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Article

Virtual Choirs in Care Homes: The Development and Early Assessment of a New Virtual Reality Choir Intervention

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Abstract: Engaging with music has been shown to have a positive impact on the quality of life of residents in care homes, who are known to be affected by anxiety, depression and loneliness. Based on the known benefits of in-person singing activities, a new Virtual Reality (VR) choir application was developed to facilitate group singing, aiming to improve residents' wellbeing and sense of community. Co-designed with Alzheimer Scotland, the intervention was tested in two care homes for functionality and to develop an approach towards assessing feasibility. Residents participated in scheduled sessions over a five-week period, in addition to staff engaging in independent ad hoc use of the experience with residents. Data on reactions to the intervention, the quality of life of participants and preferences about the outcome instruments were collected. The VR intervention proved technically successful, user-friendly, and allowed multiple users to sing together. Participants and staff showed strong enthusiasm for the intervention, with residents actively engaging in singing and movement, although some residents found the headsets uncomfortable. This suggests that VR choirs could be a valuable, scalable activity in care homes, especially when in-person facilitators are unavailable. Preliminary observations indicated that the intervention was not detrimental to participants' health; however, the sample size was very small and a larger feasibility study is required to examine the intervention's effectiveness, scalability, and cost-effectiveness. This research highlights the challenges associated with measuring the feasibility of VR interventions in residential care settings, and the value of capturing qualitative data in an ecological setting that represents the intended use of the intervention.

Keywords: virtual reality; care homes; singing; wellbeing; feasibility; music intervention; choirs

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1. Introduction

Anxiety, depression and loneliness are prevalent in residents in care homes, and with an aging population and more people living longer with chronic conditions, care home populations are likely to increase [1]. There remains limited evidence related to interventions to prevent and manage the anxiety, depression, and isolation of care home residents [2], although enjoyable and social activities have been identified as beneficial [3]. Music interventions, and music therapy in particular, have been tailored as a way of supporting care home residents to support their quality of life e.g., [4,5]. The use of Virtual Reality (VR) as a tool to support the quality of life of care home residents is currently being explored but is still relatively new, and VR music interventions are in the very early stages of design and adoption. There are research questions to be addressed with regard to the

design, effectiveness, and cost-effectiveness of VR music interventions for use by care home residents and how their potential benefits are measured. This paper reports the co-design, development, and testing of a new VR group singing intervention with a pre-feasibility protocol to consider how to assess the intervention's efficacy and value in the future.

Engaging with music as a passive or active pastime has been shown to have a beneficial impact on the quality of life of residents in care homes [6]. Music interventions include music therapy, personalised listening, structured singing, and music therapeutic care. These have been shown to improve social interactions of care home residents with dementia, as evidenced by increased verbal and non-verbal communication [4].

Music technology provides numerous avenues of exploration to engage care home residents in music. Its potential to support positive health- and wellbeing-related outcomes has been considered across multidisciplinary perspectives and for multiple use cases [7]. The scope and breadth of digital music intervention is broad, encompassing any engagement with digital technology associated with music, from personalised digital playlists [8] to bespoke musical instruments [9]. The outcome measures associated with evaluation of digital music interventions are commonly positive [4]. There is also a growing emphasis on co-design and evaluation, putting the end-user at the forefront of decision-making in the design of interventions and technologies [10]. Whilst in-person activities have been the focus of more research and are generally seen as the optimal experience, there is increasing evidence that digital technologies that enable remote participation also yield positive results [11]. For instance, anxiety, depression, loneliness, perceived stress, and sleep satisfaction were reported to improve in care home residents who took part in an online music and movement intervention over a period of 12 weeks [12]. However, the effects of movement compared to the music intervention were not separated in the analysis, so these results cannot be solely linked to online musical activities. As digital technologies and associated hardware develop and become cheaper and easier to use, there is an opportunity to extend the offering of music technology even further.

Virtual Reality has slowly started to have an impact on the care sector. A recent study by Li et al. observed a positive psychological impact on elderly residents in a nursing home who engaged in VR group-based activities over a period of four weeks [13]. Validating VR specifically as a tool for music therapy for the elderly, Perez et al. created a simple but immersive 360 degree passive listening experience, with results showing that the residents of a nursing home experienced similar levels of presence in the VR environment to younger populations [14]. The recognised potential of Augmented Reality (AR) and VR in supporting the lives of older adults led to a proposed evaluation framework for VR/AR in three main categories: physical, social, and psychological wellbeing [15].

Virtual choirs, in which digital technology is used to facilitate some form of remote participation in group singing, were popularised during the COVID-19 pandemic when in-person activity was restricted[16]. Whilst in-person singing mostly went back to business as usual post-pandemic, virtual choirs have remained popular in many different contexts. Several models of virtual choirs have emerged over the last decade that provide different options for remote choir participation. Some utilize traditional teleconferencing software [17–19] or recording workflows [20,21], whilst others involve specifically developed technologies such as VR [22]. Each model facilitates access to different elements of the in-person choir experience, some with real-time interaction and some based on pre-recorded stimuli [23] .

VR presents solutions to several challenges associated with in-person music interventions, especially in a care home setting, particularly the need to schedule activities and establish 'ground rules' for the facilitator and the other volunteers involved [24]. Providing residents with the agency to choose when and where they take part in group singing activi-

ties is a large potential benefit of VR choirs. These scheduling benefits would still require staff training, as essential additional health and safety considerations arise when working with VR. In the past, Technical Virtual Reality Choir frameworks and recording workflows have been developed which provide a a fully immersive experience of being within a choir and blending your voice with the rest of the choir as you sing along [25]. A limitation of these frameworks to date is that, thus far, they have been restricted to single users.

It was the purpose of this project to build on the known benefits of the virtual choir models and develop a VR choir application that could be used in residential care homes, providing opportunities for remote and synchronous in-person group singing through VR.

This paper describes the co-design of the new VR group singing application, which allows multiple users to sing together while immersed within a pre-recorded choir. A two-pronged study was conducted to assess the potential use of such an intervention and how the effects of the intervention on health-related quality of life, physical wellbeing, and mental wellbeing of residents in care homes might be measured in a future full-feasibility and randomised control trial.

2. Materials

2.1. Co-Design and Specification

The specification for the application was developed through a co-design process with project partners Alzheimer Scotland, their Dementia Circle, multiple community choir leaders, and care home managers and staff. Initially, focus groups were formed to develop an initial specification for the intervention, including its technical capabilities and content. The focus was on participants' experience, enthusiasm, and concerns related to engaging with VR in care homes and with people with dementia; challenges experienced by VR users with dementia and in care homes; and key considerations when running in-person dementia choirs and choirs in residential care homes, including repertoire, how the music is taught, peripheral activities such as tea and coffee breaks and socialising, etc.

2.1.1. Technical Specification

Based on the outcomes of these focus groups and the existing literature discussed in the Introduction, the following initial technical specification was created for Care Reality to develop the VR Application:

- Ideally hardware-agnostic (compatible with various devices) for future scalability
  - PICO 4 headsets were used in this study, as the focus groups deemed them more comfortable than the Meta Quest 2, which was the alternative model available during development
- System must run on local Wi-Fi connections and connect automatically to avoid reliance on varying internet connections that might impact the VR experience.
- Loading screens and 'lobby area' not confusing or disorientating
- Ease of use (easy both for care home staff to run the experience and for residents to engage with it)
  - The person experiencing VR only needs to put the headset on and look around
  - Remotely controlled by a tablet/phone (also very simple for care home staff to use so they can control what happens in VR). This includes connecting the headsets to the application (which occurs automatically upon connection with the app) and then choosing songs based on easily viewed icons and titles.
  - Minimal initial set-up (no expertise required and quick to set up)
- Minimise the potential hazards of using VR through experience design

- A seated experience with 3 degrees of freedom, whereby the user has a 360 degree experience as they rotate their head but the VR environment is static from that position, so there is no need for the user to stand or move as they cannot move through the virtual environment.
- A safety announcement in VR to remind the user they are in VR and can remove the headset anytime
- Guidance reminding users not to use the VR headset for longer than 15 min in any session

Desirable but non-essential functionality included the ability to communicate by talking through the VR headsets in real time within the application to allow participants who were not in the shared physical space but were elsewhere in the care home to participate. This was implemented but was not tested or utilized in the study reported here.

The system design is shown in Figure 1.

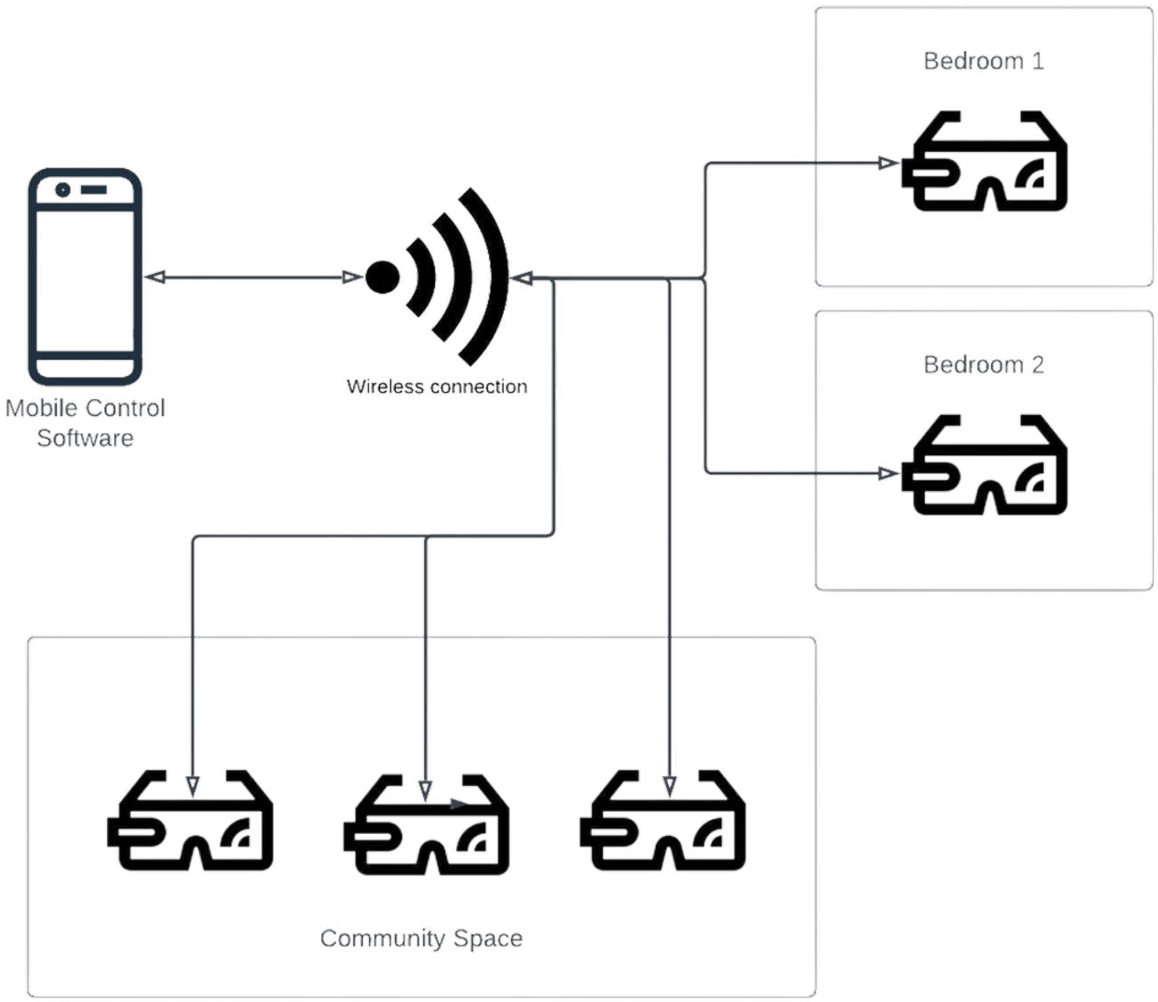

Figure 1. System design.

2.1.2. Choir Video Content

Alongside the technical specifications of the app, the experience that would be played back was also designed as part of the co-design process and focus groups. These would be a bank of short videos with 360 degree audio and visual playback to be incorporated into the app and stored locally on the headsets. Based on previous work on community-based choir

engagement, alongside the priorities of choir leaders when working with dementia patients and in care homes, the following criteria for the 360 degree recordings were outlined:

- All recordings should take place in visually interesting surroundings—ideally outside.
- The group should be directed and taught the songs by rote as part of the recording.
- The songs should be easy to sing.
  - The recordings should be made up of well-known songs and melodies.
  - The songs should be within a standard vocal range (not extreme tessituras).
  - Only simple harmonies should be involved (those that enrich the experience but do not necessarily need to be sung).
- The experience should involve musical material that is likely to be known to the users but is outside of copyright.
- A warm-up video of a few minutes should be included and led by the choir director (while remaining seated).
- The director and choir should engage with the video camera so the person in VR feels included.

2.1.3. Alpha Version and Testing

An alpha version of the app was developed and tested with the AGE UK Dementia Circle staff, who provided feedback on usability and general enjoyment. One or two members of staff joined all team meetings throughout the project to feed into its development, and then five members of staff were involved in testing at different locations in Scotland. Then, there was a period of iterative design with the focus group and a Beta version created alongside new material recorded in 360 degrees, which was tailored to the feedback from the focus groups and initial testing.

2.1.4. Beta Version and Testing

Following the Alpha stage, the functions of the Beta version which was used in the pre-feasibility study were as follows:

- A mobile app controller.
- A very simple user interface.
- Automatic connection to a local IP address.
- A new virtual environment for the lobby area (the virtual lobby that people experienced while the app was loading).
- A bank of nine song recordings was included.
  - Warm Up.
  - Fellowship Song.
  - Light of Mine.
  - Loch Lomond.
  - Original Song.
  - Peace Song.
  - Danny Boy.
  - White Cliffs of Dover.
- A warm-up video.

The staff at Alzheimer Scotland informally tested the updated intervention with members of the Dementia Circle, a group of people affected by dementia who are interested in engaging with technology to improve their everyday lives. This testing was positive, and the staff were able to carry out the intervention based on the instructions provided with minimal troubleshooting from the Care Reality team. This version of the intervention was utilised in the feasibility studies to test the usability of the application by care home

staff in a care setting and explore ways to measure its efficacy and cost-effectiveness in a full feasibility study at a later date.

3. Feasibility Studies: Methods

This study was a two-pronged design with two specific objectives:

- Ad hoc engagement: Understand the practicalities of utilising the technology within the daily running of residential care homes.
- Pre-feasibility study: Develop and test a feasible protocol to assess the efficacy and wellbeing benefits of the intervention.

The guidelines for implementing and evaluating music in care homes were followed as part of the development and implementation of the study [24].

3.1. Ethical Approval

Ethical approval for this study was obtained from the Physical Sciences Ethics Committee at the University of York, ensuring compliance with their 'Code of practice and principles for good ethical governance' (Daffern20231220). The study was explained verbally, and time was allocated for one-to-one discussion and questions prior to participants providing their informed written consent to take part. Participants were verbally reminded of the study before each session and were able to withdraw at any time without giving a reason.

3.2. Participants

Two residential Care Homes in Scotland took part in the study. Once staff had tried out the intervention and had a full understanding of both prongs of the study, we worked with them to identify suitable participants for the pre-feasibility study. Only residents with capacity to consent could take part and care home staff were asked to recruit 10 residents for the initial visit based on their knowledge of the study and the residents. Care Home 1 can accommodate 60 residents in residential care, whilst Care Home 2 had 54 residents at the time of the research. Each of these care homes is part of a different larger group of private care homes. On the first day of the study, Care Home 1 had other activities taking place that day and this reduced the availability of residents. Several residents were reluctant to take part in the pre-feasibility study once the study had been explained, mostly due to the need to answer questionnaires as part of the study, although some were put off by the idea of VR and putting on the headset. Due to these factors, four participants were initially recruited in Care Home 1 and seven in Care Home 2. Whilst only 11 participants completed the baseline session for the pre-feasibility study, an additional 2 participants took part after the baseline session, although they were not originally recruited to the study (ID 12, 13). Additional residents had the opportunity to engage informally with the VR choir by asking (or being encouraged by staff) to try the experience as part of the ad hoc engagement.

3.3. Ad Hoc Engagement: Method

Prior to collecting any data, care home staff were trained to use the VR application and taught how to record engagement during a session which was dedicated to training staff to use the VR application. This session was also used to recruit participants for the pre-feasibility study. Two VR headsets and a mobile phone (controller) were provided for the five-week study duration. Staff were given information sheets and consent forms alongside feedback sheets to log information about residents' engagement.

Ad Hoc Engagement: Intervention Delivery

Care home staff could choose, by themselves or with residents' guidance, from any of the eight videos that were uploaded within the application. They were asked not to use the VR headsets for any other activities for the duration of the study. Residents could take part alone or with one other resident, utilizing both headsets to sing together. It was advised that they started with the short warm-up video, but this was not essential. Staff were informed that sessions should last for around 15–20 min and for no more than half an hour to avoid fatigue resulting from wearing the headsets.

3.4. Pre-Feasibility: Method

Residents enrolled in the pre-feasibility study took part in facilitated sessions at weekly intervals for three weeks, in which research assistants involved in the project helped them to sing together using the VR intervention during the sessions. Self-reported questionnaires were administered by researchers where possible, and by care home staff on occasion. Baseline data were collected before the first session and the full set of questionnaires was repeated after the final session (Day 22). A smaller set of measures, including measures related to mood, were collected during each session throughout the study period (Days 1, 8, 15, and 22).

3.4.1. Pre-Feasibility: Intervention Delivery

The researchers set up the room with the VR headsets prior to the residents joining each session. With help from care home staff, they then supported the residents by reminding them about the study, confirming their continued consent to take part, and asking brief questions about their mood before the session began. Once the participants were wearing the headsets, the researchers used the mobile application to play several songs from the uploaded videos, giving the residents opportunities to show a preference and repeat songs when desired. The intervention session time, which was the time they spent singing, was led by participants for up to half an hour, after which they completed the same mood scale questions and provided informal feedback by chatting to the researchers.

3.4.2. Pre-Feasibility: Data Collection

Data on residents' demographics and self reported measures of health-related quality of life (HRQoL), social connectedness, and loneliness were collected at baseline.

As there is strong evidence that group singing activities have short-term benefits on emotion and mood, with less strong evidence of the long-term effects, e.g., [26], this study also explored the most appropriate tools for assessing the immediate impact of the intervention on mood based on pre and post measures during each session. The following measures were used to assess acute mood pre and post each engagement with the intervention:

- UWIST [27]: This is a list of 24 adjectives to be ticked against a scale of affinity with that item. This was chosen due to its previously reported use in VR studies involving elderly populations [28]. However, this was only completed by three participants in session one in Care Home 1 and was found to be too complex for residents. Therefore, no results are reported here.
- Circumplex model of affect [29]: Participants were asked to place a mark on a mood wheel (reflecting the circumplex model) that best represented how they felt in that moment. This tool was adopted from Day 1 in Care Home 2 after the UWIST tool was found to be unsuitable, to see whether a single-item visual scale would be less onerous.
- Gender-adjusted Self Assessment Manikin [30]: This tool is commonly associated with research in a VR context and was added to the protocol on Day 8 to assess its usefulness as a simple visual scale compared to the mood wheel.

Short questionnaires, the 3-item UCL-Loneliness [31] and 10-item UCB State Social Connection [32], also asked at baseline and after each session, were used to assess loneliness and social connectedness, respectively. The 10-item UCB scale was only used in the first session in Care Home 1 and was removed from the protocol thereafter to shorten the time spent on data collection, and therefore no results are reported for this scale.

To assess economic outcomes in a future trial, outcome instruments for measuring general health-related quality of life (HRQoL), physical wellbeing, and mental wellbeing were collected. Typically, in health economic evaluations, HRQoL is measured using generic instruments such as EQ-5D to measure health; however, some interventions, particularly those used in social care and public health, have broader impacts beyond health. To capture this, capability wellbeing was assessed, in line with guidance from the National Institute for Health and Care Excellence (NICE), to consider the use of this outcome instrument in publicly funded social care [33]. Additionally, given the potential for the intervention to impact mental wellbeing, a specific outcome instrument was used to measure this. HRQoL was measured using the EQ-5D-5L questionnaire, a measure that is widely used for the calculation of quality-adjusted life years (QALYs) in economic evaluation. Residents were asked to complete the questionnaire at baseline prior to use of the intervention and over a 3-week period, at weekly intervals following use of the intervention. Capability wellbeing (measured using the ICEpop CAPability measure for Older People (ICECAP-O) was assessed, as it measures a person's ability to achieve capabilities important to people's lives more generally [34]. Additionally, mental wellbeing (measured using the Short Warwick–Edinburgh Mental Wellbeing Scale (SWEMWBS) [35]) is assessed to measure how the person is feeling and functioning [36] . SWEMWBS data were collected at baseline prior to use of the intervention, and after 3 weeks (at day 22) directly after using the intervention. The self-reported questionnaires were administered by researchers where possible, and by care home staff on occasion.

- Health-related quality of life (HRQoL): HRQoL was measured using the EuroQol 5 Dimensions (EQ-5D-5L (Rabin et al, 2001). This profiles health-related quality of life (HRQoL) on the dimensions of mobility, self-care, usual activities, pain/discomfort and anxiety/depression based on five levels of severity (no problems = 1; extreme problems = 5). A UK national population tariff was applied to create a summary score value for each health state described. For the UK, as recommended by NICE (NICE PMG36, 2023), the crosswalk range of scores is −0.532 to 0.987 [37] with 1 representing full health and 0 representing death, while negative values relate to states worse than death. Additionally, a visual analogue score was completed by each participant, indicating their individual evaluation of their own health state (range 0 to 100 with 0 representing death and 100 full health).

- ICEpop CAPability measure for Older People (ICECAP-O): The ICEpop CAPability measure for Older People (ICECAP-O) assesses five capabilities that are important to one's wellbeing, comprising attachment, security, role, enjoyment, and control [38]. The instrument can be used as an important addition to generic health questionnaires when evaluating quality of life extending beyond health; for example, in settings such as care homes. NICE explicitly refers to the use of ICECAP-O in its guidance [33,39] for the economic evaluation of interventions funded by the public sector with a social care focus. ICECAP-O uses a UK general population tariff based on best–worst scaling with 0 indicating no capability and 1 representing full capability, to enable its use in economic evaluation both within the field of health and across public policy generally [34].
- SWEMWBS: The Short Warwick–Edinburgh Mental Wellbeing Scale enables the monitoring of mental wellbeing in the general population [35]. The 7-item SWEMWBS is useful to save space and time in evaluations. The instrument asks for responses to the following 7 statements;

  1. I've been feeling optimistic about the future.
  2. I've been feeling useful.
  3. I've been feeling relaxed.
  4. I've been dealing with problems well.
  5. I've been thinking clearly.
  6. I've been feeling close to other people.
  7. I've been able to take up my own mind about things.

  The participant gives each statement a score from 1 to 5, which encompasses things that they experience none of the time (1) to all of the time (5), using a Likert Scale; thus, higher raw scores indicate that the individual is experiencing better mental wellbeing.

3.5. Debrief Interviews

After the follow-up session, participants underwent a relaxed forum with the researchers in which they were asked informally about any feedback related to the study. The staff then took part in an informal semi-structured interview with the researchers to provide feedback on both the intervention and the running of the feasibility study.

4. Results

The following section presents the results of the pre-feasibility study, ad hoc engagement, and debrief interviews. Quantitative data are reported to provide an indication of trends within individuals. Due to the small sample size, outcomes have weak statistical power and are not generalizable.

4.1. Pre-Feasibility Study: Results

4.1.1. Baseline Characteristics

Table 1, reports the age and gender of participating residents. The average age of residents participating in the study was 72.4 years of age (ranging from 41 to 94) (note that this includes all participants, including ID 12 and 13, where their data are available), including eight females and two males. Information on age and gender was not available for the other residents.

Table 1. Participant demographics and completed outcome measures in the pre-feasibility study.

ID	Age	Gender	EQ-5D 5L Scores	EQ-5D 5L Visual Analogue Scores	ICECAP-O	SWEMWBS
1	X	X	x	x	x	x
2	79	Female	✓	✓	✓	✓
3	X	X	x	x	x	x
4	94	Female	✓	✓	✓	x
5	75	Female	x	x	x	x
6	41	Male	x	x	✓	✓
7	80	Female	x	x	x	x
8	43	Female	✓	✓	✓	x
9	87	Female	x	x	x	x
10	84	Male	✓	x	x	✓
11	60	Female	x	x	x	x
12	81	Female	x	x	x	x
13	X	X	x	x	x	x
	Average 72.4	Female 8/10	Complete scores at all time points = (✓) not completed at all time points = (x)			
		Male 2/10	4	3	4	3

X = missing data.

4.1.2. Engagement with the Intervention

The amount of time spent wearing the VR headsets and singing and the choice of songs was led by the participants in discussion with the research lead on the day of the session. The researchers reported that sessions lasted around half an hour, with longer sessions in Care Home 2 (where more residents were taking part) that required the researcher to end the session. The initial reactions to the intervention were positive for both residents and staff: the residents often sang along, even if they had stated before putting the headset on that they 'couldn't sing' or 'wouldn't sing', and physically responded to the music, tapping their feet or nodding their head. It was noted that taking part sparked conversations between residents, discussing musical tastes and recalling memories based on singing or the music itself.

4.1.3. Acute Measures of Mood

The researchers reported limitations with regard to all the tools assessed for measuring acute mood during the intervention. UWIST was discontinued after its first use, as it was deemed too arduous and confusing to residents. When using the Circumplex Mood Scale, residents tended to focus on the words on the circle that was presented to them, and might circle a word rather than placing a mark within the scale on the circle as intended. Quantifying the results in the intended manner (based on a grid system) was therefore unreliable in this case. The SAM assessment scale was utilised pre- and post-intervention from Day 8 and some participants preferred this to the mood wheel; however, some residents found the pictures hard to interpret and felt, in particular, that the dominance and arousal scales began to look negative as scores increased. The chart in Figure 2 shows the averaged data from the five participants for whom data were available. No change was observed for Valence post-intervention on any session. Small decreases in both arousal and dominance were observed, but these may be down to the negative connotations of the pictures or genuine changes in these attributes.

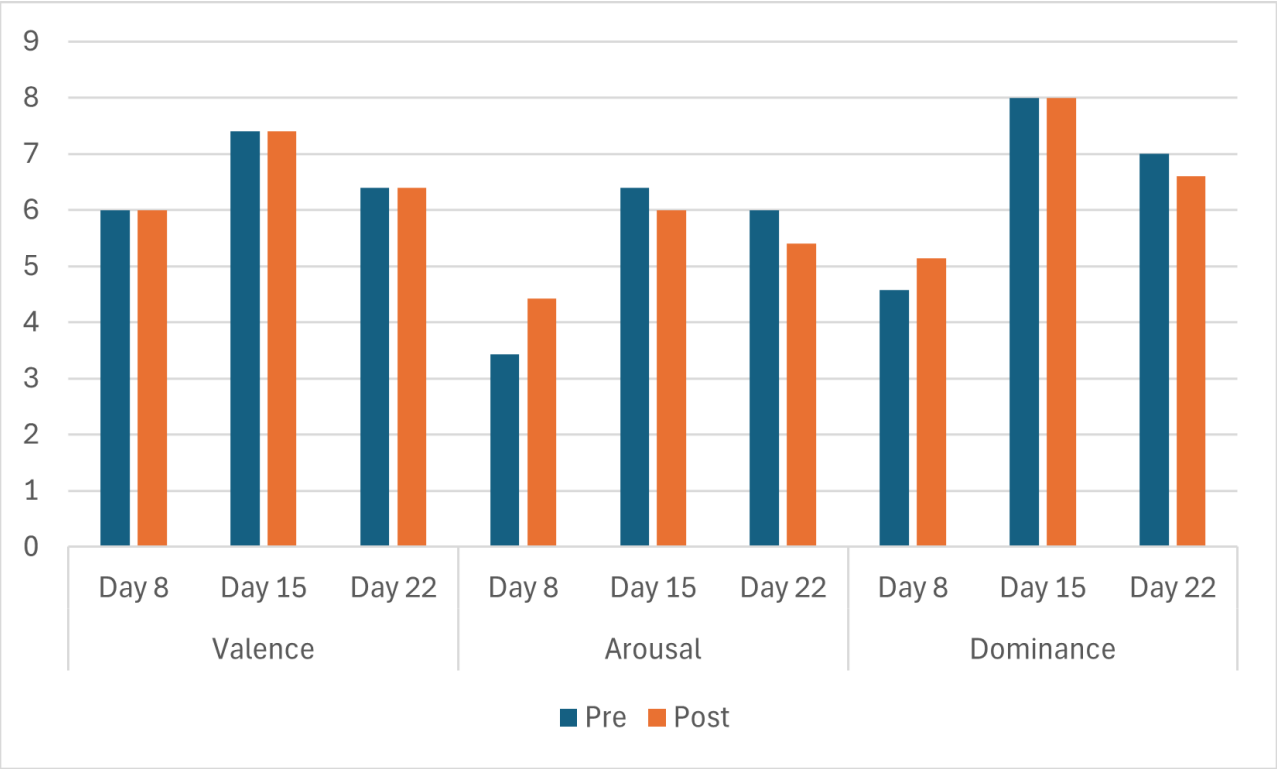

Figure 2. Mean scores from five participants who responded to the SAM.

4.1.4. Loneliness Measures

The 3-item UCLA Loneliness scale was found to be easy to complete. No participants reported an increase in loneliness across the study, although only three participants provided a full set of responses, so the data are not inherently valuable without further study of a larger number of participants.

4.1.5. Health-Related Quality of Life (EQ-5D-5L)

EQ-5D-5L raw scores are reported in Table 2.

The full ranges of scores were used, from 1 (no problems) to 5 (extreme problems) on the HRQoL dimension in question. A complete set of EQ-5D-5L raw scores was obtained for 11 participants at baseline and for 4 of these participants at every subsequent time point. The average age of the four participants (ID 2, 4, 8, 10) for whom we have complete data was 76.0. EQ-5D-5L weighted scores are reported for each participant, and on average at each time point, in Table 3. Typically, average scores were lower (i.e., indicating lower HRQoL) when all scores were used (including where some scores were missing) compared to the complete case analysis. In both cases, the lowest scores were reported at baseline with higher scores thereafter, suggesting improved HRQoL.

Table 4 reports VAS scores for all participants and complete cases (ID 2, 4, 8). Using all of the EQ-5D VAS responses and comparing baseline scores to final scores, there was a small increase in HRQoL (baseline mean 67.7, SD 4.9 to day 22 mean 69.4, SD 5.7), whilst for complete cases (n = 3), there was a decrease in HRQoL (baseline mean 78.3, SD 10.1 to day 22 mean 67.3, SD 10.1).

Table 2. ED-5D-5L. raw scores.

	Baseline					Day 1					Day 8					Day 15					Day 22				
ID	**Mobility**	**Self-Care**	**Usual activities**	**Pain**	**Anxiety/depression**	**Mobility**	**Self-Care**	**Usual activities**	**Pain**	**Anxiety/depression**	**Mobility**	**Self-Care**	**Usual activities**	**Pain**	**Anxiety/depression**	**Mobility**	**Self-Care**	**Usual activities**	**Pain**	**Anxiety/depression**	**Mobility**	**Self-Care**	**Usual activities**	**Pain**	**Anxiety/depression**
1	1	1	3	4	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	3	1	2	4	2	3	2	2	3	2	3	2	3	4	1	3	2	3	3	1	3	2	2	3	2
3	3	2	3	2	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	2	1	2	1	1	2	1	2	1	1	2	1	1	1	1	3	1	1	1	1	2	1	2	2	2
5	3	3	2	4	1	X	X	X	X	X	X	X	X	X	X	X	XA	X	X	X	X	x	X	X	X
6	3	2	2	2	2	2	2	1	2	3	2	3	1	2	2	X	X	X	X	X	3	1	2	2	2
7	2	2	2	1	2	1	2	2	2	2	2	3	3	2	2	3	2	2	3	2	X	X	X	X	X
8	3	1	1	1	5	1	1	1	1	3	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2
9	4	4	1	5	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10	4	5	2	1	1	1	2	1	1	1	3	3	2	1	1	1	1	1	1	1	1	5	2	1	1
11	1	1	1	1	2	1	1	1	1	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12	X	X	X	X	X	1	1	1	1	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13	X	X	X	X	X	X	X	X	X	X	1	2	2	3	1	X	X	X	X	X	X	X		X	X

Table 3. EQ-5D-5L weighted scores.

ID	Baseline	Day 1	Day 8	Day 15	Day 22
1	X	X	X	X	X
2	0.497	0.578	0.307	0.575	0.578
3	X	X	X	X	X
4	0.837	0.837	0.902	0.871	0.704
5	0.312	X	X	X	X
6	0.619	0.616	0.635	X	0.669
7	0.7	0.697	0.617	0.578	X
8	0.314	0.817	0.985	0.89	0.847
9	−0.029	X	X	X	X
10	0.541	0.946	0.68	0.989	0.871
11	0.889	0.889	X	X	X
12	X	0.988	X	X	X
13	X	X	X	X	X
Total number of participants at this point	9	8	6	5	5
Average EQ-5D-5L score (all)	0.520	0.796	0.688	0.781	0.734
Average EQ-5D-5L score (complete case)	0.547	0.795	0.719	0.831	0.750
Average all	72.4	Average (complete case)	76		

Table 4. EQ-5D-5L visual analogue scores (VASs).

ID	Baseline	Day 1	Day 8	Day 15	Day 22
1	60	X	X	X	X
2	**60**	**75**	**65**	**75**	**67**
3	50	X	X	X	X
4	**95**	**80**	**80**	**95**	**85**
5	70	X	X	X	X
6	50	70	85	X	70
7	85	75	72	50	X
8	**80**	**25**	**75**	**50**	**50**
9	50	X	X	X	X
10	85	80	X	80	75
11	60	50	X	X	X
12	X	99	X	X	X
13	X	X	X	X	X
Complete case scores					
Mean	78.3	60.0	73.3	73.3	67.3
SD	10.1	17.6	4.4	13.0	10.1
95%CI lb	58.5	25.6	64.7	47.8	47.5
95%CI ub	98.2	94.4	82.0	98.8	87.1
All scores					
Mean	67.7	69.3	75.4	70.0	69.4
SD	4.9	7.9	3.4	8.8	5.7
95%CI lb	58.2	53.7	68.7	52.7	58.2
95%CI ub	77.3	84.8	82.1	87.3	80.6

lb = lower bound, ub = upper bound; Rows in bold = complete case scores.

4.1.6. ICECAP-O

ICECAP-O raw scores are reported in Table 5. Complete ICECAP-O scores were obtained for 11 participants at baseline. Complete cases were available for four participants (ID 2, 4, 6, 8). The average age of the participants for whom we had complete ICECAP-O data was 64.25.

Table 5. ICECAP-O raw scores.

	Baseline					Day 22				
ID	Attachment	Security	Role	Enjoyment	Control	Attachment	Security	Role	Enjoyment	Control
1	2	1	2	2	2	X	X	X	X	X
2	4	2	3	2	3	4	2	2	4	3
3	3	3	2	3	2	X	X	X	X	X
4	4	4	2	3	2	3	3	3	3	3
5	3	3	3	3	2	X	X	X	X	X
6	2	2	2	2	2	4	3	2	3	3
7	3	3	3	2	3	X	X	X	X	X
8	3	4	4	4	3	2	4	4	3	3
9	4	3	4	4	1	X	X	X	X	X
10	4	4	4	3	1	X	4	3	4	1
11	3	2	4	3	3	X	X	X	X	X

1 = none, 4 = all.

ICECAP-O weighted scores are reported in Table 6. At baseline, across all participants, the average ICECAP-O weighted score was 0.75 (SD 0.13). For the complete case analysis, it was 0.79 (SD 0.17) at baseline and 0.84 (SD 0.03) at day 22, suggesting improved capability wellbeing.

Table 6. ICECAP-O weighted scores.

ID	Age	Gender	Baseline	Day 22
1	NA	NA	0.52	NA
2	79	Female	0.8	0.8
3	NA	NA	0.74	NA
4	94	Female	0.83	0.87
5	75	Female	0.79	NA
6	41	Male	0.56	0.84
7	80	Female	0.82	NA
8	43	Female	0.95	0.85
9	87	Female	0.67	NA
10	84	Male	0.74	NA
11	60	Female	0.84	NA
Average age	71.44	Total number of participants by time point	11	4
Average (all)	72.4	Average ICECAP-O score (all)(SD, min–max)	0.75 (0.13), 0.52 to 0.95	
Average (complete case)	64.25	Average ICECAP-O score (complete case) (SD, min–max)	0.79 (0.17) 0.56 to 0.95	0.84 (0.03) 0.80 to 0.87

4.1.7. SWEMWEBS

SWEMWBS raw scores are reported in Table 7. Complete SWEMWEBS scores were obtained for 11 participants at baseline. Complete cases were available for three residents (ID 2, 6, 10). The average age of the residents for whom we had complete SWEMWEBS data was 64.25.

Table 7. SWEMWBS raw scores.

	Baseline								Day 22							
ID								Raw Score								Raw Score
1	2	1	1	3	3	1	3	14	X	X	X	X	X	X	X	X
2	3	2	4	4	4	4	5	26	3	2	4	5	5	3	5	27
3	3	2	3	3	2	3	3	19	X	X	X	X	X	X	X	X
4	2	1	5	5	5	3	4	25	3	4	5	X	5	4	4	X
5	2	4	3	4	4	4	4	25	X	X	X	X	X	X	X	X
6	4	2	3	3	3	3	5	23	3	3	3	3	3	3	3	21
7	3	3	3	3	3	3	3	21	X	X	X	X	X	X	X	X
8	3	3	4	4	2	1	5	22	X	4	5	5	2	1	5	X
9	4	1	4	3	5	4	4	25	X	X	X	X	X	X	X	X
10	4	4	5	4	5	5	4	31	5	1	3	3	2	4	5	23
11	3	4	3	3	2	3	2	20	X	X	X	X	X	X	X	X

1 = none; 5 = all of the time.

Weighted scores are reported in Table 8. At baseline, across all participants, the average SWEMWBS weighted score was 20.93 (SD 3.35). For the complete case analysis, it was 24.02 (SD 3.77) at baseline and 21.36 (SD 2.49) at day 22, suggesting a reduction in mental wellbeing.

Table 8. SWEMWEBS weighted scores.

ID	Age	Gender	Baseline	Day 22
1	X	X	15.32	X
2	79	Female	23.21	24.11
3	X	X	17.98	X
4	94	Female	22.35	X
5	75	Female	22.35	X
6	41	Male	20.73	19.25
7	80	Female	19.25	X
8	43	Female	19.98	X
9	87	Female	22.35	X
10	84	Male	28.13	20.73
11	60	Female	18.59	X
Average age	71.44	Total number of participants by time point	11	3
Average (all)	72.4	Average SWEMWEBS score (all) (SD, min–max)	20.93 (3.35), 15.32 to 28.13	
Average (complete case)	64.25	Average SWEMWBS score (complete case) (SD, min–max)	24.02 (3.77, 20.73–28.13)	21.36 (2.49, 19.25–24.11)

4.1.8. Researchers' Observations

The researchers running the pre-feasibility sessions were asked to keep a reflective diary after each session to note observations they made about the success of the protocol, the administration of the chosen outcome measures, the engagement of the participants, and any feedback they gathered through conversation and observation.

All researchers noted that participants were put off by the collection of outcome measures, even when enthusiastic about the VR experience, and felt that the questionnaires in themselves impacted the mood of the participants and was the reason for the high attrition rate.

Valuable observations were made about participants' engagement in VR, both in terms of how they participated in the activity and how they engaged over the repeated sessions.

Researchers reported overall positive responses from those who continued to take part:

> 'All residents except 2 sang along, the 2 were seen to be tapping their feet and looking around the environment in the headset'.

> 'Overall, the session went very smoothly and the residents seemed to enjoy the experience and are looking forward to next week's session'.

> '[all participants] sang along, [2 participants] replicated hand movements of Sing from your seat song, [two others] both tapped their feet'

> 'The other three participants stayed in for all 9 tracks and we also played half of 'Light of Mine' and all of 'Loch Lomond' again for them, I think they would have happily stayed in longer'.

> 'We asked several times throughout if anyone had had enough and only [one participant] said yes'.

> '[Three participants] all sang along with most of the music. [One participant] told me afterwards that she enjoyed it but she found some of the higher notes difficult, asked if anything could be done about that'.

> '[One participant] enjoyed the application very much, singing along to most songs, and would only stop using the application if it saved us time. Went through all songs. Also commented that she liked the headset and idea of VR in general'.

> 'I asked [one participant] if she enjoyed the experience as she never sings, though one of the care staff commented that she had joined in a little in the warm-up'.
>
> '[Participant] said she does enjoy it. I asked "do you enjoy just listening to it?" and she said yes'.

Several participants that signed up to the pre-feasibility study did so out of curiosity and with an understanding they did not have to sing themselves if they did not want to, showing reluctance to sing, but once in the VR they sang or hummed along or moved in response to the music:

> 'First session had a resident who was..."not a singer", but they were singing along throughout all songs'.
>
> 'One participant was adamant, again, that she wouldn't sing. In this intervention, she was seated next to another participant who was actively singing, instead of across the room from them as with last week. Saw her mouthing along to lyrics this time around'.
>
> '[One participant] didn't sing at all, had her arms crossed throughout, but she did start tapping her foot to the beat after a while and stayed in the whole time'.

There were also observations of increased social interaction between residents, and between residents and care staff, both within and after individual sessions but also over time as the weeks progressed. This suggests that the VR choir not only gave people an opportunity to engage in group singing, but, as observed in in-person choirs, also contributed to social engagement and community building:

> 'Participants gossiping with us about other participants from the previous weeks'.
>
> '[Participant] was very chatty today, she called me over to gossip at the beginning (she was in the room when we arrived because her room had maintenance going on). She said it was very interesting to have learnt a lot about [another participant] the previous week because "she never talks to anyone here". We had a bit of a chat about [participant]'s life, she was a librarian and worked in book shops'.
>
> '[Participant] was very excited to go in again and convinced [another participant] to join after he said no then [that participant] sang along during loch lomond'!

Over the course of the pre-feasibility study, a specific relationship grew between two residents:

> 'Said it didn't make her feel angry like last week because she knew what to expect. [participant A] was very pleased to see that [participant B] was enjoying it. [Participant B] sang along to the ones she knew. Didn't sing to fellowship song or peace song but did applaud at end. Hummed along with Original Song, didn't sing many words. [Participant B] said she really enjoyed it. At one point when we asked if she had had enough she said "no, this is fun!"
>
> Both [participants A and B] gestured to the choir (ie waving during warm up).
>
> Participant B started singing during the warmup and continued throughout the session.
>
> Participant A was not singing but tapped her feet to the beat (specifically during loch lomond).
>
> Participant B's singing stopped when she didn't know lyrics → later on she would hum, vocalise, or use 'la' to the melody.
>
> Participant A stopped participating after loch lomond → said she got bored but was happy Participant B was enjoying herself.

> Participant B really liked it and got into it!
>
> Participant B wanted to keep singing but didn't want to 'burden' us (kept saying things along the lines of "I don't want to put you through it/take too much of your time/etc" when asked if she wanted to continue → we were able to reassure her that she could do as many songs as she wanted and she ended up doing all of them.
>
> Participant B specifically asked for a cheery song at one point so we played fellowship song.
>
> Participant B clapped after songs and followed the hand gestures/dances the choir was doing.
>
> Participants A and B seem to have a stronger relationship each week they are in the experience together, noticeably chatting before and after more so than in initial weeks.
>
> Participant A spent her longest time in the experience, still not fully enjoying it but seeming to stay in longer due to participant B enjoying it.
>
> [Participant A] sang! She began singing in Danny Boy, saying "I'll give singing a go, as this ones a bit lower." She had commented before we began that she has a very low voice, like a Tenor.
>
> Participant B sang during Danny Boy, Light of Mine, Loch Lomond, White Cliffs. She left after White Cliffs.
>
> Participant B was looking around behind her in Light of Mine'.

Care home staff reported to researchers that one participant who showed physical signs of anxiety including shaking, visibly showed signs of calming when in VR, with the researcher noting the following observation:

> '[Participant] came in with a bit of a shaky leg which stopped once she was in the VR (would occasionally tap/shake but not to the same extent)'.

It must be noted that whilst those continuing to take part in the study were clearly engaged and enjoying the experience, there were also several residents who reduced the length of sessions, or withdrew. Whilst this was often related to the questionnaires rather than the VR experience, some residents were not well suited to the VR experience itself, with one report that a resident became upset and confused in the VR experience ('The new resident decided to not take part further after about 2 songs, said they felt sad and seemed a bit confused by going between the virtual experience and reality'). Clearly, as with exposure to any activity provided to a broad demographic of potential participants, the results depend on the tastes and personalities of the individuals involved. Not everyone enjoys singing, or music. Therefore the participant sample was, as with most arts intervention studies, self-selecting, and does not suggest that everyone will enjoy or benefit from the experience. The additional factor of VR and the requirement to wear a headset was also off-putting for some users and, especially in this population, could cause additional confusion and negative emotion. This was monitored throughout the study and would be an essential factor in the implementation of any such intervention within a care setting.

Comments about potential improvements to the experience with regard to both the hardware discomfort and the content also emerged during the researchers' discussion with participants and observations, including the following:

> 'was asking the people in VR if they had a "spare book" and gesturing to them, because she didn't know the words to the verses of 'Light of Mine"

'One participant left about halfway through, she said the headset was making her nose hurt.'

'[One participant] seemed to enjoy the VR but it wasn't his type of music. He told me he likes acoustic guitar music. He wasn't as engaged with the singing, but he was looking around a lot in VR.'

4.2. Ad Hoc Engagement: Results

During the ad hoc engagement, the intervention was used in both care homes, with 21 sessions recorded in Care Home 1 and 11 sessions in Care Home 2. Overall, both care homes provided positive feedback. Common signs of positive engagement recorded by Staff included the following:

- Started singing along.
- Was moving along to the music.
- Didn't want to stop!

Comments included the following:

'Ok… still looking for Rock Music but said he really enjoyed it'.

'[participant] enjoyed 3 music songs and was very calm and relaxed after'.

'Loved taking part. Very contented during the session. Looked relaxed and engaged. Feet tapping away. Said her neck was a bit sore'.

'enjoyed the time. really good and had fun. Was singing along. Very happy session.'

'Happy initially, however became emotional when she listened to some of her husbands favourite songs'.

'LOVED IT: very used to VR headset as he is a big gamer/Wants more modern music.'

'Love it. Coped well with Headset and music. So engaged. Great session.'

'Loved the music - Loved Singing along. Did state the headset feels a bit too heavy: would try it again!'

'Good enjoyed singing along. Happy to stay for the session.'

'Enjoyed it very much. Would have stayed longer—but her head was feeling heavy!'

'Enjoyed 3 music songs and was very calm and relaxed after'.

The limitations recorded by staff across the two homes were as follows:

- Found the headset uncomfortable.
- The headset was too heavy.
- Wanted more music/a different choice of music.
- Wanted the words on the screen.

One resident 'Enjoyed but tried to get up and dance around' and one session was terminated after five minutes with the report 'Not engaged at all!'. There were also comments recording emotional responses to the music that were both positive and negative, highlighting the implications of the musical material and its personal connection with individuals: '... started to cry at "Danny Boy" as she hasn't sung this in a while'; 'Loved listening to a few songs, however became quite tearful towards the end of the session'.

The staff were very positive about the intervention during the debrief interviews and all expressed disappointment at giving the headsets back. The staff in Care Home 1 had some experience with VR headsets, with a headset in house that was being trialled for dementia training for staff, but had not been utilised with residents. When asked for general feedback about the intervention and running of the study, Care Home 2 responded:

'Definitely very good feedback and everything I think has been based on if you want dementia friendly residents at the same time as well, everything's been in a good approach, everything's been little information at each time, so very very good'. Some staff in Care Home 2 had personal experience of VR but it had not been integrated into the work environment before the project. In explaining how they offered the experience to residents, they would use their usual approach of offering two activities 'A or B' (where A might be a pack of cards and B the VR headsets) '... And a lot of, quite recently, a lot has been the headsets, so we kind of go, "oh, this is a great choir. You're in a field, you're singing. You see a lot of wildlife," and they love it. They absolutely love the fact that, "actually, I can't go to a field anymore to go watch, I don't know, sheep[s] running across the field". They put this on and they're in that field watching that. So, we kind of sell everything we do to them'.

The following themes came out of those discussions.

4.2.1. Cost of the Intervention

The budgets across Care Homes for social/arts activities are limited and there was discussion about how VR headsets might be funded in the long term to allow this intervention to be permanent. The staff were quite optimistic that they would fundraise specifically for the intervention, especially based on being able to make use of other applications of VR if they purchased the hardware.

4.2.2. Agency

Being able to provide a singing activity for residents that was not scheduled was considered highly valuable. Staff were able to use the intervention during quiet times or to respond to residents' needs. Care Home 1 expressed the following statement: 'it's been quite positive, quite short sessions, I would say kind of 10 min or so, but no, the general feasibility of the having the headsets on site as well has been very useful. So not just having them for when you guys are coming in, being able to like find the time ad hoc-ly to use them elsewhere'.

4.3. Ease of Use

Staff were impressed by how easy the intervention was to set up and use, although some residents were initially daunted by the prospect of wearing the headsets. For the sessions in the ad hoc trial, staff reported each session taking between 10 and 30 min to run, with residents engaging in singing for around 15 min.

4.4. Limitations

The physical restrictions of the headset were the main negative highlighted by both staff and residents, with requests for additional material and being able to choose 'any song' also referenced.

5. Discussion

This project evaluated the feasibility and usability of a novel intervention aimed at enhancing health-related quality of life (HRQoL) and wellbeing through an immersive technology-based group singing intervention. Overall, the intervention was successful in fulfilling its minimum viable product (MVP) as outlined in the initial project brief, demonstrating that it was both useable and acceptable to participants. The co-design approach to developing the VR application for the intervention proved highly valuable, with the specification focusing on simplicity of use and enabling multiple users to engage in a shared space (rather than a remotely isolated space). Feedback from focus groups and Alpha and Beta tests with choir leaders, choir members, care home staff, staff from

Alzheimer Scotland, and members of their dementia circle were highly positive about the intervention, believing it to have huge potential as a valuable contribution to the quality of life of people in residential care and people with dementia. However, several key challenges and limitations were identified in the feasibility study that followed, particularly with respect to attrition rates, data collection, and protocol adjustments.

The focus of this work was to co-design, create, and perform initial testing of the virtual choir experience and begin to explore the feasibility of the intervention. As such, only a small number of participants were recruited to assess the suitability of outcome measures and determine the most suitable data collection method for a future full feasibility trial. The interest was focused on the administration of tools and the outcome measures themselves were not intended to be generalizable or have statistical power. A notably high attrition rate was observed in the early feasibility test, which was anticipated given the nature of the study. However, it appeared that participants' reluctance was generally related to completing follow-up questionnaires than to the intervention itself. In response, mid-study adaptations to the protocol were necessary to address this issue, reducing the number of questionnaires. The final dataset was too small to draw definitive conclusions regarding long-term improvements in HRQoL or overall wellbeing. Nevertheless, acute measures of mood and longer-term HRQoL metrics suggested that the intervention was not detrimental, and potential benefits may have been observed with a similar approach in a larger, more adequately powered study. Approximately one-third of the sample (n = 3–4) completed the outcome measures at each time point, with preliminary trends indicating potential improvements in HRQoL and capability wellbeing from baseline to day 22, though mental wellbeing appeared to decline slightly over the same period. These results should be interpreted with considerable caution. The sample size was very small and there is substantial uncertainty around the estimates. It is not possible to generalize findings from this research. Considering the very small recruitment target for this initial feasibility, the study showed promise, particularly regarding the feasibility of collecting outcome data within this population.

The care home staff's initial enthusiasm for the intervention was maintained through its duration and demonstrated in the ad hoc engagement strand of the study, where each care home recorded uses of the intervention from other residents as and when they were interested in trying it. The reduced engagement by Care Home 1 compared to Care Home 2 could be due to several factors, including a heavier activities schedule at the time of the study and the fact that the home housed fewer residents overall.

Although staff remained enthusiastic about the intervention, the debrief interviews with care home staff identified several barriers, particularly around cost considerations. Activity budgets are relatively small, and therefore fundraising would need to be conducted to enable engagement with the intervention. Modelling the intervention's economic feasibility as a business case presents challenges, although within the broader context of virtual reality (VR) utilization, there is potential for scaling up. In particular, staff were enthusiastic about the prospect of exploring other applications within VR for residents and expressed that having multiple uses in addition to the singing intervention would make the headsets much more cost-effective and would make it more likely that they might purchase the hardware. Other avenues to improve the economic viability of the intervention would be to incorporate the intervention within other VR packages for the same demographic.

The current study has been valuable in testing the functionality and usability of the new VR group singing intervention, identifying areas for further technical development and considerations of how to measure the efficacy and benefits of VR experiences in care homes. In particular, this research has shown promise that a VR group singing experience could elicit some of the same responses in individuals that are known to be reported and

considered beneficial in in-person singing groups. Participants engaged in the experience by singing and moving with the music and the activity also triggered social interactions and conversations between residents, who also reported enjoyment. Staff also reported the value of having the experience available to use without the need to schedule an activity, which allowed them to respond to residents' needs and granted them agency in terms of deciding when to engage with the VR choir. While the preliminary findings of the pre-feasibility study suggest that this VR-based intervention may have potential benefits for HRQoL and wellbeing, further research is needed with a larger sample size. The very positive responses from staff and residents with regard to the ad hoc engagement and the high attrition rate and voiced dislike of the measurement tools in the pre-feasibility study highlight a notable challenge with regard to attempting to assess the effect of such interventions. Administering questionnaires not only adds stress and time for the participants, it also enforces strict scheduling of the intervention, which directly contradicts one of its potential strengths (to be utilised at the resident's convenience and will). The two-pronged approach undertaken here gathered valuable ecological data around the potential for care homes to integrate a VR singing intervention into their daily routines, and their own and residents' responses to the experience captured with no external interference. In a typical feasibility design for an RCT, this insight would have been lost, but it is fundamental to understanding how VR experiences might add value to the quality of life of residents of care homes.

5.1. Limitations

5.1.1. Application Design

Key issues that need to be addressed include hardware limitations, such as the weight and comfort of VR headsets, which may contribute to participant aversion. Residents frequently noted headset weight as a deterrent, suggesting the need for ergonomic improvements. These concerns are consistent with findings from previous studies [40]. The continuous development of lighter, more affordable headsets may mitigate this barrier in the future, with a need to consider the specific needs of the elderly population when developing hardware. Additionally, staff training, content development, and the management of copyright and workflow processes for creating immersive videos remain significant challenges. Establishing a centralized repository for content could streamline these processes and enhance intervention scalability. This would also support a broader range of musical material, allowing participants to personalize the experience to their own musical tastes, as the current restrictions on the number of songs is a limitation of the Beta version used in this study. The ability to personalize the song choices is particularly pertinent, considering the emotional reactions some of the participants had to some of the songs, including crying. This reaction is unsurprising, considering the known function of music as a social surrogate [41] and its role in memory and emotional connection [42], but highlights the importance of considering the material available and agency of the participant in choosing or changing the musical repertoire. Another potential development within the experience itself would be to include the lyrics as an overlay to the video. This was consciously not included in the current version based on discussions within the focus groups, where it was felt that the text could be a distraction, especially in light of the varying eyesight of individuals. There were two noted examples of participants either asking for the 'book' or trying to take a virtual copy from a choir member within the experience, and the researchers noted that participants did not know the words to some of the songs. This should therefore be considered a priority as an optional feature in future development work for the application. Then addressing hardware, cost, and content challenges will be critical to ensuring the scalability and broader adoption of this technology in healthcare settings.

5.1.2. Pre-Feasibility Limitations

The intention of this study was to provide preliminary testing of the application and develop a protocol to assess which tools and protocol might be suitable for a future feasibility study. As expected, therefore, the sample size was too small to draw any conclusions about the outcome measures. A larger, well-powered randomized controlled trial (RCT) is essential to confirm these results and address the current study's limitations. Future studies will need larger sample sizes with statistical power for findings to be generalizable. To guide the development of a full feasibility study into a RCT evaluating this intervention, several areas of uncertainty must be addressed. Firstly, the effect size and duration of the intervention's impact on HRQoL and wellbeing remain unclear. Secondly, while repeated measures were collected throughout the study, no adjustments were made for potential within-subject correlations, which may have influenced the results. Future studies should account for these correlations to increase the precision of effect estimates. Additionally, the relationship between improvements in wellbeing and HRQoL with potential reductions in medication usage or other health resource consumption warrants further exploration. A control group would also need to be implemented in a future RCT and, based on the findings of this study, would be best designed as a wait-list control to avoid introducing new variables through different experiences and to avoid disadvantaging any participants.

6. Conclusions

This study reported the design and early usability testing of a multi-user VR-based choir application in residential care settings to support group singing activities, which are known to enhance wellbeing and foster a sense of community among residents. The intervention was well received, with high levels of enthusiasm from both participants and care staff, and reports of increased social interaction between residents. This suggests that such technology can effectively supplement traditional in-person activities, especially where staffing or scheduling constraints exist. The intervention proved relatively easy to integrate into care home routines dependent on staff availability, and staff reported that it had promise as a scalable tool for enhancing mood and social engagement. Based on the completion of outcome instruments at each time point by approximately one-third of participants, it seems feasible to collect outcome data from this population. Future studies, particularly larger, well-powered RCTs, are needed to validate the intervention's effectiveness and scalability. This research shows that it is essential to present VR interventions in an ecologically valid way, avoiding introducing false restrictions on the intervention's use and creating negative external pressures such as time-consuming collection of outcome measures. Addressing technical, economic, and content-related barriers will be crucial to integrating this innovative approach to group singing into routine care practices but could ultimately empower residents with greater agency over their recreational activities and foster community through the joy of singing.

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Data Availability Statement: In compliance with the data protection impact assessment undertaken for this research, anonymised data can be made available upon request where its use is in line with the ethical restrictions of the project.

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Conflicts of Interest: Authors Toomer, Cooney, Honnan and Spreadborough are employed by Care Reality Co., Ltd., as was Kavanagh for part of the project. Care Reality were the main partner of the University of York in this research and the recipients of the Innovate UK funding. Their involvement in Care Reality did not influence their role in the research undertaken. The remaining author 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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