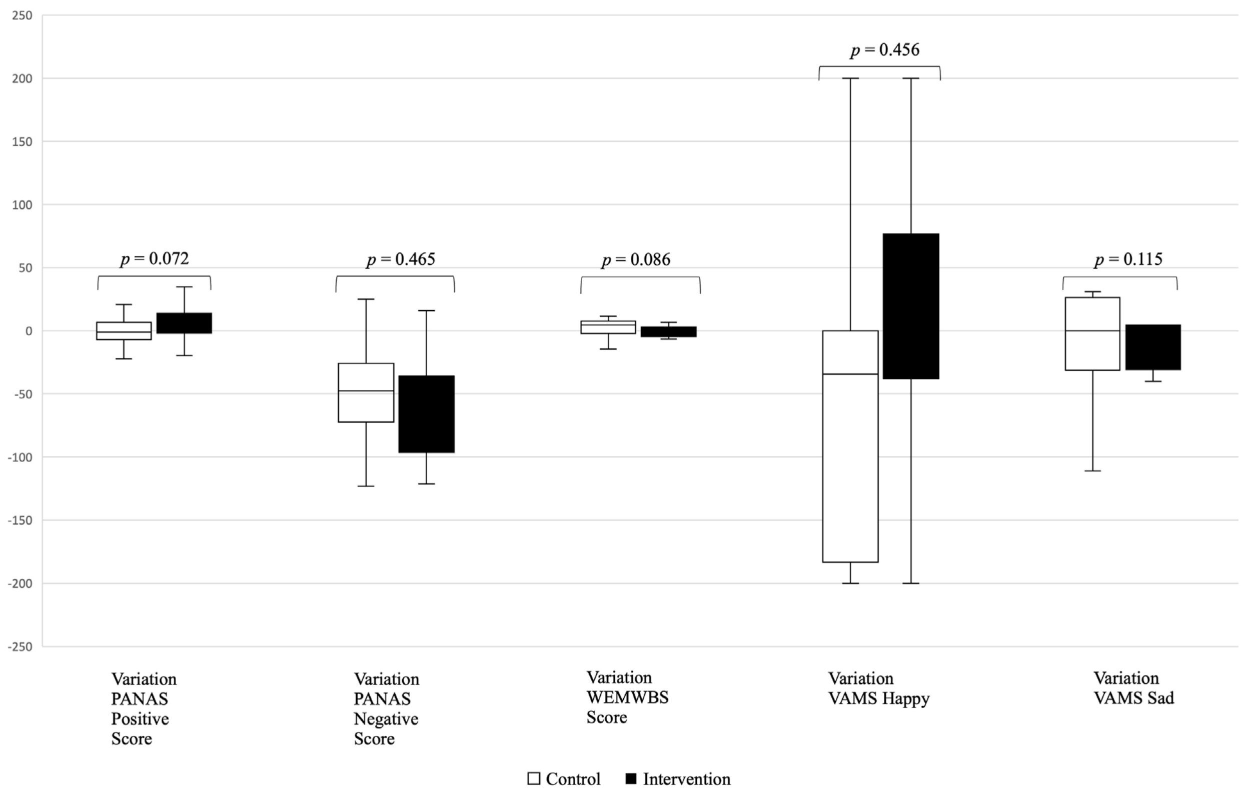

FIGURE 2
Mean pre–post differences in scales assessing positive emotional state, negative emotional state, wellbeing, happy mood state and sad mood state between control and intervention groups (N = 40). PANAS: Positive and negative affect schedule; WEMWBS: Warwick-Edinburgh Wellbeing scale; VAMS: Visual analog mood scale; p-value significant fixed at 0.05 indicated in bold.

TABLE 4 Multiple linear regressions showing the association of the intervention (used as independent variable) with change (between after and before intervention) in mean values of scales assessing wellbeing, positive emotional state, negative emotional state, happy mood state and sad mood state (used as the dependent variable, separated model for each variable) adjusted by the participants' baseline characteristics (*n* = 40).

Outcome measure	β	[95% CI]	p-value	Adjusted R^2	*Cohen's d*
PANAS positive score‡	15.9	[6.8; 25.1]	**0.001**	0.32	−0.66
PANAS negative score‖	1.8	[-29.6; 33.1]	0.909	0.13	0.21
Warwick-Edinburgh Wellbeing scale§	−10.2	[-35.1; 14.8]	0.412	0.10	0.41
VAMS happy¶	24.8	[-56.9; 106.5]	0.541	−0.02	0.11
VAMS sad¶	17.5	[-80.5; 111.4]	0.719	0.05	−0.42

β: Coefficient of regression beta; CI: confidence interval; ‡: Ranging from 10 (lowest level of positive emotional state) to 50 (highest level of positive emotional state); ||: Ranging from 10 (lowest level of negative emotional state) to 50 (highest level of negative emotional state); §: Ranging from 14 (i.e., none of the time) to 70 (i.e., all the time); ¶: Ranging from 0 (neutral) to 100 (highest level of the described mood); Values in bold indicate statistical significance at p < 0.05. All models adjusted for sex, CARE score, liking classical music, and neurocognitive disorder.

positive score (d = −0.66), supporting the clinical relevance of the observed improvement. Other outcomes showed small or negligible effects (see Table 4), consistent with the non-significant findings.

Discussion

This study showed a high acceptability of a music-based virtual reality (VR) intervention in the studied sample of geriatric outpatients. However, the mental health effects observed were mixed. A significant increase in positive emotional state was reported in the intervention group, but no other significant effect was reported.

First, the results demonstrated a very high adoption (willingness to complete the entire study), as assessed by a particularly high retention rate (95.2%), suggesting that older adults can effectively engage with VR interventions. This aligns with prior systematic review showing that retention rates in VR interventions among older adults vary from 70.0% to 100% (Miller et al., 2014). Our results confirm the growing interest in immersive VR experiences suggested by recent studies (Huygelier et al., 2019), alongside previous studies where retention rates are in the highest range [from 84.0 (Benbow and Anderson, 2019) to 93.4% (Casuso-Holgado et al., 2022)].

Second, the VR intervention led to a very high satisfaction as shown by the high rates of user satisfaction and perceived effectiveness. The user satisfaction rate aligns with a previous study in which up to 90.0% of participants expressed a willingness to repeat the VR experience (Tennant et al., 2020). Similar findings have been reported by other studies assessing strong satisfaction rates in palliative care (Brungardt et al., 2021) and among older adults with mild cognitive impairment (Arlati et al., 2017; 2021). Perceived effectiveness in this study aligns also with previous study, reporting a significant subjective improvement of mental health issues among participants after VR musical intervention (X. Lin et al., 2023; Brungardt et al., 2024).

Third, regarding the third and last criteria for acceptability, SSQ scores allowed us to conclude to a very good tolerance of the VR intervention. These findings on VR tolerance and cybersickness are in line with previous studies, reinforcing the idea that VR is generally well tolerated by older adults. Although some research has identified cybersickness as a potential barrier to engagement in this population (Kennedy et al., 1993), other studies have shown that such adverse effects are typically minimal. In this study, 95.0% of participants reported no symptoms of cybersickness, exceeding the tolerability rates reported in earlier trials where minimal symptoms were observed in approximately 11.7% of older adults (Siette et al., 2024). Unlike many studies that define minimal cybersickness as assessing lower SSQ scores than threshold typically regarded as within an acceptable range (i.e., below 15) (Kennedy et al., 1993), we adopted a more restrictive threshold of 9 (Lin et al., 2023), yet still observed superior results. The present static VR design likely contributed to these findings, as static VR is known to reduce motion sickness, even if it can still cause visual fatigue and discomfort (Pavic et al., 2023). Conversely, a subset of studies has reported higher rates of discomfort, particularly when VR exposure times are extended beyond 20-30 min (Doré et al., 2023; Kennedy et al., 1993; Siette et al., 2024) or among participants with limited prior VR experience (Jayakody et al., 2024). However, given the older adult population and our team's VR expertise, we designed 15-min sessions to minimize side-effects and adhere to recent VR best practices (Cinalioglu et al., 2023; Sekhon et al., 2024), it's important to note that information about participants' previous experiences of VR were not collected.

Altogether, the study reported positive results in all acceptability criteria (adoption, satisfaction and tolerance) supporting the fact that the intervention can meet the interest of geriatric outpatients and was particularly engaging and well-tolerated by them. Although acceptability results were encouraging, the 80% retention threshold, drawn from previous digital health and VR studies in older adults (Walters et al., 2017), is somewhat arbitrary and context-dependent. Moreover, satisfaction measures such as willingness to repeat the intervention may be influenced by social desirability bias, especially given the novelty of VR. Self-reported questionnaires may thus overestimate true satisfaction. Future studies could reduce this bias by using objective metrics (e.g., re-use behavior) or qualitative interviews conducted by blinded assessors.

Finally, regarding the mental effects of the intervention, the significant increase in positive emotional state suggested that the VR experience elicited positive emotions. These results align with previous studies demonstrating that VR-based music interventions enhance emotional engagement (Hung et al., 2025) and induce positive emotional state in older adults (Y. Kim et al., 2024; Restout et al., 2023; Yang Q. et al., 2025; Yu et al., 2024). One possible explanation for these findings is the immersive nature of VR, which has been linked to heightened emotional arousal compared to traditional music listening (Pavic et al., 2023), with high enjoyment and minimal symptoms of cybersickness (Arlati et al., 2021; Jayakody et al., 2024). This interpretation is supported by the regression model, where the intervention accounted for a meaningful portion of the variance in PANAS positive change (adjusted R^2 = 0.32), indicating moderate predictive value. Other outcomes (WEMWBS, PANAS negative, VAMS), however, showed minimal explanatory power (adjusted R^2 between −0.02 and 0.13). While no minimal clinically important difference has been established for PANAS in older adults, changes above 0.5 standard deviations are typically considered clinically relevant (Norman et al., 2003). The effect size observed here aligns with those reported in traditional music therapy for emotional outcomes (d = 0.5–0.8) (Ueda et al., 2013; Zhang et al., 2017), suggesting that immersive VR may provide similar or even enhanced emotional benefits. The broaden-and-build theory (Fredrickson, 2001) posits that positive emotions expand an individual's cognitive flexibility and psychological resources, effects likely amplified by VR's sensory richness. Embodied cognition theory further suggests that bodily engagement with virtual environments intensifies emotional responses. VR also offers a secure, controllable context conducive to emotion regulation, which may further contribute to its therapeutic value in geriatric mental health.

In contrast, the lack of significant effects on wellbeing or mood may reflect methodological and theoretical factors. The study was powered to detect changes in positive emotional state (PANAS positive), not in secondary outcomes such as wellbeing or mood, possibly limiting statistical sensitivity. Furthermore, while positive emotions can contribute to enhanced wellbeing, the transition from momentary affect to broader psychological change is neither immediate nor guaranteed (Le Nguyen and Fredrickson, 2018). Short exposures to music or immersive content have been shown to produce measurable short-term emotional and physiological benefits in older adults (Bradt and Dileo, 2014; Chanda and Levitin, 2013). However, the short duration of the intervention (15 min) and the single-session design, although relevant in geriatric contexts where time and attention are limited, may have been insufficient to generate lasting changes in wellbeing, as observed in prior studies using longer and non-VR interventions (Beauchet et al., 2022b).

This divergence in outcomes may also relate to differences in psychological constructs: the PANAS captures immediate emotional response, whereas wellbeing and mood reflect more stable traits requiring sustained engagement to shift. Thus, VR may serve as a transient enhancer of affect, with durable psychological benefits likely requiring repeated or personalized interventions. Moreover, virtual reality may induce non-conventional emotional responses that are not fully captured by standardized wellbeing or mood scales (Pavic et al., 2022). Although some studies have reported improvements in wellbeing after a single VR session (Chaze et al., 2022; Makmee and Wongupparaj, 2025), our findings are more consistent with research suggesting that repeated sessions over time may be required to achieve meaningful psychological outcomes (Särkämö et al., 2014; Veal et al., 2022). This aligns with broader clinical evidence showing that the effects of VR interventions on wellbeing are often variable and may depend on intervention intensity and duration (Doré et al., 2023; Restout et al., 2023; Yang et al., 2025a). Individual variability in cognitive status and priori technology exposure could also have influenced the outcomes. The study population included individuals with neurocognitive disorders. While music has been shown to benefit this group (Beauchet et al., 2022b; Kim et al., 2023), variability in cognitive function may have affected their ability to fully engage with or benefit from the intervention.

This study presents several methodological strengths that support the reliability and relevance of its findings. It employed a randomized controlled trial design, which is considered as the gold standard for evaluating the efficacy of health interventions (Hariton and Locascio, 2018). Given the novelty of the intervention in this population and the limited available data on its specific mental health effects and tolerability, conducting a small-scale trial was ethically appropriate prior to launching a large-scale study. Despite its exploratory nature, the study maintained methodological rigor and retained statistical power, with the sample size determined through an *a priori* power calculation based on the PANAS positive score. The intervention was delivered under standardized conditions using a high-quality, pre-recorded music-based VR experience specifically developed for the study. This ensured consistency across participants and improved internal validity. The use of validated psychometric instruments (PANAS, WEMWBS, VAMS) further strengthened the assessment of emotional and psychological outcomes, allowing comparisons with existing literature. Moreover, the study was conducted in a real-life clinical setting with geriatric outpatients, enhancing ecological validity and demonstrating the feasibility of VR interventions in routine care.

While this pilot study presents promising findings, a few methodological considerations must be acknowledged to contextualize the results and guide future research. First limitation concerns the sample size and study design. A significant gender imbalance was observed between groups despite random assignment, likely due to the use of simple randomization within a small sample, where unequal group characteristics can emerge by chance. Although sex was statistically controlled for in all regression models, gender differences in emotional processing and technology acceptance among older adults may have influenced the outcomes (Pavic et al., 2023). Moreover, the relatively small sample size ($n \leq 40$) reduces statistical power and may have limited the ability to detect significant effects on wellbeing and mood (Rossi, 1990; Yang Q. et al., 2025). Second, selection bias and socio-demographic homogeneity represent additional limitations of this study. The sample was not socio-demographically diverse, being entirely Caucasian and recruited from specialized geriatric and memory clinics, which limits generalizability to broader and more diverse older populations. A preference for classical music was also prevalent (95%), suggesting a potential self-selection bias favoring individuals predisposed to respond positively. In addition, feasibility issues with current VR technology have been noted. VR hardware can be costly, require supervision, and present usability challenges that limit adoption among older adults (Appel et al., 2019), underscoring the need to improve accessibility and staff training for clinical use. Third, uncontrolled individual differences may also have influenced the outcomes. The heterogeneity in cognitive status and the lack of neuropsychological stratification may have introduced variability in emotional responses, although this reflects clinical practice. Additionally, the absence of musical personalization, despite most participants expressing a liking for classical music, could limit emotional resonance and physiological effects (Kim et al., 2024; Pereira et al., 2011). Incorporating user preferences may improve engagement and therapeutic impact, particularly in diverse clinical populations.

Lastly, the lack of an immersive, non-musical control group is another limitation of this study. Because the control group received only the audio component, it is not possible to fully disentangle the specific effects of music from those of visual immersion and the novelty of VR technology. Previous studies have shown that immersive VR alone can enhance mood and emotional engagement, even without music (Lin et al., 2018), suggesting that some observed effects may be driven by non-musical features. Future studies should adopt a factorial design (e.g., music vs. no music × VR vs. audio-only) and include short-term follow-ups to clarify the respective contributions of music and immersion and to assess the stability of these outcomes over time.

Conclusion

This pilot study found that a music-based VR intervention was highly acceptable and led to a significant improvement in positive emotional state among older adults in geriatric outpatients. The findings suggest VR's potential as an engaging tool to improve positive emotions in geriatric care. Although traditional music therapy remains less costly and more widely available, integrating VR-based music therapy into clinical practice could offer an innovative and scalable approach to enhance mental wellbeing, particularly in contexts where access to trained therapists is limited (Bradt and Dileo, 2014). However, current hardware (e.g., MetaQuest Pro) is expensive, requires supervision and is not yet widely adopted by older adults, which limits feasibility in both clinical and home settings. Improving usability, simplifying hardware, and training staff are key steps to increase accessibility and cost-effectiveness (Appel et al., 2019). Future research should focus on adapting VR systems for independent use, testing home-based personalized interventions, and incorporating objective physiological measures to better understand how immersive technologies influence emotional processing and support mental health in aging populations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by CIUSSS Centre-Sud-de-l'Île-de-Montréal (Quebec, Canada) Research Ethics Committee Vieillissement et neuroimagerie. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KG: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review and editing. KD: Writing – review and editing. JC: Conceptualization, Writing – review and editing. HS: Conceptualization, Writing – review and editing. TT: Writing – review and editing. AG: Writing – review and editing. OB: Conceptualization, Data curation, Formal Analysis, Supervision, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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