

Development and Feasibility Testing of an Online Virtual Reality Platform for Delivering Therapeutic Group Singing Interventions for People Living with Spinal Cord Injury

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Introduction

Spinal cord injury (SCI) causes partial or complete loss of motor and sensory function below the level of injury. Cervical SCI, or quadriplegia, frequently results in loss of function in the respiratory muscles with subsequent decreases in both inspiratory and expiratory muscle strength. Respiratory dysfunction is therefore a major cause of illness and death in this population¹ due to ineffective cough, increased respiratory tract infections, and reduced chest wall compliance.^{2,3} In addition, respiratory dysfunction can negatively affect speech by reducing vocal loudness and phonation length.⁴ Social isolation and depression are significant risks for people with quadriplegia⁵, with significantly lower health-related quality of life^{6,7} and a suicide rate that is 2-6 times higher than the general population.⁸

Singing can be used therapeutically to improve physical function and mental wellbeing. When singing we use larger lung volumes, higher air pressures and greater respiratory control.⁹⁻¹¹ In addition, the pleasure and reward systems in the brain are activated during singing, including the stimulation of dopamine¹² and oxytocin release,^{13,14} and decreased release of the stress hormone cortisol.^{15,16} Singing is also accessible for people with quadriplegia; it is one of the few activities that people with very limited physical

function can participate in independently.¹⁷ Group music therapy is optimal because many of the motivational and emotional benefits come from singing with others rather than in isolation^{13,18,19} and it is more time and cost effective than individual treatment.

Our previous randomised controlled trial demonstrated significant improvements in speech loudness and maximum phonation length following face-to-face therapeutic singing interventions for people with chronic quadriplegia.^{20,21} Participants also exhibited improvements in mood and social connectedness following the group singing intervention.^{17,20} The primary limitation of this previous study was the small sample size and thus limited statistical power. The main barrier to participation for people with quadriplegia in that trial was the need to travel to attend the face-to-face group intervention. People living with SCI often have complex and time-consuming daily routines (bowel and bladder care, assistance with dressing and access to transport, etc.) that limit their ability to participate in activities outside the home during “working hours”. In addition, disproportionately high numbers of people with quadriplegia live in rural and remote areas,²² which often renders travel to metropolitan areas for therapy unachievable.

In order to address the issue of access to therapy, we needed to develop a solution that allowed people to attend online group music therapy sessions from home. The aims of this current project were two-fold; to develop a low-latency telehealth solution for real-time group singing therapy and to determine the acceptability and feasibility of this solution with end-users living with spinal cord injury.

Phase 1 – Overcoming latency issues and testing platforms for online group singing

Although our therapeutic singing protocol incorporates both respiratory and vocal exercises as well as singing popular and familiar songs, we have found that singing songs is more engaging and motivating for therapy than sustained note singing exercises. It is this group singing of songs that requires low-latency audio to sing in time over the Internet. The main barrier to real-time singing over the Internet using readily-available video conferencing technology such as Skype, is latency caused by audio processing and network delays. Research has shown that between 20-30ms is the ideal latency to sing rhythmic songs (eg. pop songs) accurately in time²³.

Initial tests using hardware-based Polycom video conference equipment within a LAN (local area network) highlighted the non-suitability of this system for real-time musical

performance, showing delays of close to one-second. After exploring a number of potential solutions, we discovered a software program called 'Jacktrip'^{24,25} (developed at Stanford University), which provides a system for low latency, yet still high-quality, audio performance over the Internet. It achieves this by using a range of strategies, including uncompressed audio streaming.

We combined this low-latency audio solution with a virtual reality (VR) program to allow participants to 'see' as well as hear each other. We chose to explore VR as it offered the potential for a more immersive and engaging visual medium than videoconferencing, which in turn could facilitate better group dynamics and peer support opportunities. It also allowed for the potential of lower latency due to reduced data usage.

Phase 1 – Methods development

We recruited a sample of convenience of six inpatients from the Victorian Spinal Cord Service to trial several different VR headset systems in this first round of testing. Inclusion criteria were: current inpatient with any level of spinal cord injury at Royal Talbot Rehabilitation Centre, and exclusion criteria were significant visual, auditory, or cognitive impairments. The headsets trialed included PC-based systems, such as the Oculus Rift and HTC Vive, as well as the untethered Samsung Gear VR. We used vTime, a social VR application that allows up to four users to meet in a private virtual environment. In the application, users were able to collectively select their meeting space from multiple available options including a campfire, tropical island, cliff edge, and outer space settings. We conducted two testing sessions comprising three participants plus one therapist. The study was approved by the Austin Health Human Research Ethics Committee (LNR/16/Austin/121) and written informed consent was obtained from all participants.

Participants were located in separate but adjacent rooms within the same building and Ethernet cabling was connected between the rooms to create a LAN. The setup was designed to mimic a low-latency, high-speed broadband connection as if the participants were located at home but geographically separated. As a result of this 'in-house' setup, the audio latency between participants was approximately 3ms, arising almost exclusively from the input/output sampling latency of the audio interface. In a real-world situation where participants are geographically separated there is a fundamental 'time-of-flight' latency that cannot be overcome. It takes an electrical and/or optical signal approximately 5

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microseconds to travel each kilometre. There are also latencies introduced from devices along the way such as switches and routers. Bearing such practicalities in mind, it is possible that participants could be separated by as much as 1000km and still be able to have a good singing experience. All they require is a high-quality broadband connection that can support 1 Mbit/s each way per participant.

The audio of each participant was captured via a Shure SM35 microphone connected to a Focusrite Scarlett 2i2 audio interface and connected via USB 2.0 to a MacBook Pro. It was then routed through the JACK software and on to the Jacktrip application where it was sent to the other participants via the LAN. Through a set of connections within the JACK software, each participant could hear the others via headphones that were connected to the audio interface.

The participants were visible to each other in the vTime VR application as their chosen avatar via the Gear VR headsets which were networked to a 4G data connection hotspot. Due to the nature of the system being used to capture and network the head movements, there was a latency between audio and the VR visuals of approximately one second. This was found to not affect the singing experience detrimentally as participants found they could rely on real-time audio cues rather than visual cues to sing together. Participants sang familiar songs with choruses that they were able to recall from memory (as the vTime software was unable to easily display lyrics in VR). These songs included “Knocking on Heaven’s Door” by Bob Dylan,²⁶ “Buffalo Soldier” by Bob Marley,²⁷ and “Let it Be” by The Beatles.²⁸

We used three validated questionnaires to evaluate the overall user experience of VR for singing therapy, as well as thematic analysis²⁹ of interview data to determine individual preferences and feedback on the different VR equipment trialed. The Quebec User Evaluation of Satisfaction with assistive Technology (QUEST), is an outcomes assessment tool designed to measure satisfaction with assistive technology in a structured and standardized way using 5-point Likert scales, which are averaged to give a total score ranging from 1-5³⁰ The System Usability Scale (SUS), is an instrument designed to document users’ experiences of technology which has good internal consistency.³¹ The SUS yields a single number ranging from 0-100 representing a composite measure of the overall usability of the system being studied. The Psychosocial Impact of Assistive devices Scale (PIADS) is a 26-item, self-report questionnaire designed to assess the effects of an assistive device on

functional independence, well-being, and quality of life.³² Each item has a score range of -3 (maximum negative impact) to +3 (maximum positive impact). The PIADS has 3 subscales measuring competence, adaptability, and self-esteem and has good internal consistency, test-retest reliability, and construct validity.¹⁶

Semi-structured, individual, participant interviews were completed following participation in a VR testing session. All interviews were audio recorded using a digital mp3 recorder, transcribed into text files, and checked back against the original audio recordings for accuracy and correction of any transcription errors. We used MAXQDA (a qualitative data management software program) to manage and organize the data, and conducted a thematic analysis of this data²⁹. Our analysis was guided by the following research question: “How do people with a spinal cord injury experience virtual reality and online singing groups?” We asked questions that aimed to capture general information about the experience of virtual reality and singing in different group contexts (interview questions are presented in Appendix A).

Author 1 (JT) read the data set through in its entirety several times prior to coding to ensure familiarisation with the content and immersion in the data. This reading was done in an active way by searching for patterns and meaning, thus allowing the gradual shaping of ideas and development of patterns. Next, codes were assigned to sections of the text and these codes were grouped together where appropriate. Some segments of text were included in more than one code or theme. These codes were then reviewed and inspected for emerging patterns/themes and also checked for variability and consistency. The final themes and subthemes were defined and named. The coding was reviewed and verified by author 5 (DB) and any discrepancies were resolved by discussion.

Phase 1 – Results

Participant demographics and quantitative results are shown in Table 1. The median QUEST score was 4.31 out of 5 (range 4.25-4.63), indicating that overall the participants with spinal cord injury were satisfied with the VR technology they tried. The QUEST also asked participants to select from a list the three most important aspects of the device to them. The most commonly chosen items were: easy to use, comfort, and effectiveness (weight and adjustments were also selected once). The median SUS score for our phase 1 testing was 58.75 out of 100 (range = 40-70). The perceived psychosocial impact of the VR

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devices (as measured by the PIADS subscales) indicated a 'somewhat positive impact'. The median PIADS subscale scores were: competence, 1.04 (0.17-1.42), adaptability, 1.33 (0.50-2.33), and self-esteem, 0.56 (0.13-2.25).

Table 1. Phase 1 participant demographics and raw scores

Participant ID	Gender	Age	Injury Level	QUEST	SUS	PIADS - Competence	PIADS - Adaptability	PIADS - Self-esteem
1	Male	28	C7A	4.25	40	1.00	1.00	0.13
2	Male	70	C5A	3.88	60	1.08	1.17	0.38
3	Male	61	T10A	4.38	50	1.42	2.33	1.75
4	Male	52	T1A	4.25	57.5	1.17	2.00	2.25
5	Male	34	C5B	4.63	62.5	0.17	0.50	0.25
6	Male	51	C5B	4.38	70	0.58	1.50	0.75
		51.5		4.31	58.75	1.04	1.33	0.56

Abbreviations: QUEST, Quebec User Evaluation of Satisfaction with assistive Technology, SUS, System Usability Scale; PIADS, Psychosocial Impact of Assistive devices Scale

There were several limitations in the off-the-shelf technological solutions trialed. The main limitation was that users (including the music therapy clinician) could not see song lyrics (or chord charts) when wearing a VR headset. The hand controllers of the HTC Vive could not be used effectively by most participants due to their limited hand movement. Furthermore, the setup time and physical space required to set up the Oculus Rift and HTC Vive made them less attractive options from a technical perspective. Patients with SCI preferred a light weight, wireless VR headset, making the Samsung Gear VR the overall headset of choice.

Development of a custom VR application for online group singing

Based on the results of our first round of testing with spinal patients we used the Samsung Gear VR for the next phase of exploration. We decided it was necessary to build a custom-built VR application to display song lyrics within the virtual setting and incorporate gaze-based controls to improve accessibility for people with limited hand function. Accordingly, our information technology specialists from the Networked Society Institute at The University of Melbourne designed a custom VR platform with input from an interdisciplinary team including music therapists, physiotherapists, and occupational therapists and patients from the Victorian Spinal Cord Service at Austin Health.

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The VR application allowed participants to enter the session and choose their avatar and the virtual setting for their session via a gaze-selection system (see Figure 1). The hands-free controls also assisted the music therapist who provided musical accompaniment for songs. The music therapist was able to control song selections and lyric scrolling whilst playing the guitar. A video clip demonstration of the custom VR application is available (see online video supplement – <https://vimeo.com/239389360/4186492326>).

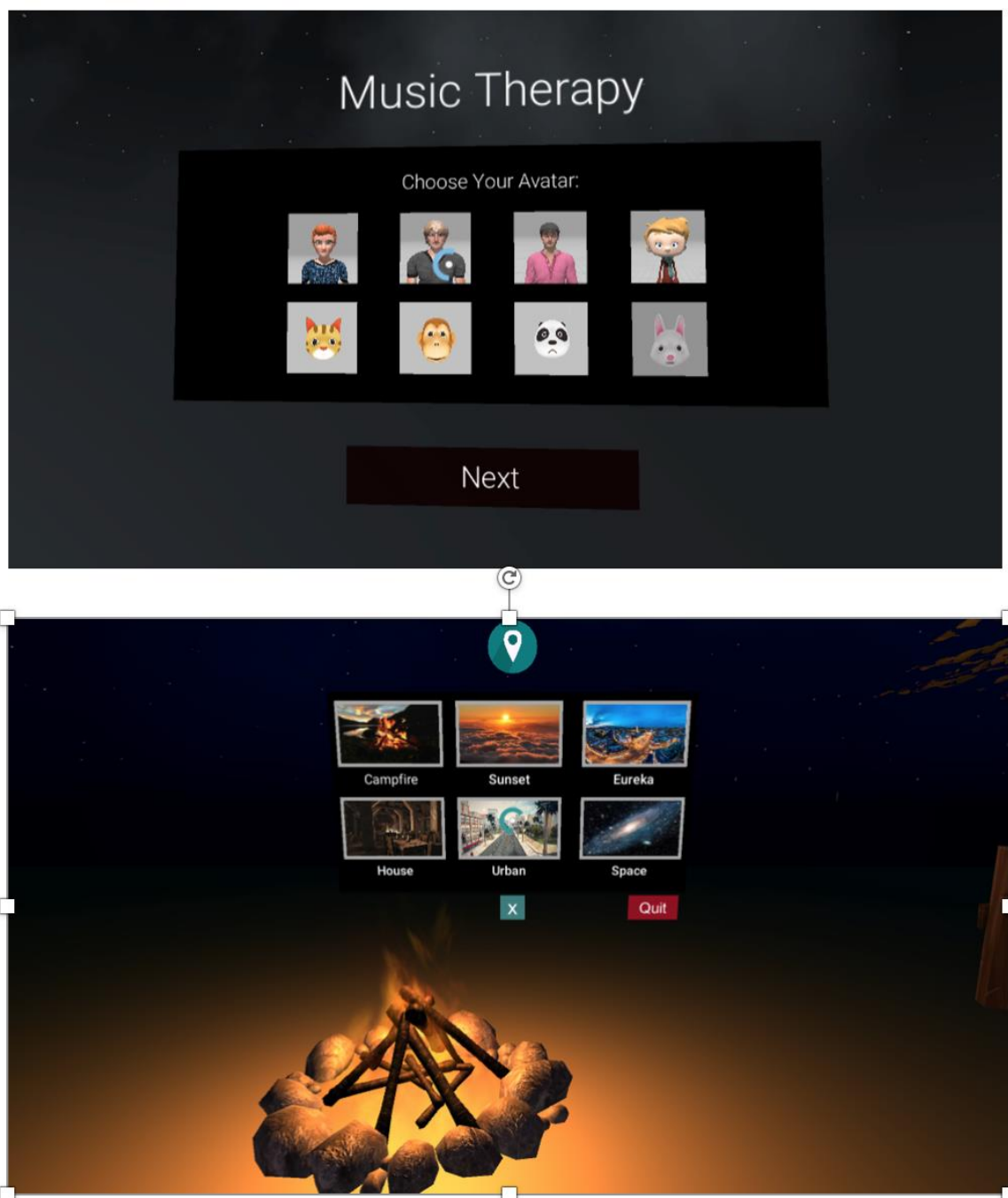


Figure 1 - Screenshot of gaze-based selection of avatar and location in our custom-built virtual reality (VR) music therapy application. Note. The white dot with the blue semicircle around it is the gaze-based selection pointer.

Phase 2 - Method

Feasibility and acceptability testing of the VR music therapy solution for group singing

We recruited another six inpatients from the Victorian Spinal Cord Service (using the same inclusion criteria as phase 1) to trial the newly developed VR music therapy solution and compared this to traditional face-to-face group singing therapy and teleconferenced group singing experiences. For the face-to-face session, participants all sat together in a

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room with a music therapist and selected from a list of six well-known songs to sing. We then put each participant in separate room in the hospital and connected them via Zoom videoconference with the Jacktrip low-latency audio setup via Ethernet cabling as described in Phase 1 method. We used the same song list and asked participants to sing together online with the music therapist. For the VR component, we had inserted an index of the same six well-known songs into our custom app for participants to select from (see Figure 2). Participants remained in their separate rooms and connected to each other in VR using Gear VR headsets and the separate low-latency audio system. We assisted participants to enter VR via the app, select their avatar and virtual location, and sing together with the music therapist in VR.

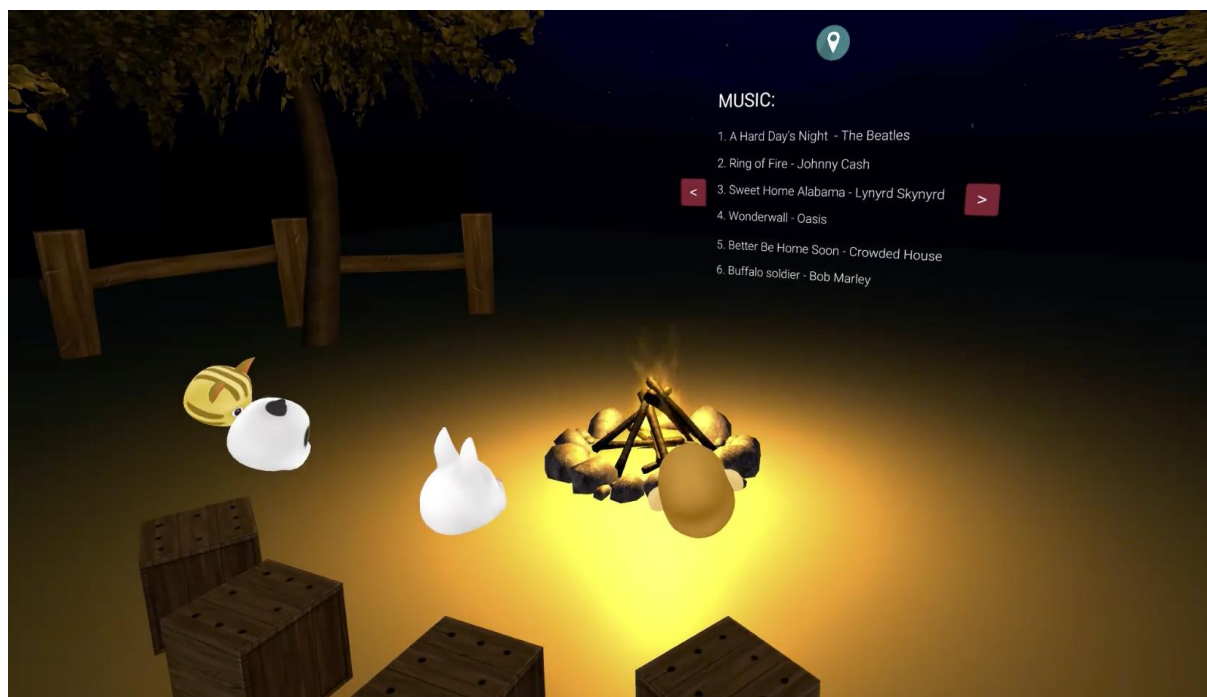


Figure 2 - Screenshot of song selection screen at the campfire location in our virtual reality (VR) music therapy application.

Again, this solution was using separate technology systems due to technical limitations with running both audio and VR in the same setup. To examine the feasibility and user experience, we used the same three validated questionnaires that we used in phase 1 to evaluate the user experience (QUEST, SUS and PIADS) and the same method for thematic analysis²⁹ of interview data.

Phase 2 - Results

Participant demographics and quantitative results for phase 2 are shown in Table 2.

Table 2. Phase 2 participant demographics and raw scores

Participant ID	Gender	Age	Injury Level	QUEST	SUS	PIADS - Competence	PIADS - Adaptability	PIADS - Self-esteem
7	Male	65	T2A	3.88	55	0.67	2.00	0.00
8	Male	26	T6A	3.75	45	1.17	1.50	2.13
9	Male	68	C4D	4.00	42.5	0.17	0.50	0.13
10	Male	46	T4A	4.88	60	2.67	3.00	2.75
11	Female	39	T3C	4.88	70	1.58	2.00	2.00
12	Male	41	C2D	4.88	47.5	2.50	3.00	2.25
Median		43.5		4.44	51.25	1.38	2.00	2.06

Abbreviations: QUEST, Quebec User Evaluation of Satisfaction with assistive Technology, SUS, System Usability Scale; PIADS, Psychosocial Impact of Assistive devices Scale

The median QUEST score was 4.44 out of 5 (range 3.75-4.88), indicating that participants were satisfied with the Gear VR headsets. The most commonly chosen items for important aspects of the device were: easy to use and comfort (other items selected included dimensions, weight, adjustments, and safety). The median SUS score for phase 2 testing was 51.25 out of 100 (range = 42.5-70). The perceived psychosocial impact of the VR devices (as measured by the PIADS subscales) indicated a ‘somewhat positive impact’ of the VR headset and platform. The median PIADS subscale scores were: competence, 1.38 (0.17-2.67); adaptability, 2 (0.50-3); self-esteem, 2.06 (0.13-2.75).

Phase 1 & 2- Qualitative Results

Thematic analysis of participant interviews from Phase 1 and 2

The thematic analysis results, summarized in Table 2, revealed 5 themes: 1) VR was a positive experience, 2) VR was immersive and transportive, 3) VR reduced inhibitions about singing in front of others, 4) VR may reduce social cues, and 5) the VR equipment was comfortable, accessible and easy to use.

Table 3. Themes and subthemes from the thematic analysis of interview data

Themes and subthemes	Subthemes
VR was a positive experience for people with a spinal cord injury	<ul style="list-style-type: none"> • VR was interesting and fun • VR was something different and new • VR felt ‘cool’ or good
VR was immersive and transportative	<ul style="list-style-type: none"> • VR was a positive distraction • VR takes you out of reality • It really felt like you were there in the VR space
VR reduced inhibitions about singing in front of others	<ul style="list-style-type: none"> • In VR the avatar acts like a mask • Singing in VR is a shared adventure
VR may reduce social cues	<ul style="list-style-type: none"> • Some people found it easier to connect with others when they could read facial expressions • VR doesn’t allow for visual cues that can help in group singing
The VR equipment was comfortable, accessible and easy to use	<ul style="list-style-type: none"> • VR headsets were comfortable • Gaze-based control system was easy to learn • Participants liked the opportunity to choose their own avatar and select their virtual destination

All participants described their experience of VR in positive terms such as “interesting”, “fun”, “different”, “cool” and “good. They also felt that VR was truly an immersive experience with some participants describing the feeling that they had been on a journey. *“I did sort of feel like I was away from this place for a little while... I guess it’s just an escape really, temporarily” (Pt 4).* The VR experience felt real to participants: *“like when we were singing, I felt like we were all sitting around a campfire. It was good” (Pt 3).* The VR experience was also described as a positive distraction: *“Well it just distracted me, I guess, from my injury and current situation, momentarily.” (Pt 4).* *“But when you’re there, in any of those places, you’re not thinking about your pain, or your disability or anything else, which is good” (Pt 3).* *“It was a release from reality... It took you into a world of fantasy, which was good... to get away from your everyday mundane boring existence (Pt 6).*

Interestingly, many participants (n=8) reported reduced inhibitions when singing in VR because the avatar acted as a kind of mask. *“You sort of get that invisible blanket where you can’t see them and they can’t see you. When you have to sing in front of people when they’re looking at you, you’re subconsciously thinking, I wonder what they think of my voice? [In VR] you’ve sort of got that invisible mask where you can make an idiot out of yourself and you think, well no one can see me, well at least, I don’t think anyone can see me” (Pt 3).* *“I think maybe being in [VR], you lose your inhibitions because you don’t see yourself and you*

don't see the other people. I think that makes a difference" (Pt 6). Two participants described the experience of VR with other participants as a shared journey. Interviewer: "You said, taking you out of your world to a different world. Can you tell me a little bit more about that? Like how was that feeling..." Pt 11: "More adventure, I suppose. Just maybe connecting with other people in a different way as well and it was just to be different characters."

Some participants (n=3) felt that because you cannot see people's faces in VR, this might reduce social cues that would help in building connections. *"[Teleconference] was good I think, with people, because I think in the end I'm not sure if it more connected with people, and that just felt more real. Whereas with the virtual reality, it's fun for a bit but then I'm not sure if down the track would be like you're connecting as much" (Pt 11). One participant suggested that there might be a negative effect of VR on group singing due to the lack of visual cues. "One of the difficulties with [singing in VR is that is it] so divorced of any kind of human cues that you get. You don't get timing, you don't get conducting, you don't get all those sorts of things that can help you get it right. And then so until everyone sort of works it out, you can end up in a position where you've got quite a bit of discordance at the start, that can be a little bit embarrassing, that can be like "we sound like crap", you know. Whereas in person you can get the visual cues as well" (Pt 1).*

Finally, the participant response to the experience of using the VR equipment was overwhelmingly positive. In phase one, the participants found all three headset options comfortable, with some preferring the wireless option of the Samsung Gear VR. The phase 2 participants all found the Gear VR comfortable and easy to use. The gaze-based control system was reported as intuitive and easy to learn, and many participants enjoyed the opportunity to choose their own avatar and select their virtual destination.

Discussion

The VR music therapy solution we have developed is a unique combination of networked virtual reality and low-latency audio that allows users to feel like they are in the same space, such as singing around a campfire, in a forest or even in space, although they could be in their own homes separated by many kilometres. The results of our quantitative evaluation of the user experience suggested that participants with spinal cord injury from

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both testing phases were satisfied with the assistive technology aspect of the VR equipment as demonstrated by the high QUEST scores. The SUS scores were moderate, suggesting that participants felt that the system was not too difficult, but also not very easy to use independently. This would make sense, as for most participants it was the first time they had experienced using VR and it does require some learning to use this new technology. The PIADS results indicated a mildly positive impact of the VR equipment on psychosocial outcomes. Given that these results were based on a single testing session, it is not surprising that participants didn't perceive a large psychosocial impact of the VR device and application. It would be useful to employ this measure again following longer term use of the VR technology in a clinical group context. The positive responses of participants to the experience of trying out the VR music therapy solution were demonstrated in both quantitative measures and the interview data. They found the hardware acceptable and the software intuitive to use.

The VR music therapy solution could enable people to participate in online therapeutic singing groups from their own home, but also facilitate the experience of going somewhere else for the group session, as demonstrated by thematic analysis results. Our preliminary data also suggests that VR, as a modality for delivering group music therapy interventions, may have potential to distract from the difficult reality of physical impairments and reduce pain perception. Users reported the feeling of having been transported to another world during the session, which face-to-face or videoconferencing alternatives cannot provide.

An unexpected finding of our feasibility testing was that many participants felt less inhibited to sing in VR. This was further explained by some participants as a feeling that the avatar acted as a form of mask, making them feel less embarrassed to sing with others in VR than if they were physically in the same room. This is an extremely pertinent point because many people with spinal cord injury (who may benefit from therapeutic singing interventions) often feel unconfident about singing.¹⁷ Furthermore, our prior research shows that singing can be used to achieve therapeutic outcomes, but many of the motivational and emotional benefits come from singing with others rather than in isolation.^{17,20}

Clearly there are many potential benefits to using VR as a modality for connecting people online for group therapy. However, as suggested by some of our participants, VR

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may also reduce social connection due to the lack of ability to read facial expressions and nonverbal cues. Similarly, such visual cues are useful when singing together in a group and were not available in the VR context we used. These are areas that require further examination in a larger sample and suggest the need to compare VR versus videoconferencing options for delivery of the visual aspect of the online group intervention. A further consideration was the overall cost of the VR music therapy solution (around AUD\$4000 per user for equipment including MacBook Pro, Samsung phone and Gear VR headset, audio interface, headphones and cables). This high cost reduces capacity for clinical translation at this stage, however this was not an implementation study, but rather a [proof-of-concept](#) study designed to help us understand what users want as a technical solution. The primary aims of this study were to develop a low-latency solution for online group singing and to assess acceptability and feasibility. As such, we were very person-focused and the technical solution we tested was the best possible version we could source from the user experience point of view. As the technology improves and becomes more affordable, equipment costs will reduce and make VR more feasible as a mode of delivery for therapy interventions. Future research will ideally explore possibilities for combining the audio and visual systems into a single platform, as well as developing a single-user mode where participants could sing along to a pre-recorded session for after-hours practice.

Conclusion

The VR music therapy solution we developed appears to a feasible solution for cooperative VR-based therapeutic singing groups over the Internet within a reasonable geographical distance. The technical solution was acceptable to participants and their quantitative and qualitative feedback provide clear directions for further development and testing. Future development will examine the performance of the solution using home-based broadband internet connections, further technical integration of audio and VR and testing of a VR music therapy solution versus traditional centre-based approaches. We anticipate that our solution could improve access and extend benefits to many other populations who are socially isolated, have difficulty travelling, live in a remote area, and who could benefit physically and emotionally from a therapeutic singing group. This solution

could thus address significant issues of equitable access to creative social opportunities for wellbeing.

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Appendix A

Phase 1 - Virtual Reality Research Interview Questions:

1. What was the virtual reality experience like for you?
 - a. What did you like about the experience?
 - b. What could be improved about the experience?
 - c. How did being in the VR environment make you feel?
 - d. Would you like to access VR again?
 - e. What (if any) are the potential ways you could see yourself using VR in the future?
 - f. What did you think of the virtual locations? Did you have a preference?
 - g. Which avatar representative did you prefer? Robot style or cartoon person?
 - h. Can you rate the level of HMD comfort from 1 to 10?
 - i. GearVR
 - ii. Oculus
 - iii. Vive
2. Can you describe how it felt physically to access virtual reality?
 - a. How did it feel to wear the VR headsets? Were they comfortable? Why or why not?
 - b. How long do you think you could wear the VR headsets and remain comfortable?
 - c. Did you have a favourite headset/VR equipment/software? If yes, why?
 - d. How easy or hard was it for you to navigate in VR? Could you operate the VR headsets adequately? If not, why?
 - e. Did you access VR while seated or lying down?
 - f. Do you normally wear glasses? If so, could you wear them comfortably under the headsets?
 - g. Did VR make you feel nauseous? If yes, to what degree?
3. What was it like to meet and interact with other people in the VR environment?
 - a. How was it to sing together with others in VR?
 - b. How did the group VR experience compare with an 'in-person' group?
4. What (if any) are the potential applications for VR in telehealth?
5. What have you learnt through participating in this research project?
6. Would you encourage other people with limited mobility in the community to explore access to virtual reality environments? Why (or why not)?

Phase 2 - Virtual Reality Research Interview Questions:

1. What was the virtual reality experience like for you?
 - a. What did you like about the experience?
 - b. What could be improved about the experience?
 - c. How did being in the VR environment make you feel?
 - d. Would you like to access VR again?
 - e. What did you think of the virtual locations? Did you have a preference?
 - f. Which avatar representative did you prefer? Animal or cartoon person?
 - g. Can you rate the level of comfort of the VR headset from 1 to 10?

2. Can you describe how it felt physically to access virtual reality?
 - a. How did it feel to wear the VR headsets? Were they comfortable? Why or why not?
 - b. How long do you think you could wear the VR headsets and remain comfortable?
 - c. How easy or hard was it for you to make selections in VR? Could you operate the VR headsets adequately? If not, why?
 - d. Do you normally wear glasses? If so, could you wear them comfortably under the headsets?
 - e. Did VR make you feel nauseous? If yes, to what degree?
 - f. Did you notice that the VR head movement was out of time with the audio? If so, how did this affect your experience?
 - g. Similarly, did you notice that the video was out of time with the audio in Zoom? If so, how did this affect your experience?

3. What was it like to meet and interact with other people in the VR environment?
 - a. How was it to sing together with others in VR?
 - b. How did the group singing VR experience compare with an 'in-person' group?
 - c. How did the group singing VR experience compare with singing via videoconference?
 - d. What were the pros and cons of each of the 3 singing conditions?

4. What (if any) are the potential applications for VR in telehealth?

5. What have you learnt through participating in this research project?

6. Would you encourage other people with limited mobility in the community to explore access to virtual reality environments? Why (or why not)?