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RESEARCH REPORT

# Utilizing Virtual Reality for Gender-Affirming Voice Training: Surveying the Attitudes and Perspectives of Potential Consumers

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## Abstract

**Background:** Undertaking voice and communication training is an important part of the gender-affirming journey for many trans, gender-diverse and non-binary individuals. Training supports the alignment of voice with gender identity helping to reduce gender dysphoria as individuals are better able to connect with their voices. However, for training to be effective, regular practice is needed and the demands of training can often be difficult to meet.

**Aims:** To investigate the interest, attitudes and perspectives on the use of immersive virtual reality (VR) to support gender-affirming voice and communication training by transgender, gender non-binary and gender-diverse people, and speech–language pathologists providing gender-affirming voice and communication training.

**Methods & Procedures:** A mixed-methods survey (i.e., collecting quantitative data through multiple-choice question and qualitative data through free text questions) was hosted online from 23 August to 21 September 2021. A total of 17 questions asked about technology use, and attitudes and perspectives towards VR. The survey included video examples of three different voice-activated VR applications to prompt participant responses about the technology.

**Outcomes & Results:** A total of 70 survey responses were included in the analysis. All participants had previous experience using smart phones, but only 27.2% had previously used VR. Four key themes were identified relating to potential uptake of VR in gender-affirming voice and communication training: (1) general audience appeal, (2) perceived therapeutic value, (3) exposure to or protection from harm and (4) relatability to real life.

**Conclusions & Implications:** VR games may represent a viable option to support practice of voice exercises. Gamification through VR is likely to motivate some to increase frequency of practice. VR applications that are used in voice

training need to be fit-for-purpose, and detailed co-design is necessary to build appropriate applications for future use. This study provides a foundation to inform the design, development and implementation of VR applications to be used in gender-affirming voice training.

**KEYWORDS**
gender-affirming voice training, transgender, virtual reality, voice

## WHAT THIS PAPER ADDS

*What is already known on the subject?*

- Speech–language pathologists work closely with transgender and gender-diverse individuals to help them achieve gender congruent voice and communication. Clients need to undertake regular and ongoing practice outside of training sessions to achieve and maintain their ideal voice. Motivation and adherence to regular practice sessions remain an ongoing challenge.

*What this study adds to the existing knowledge*

- This study explores the use of immersive VR technologies to create safe, motivating and enjoyable environments to encourage regular practice of gender-affirming voice and communication exercises. It engages stakeholders in an early-stage participant-involved design to gauge interest in, and perspectives on, VR and technology-based training support tools. The results suggest that voice-activated VR applications would highly motivate some individuals if they were appropriately designed but would not be ideal for all.

*What are the actual and clinical implications of this work?*

- Immersion in VR can be a highly motivating tool to enhance adherence to practice schedules for some individuals. However, tools need to be specifically designed with outcomes in mind to be fit-for-purpose, to support individual goals and to minimize the risk of harm. The few existing VR voice-activated applications that are available require further assessment, and redesign through co-design with users to functionally and safely support gender-affirming voice and communication training.

## BACKGROUND

Voice can convey traits such as emotion, personality, age, origin and biological sex, and is therefore integral to sense of self and identity. For individuals identifying as transgender, gender-diverse (those whose gender identity differs to their assigned sex at birth) or non-binary (those who do not identify with the binary of female or male), their voice may not feel like an expression of their 'true' identity (Casado et al., 2016). When a person's voice does not accurately reflect their gender identity, it can contribute to gender incongruence, experienced when an individual's birth-assigned sex and their gender identity do not align (Jones et al., 2019). In cases of significant distress, gender incongruence can lead to a formal diagnosis of Gender Dysphoria (American Psychiatric Association (APA), 2013) which can significantly impact on a person's emotional and psychological well-being, and quality of life. It can also impact on physical and psychosocial safety due to negative reactions that may be encountered within society (Oates & Dacakis, 2015).

However, a positive relationship reportedly exists between improved mental health and undertaking gender-affirming interventions (Riggs et al., 2020). Subsequently,

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many transgender and gender-diverse (TGD) individuals undergo gender-affirming interventions and seek multiple health services to help them achieve gender congruence (Oates & Dacakis, 2015). This may include surgeries or hormonal treatment to better align physical appearance to gender identity (Jones et al., 2019), and vocal modifications to achieve a gender-congruent voice. For many transgender people, interventions to align voice and gender identity can have greater impact on their mental health and well-being than physical changes (Oates & Dacakis, 2015).

Speech–language pathologists work closely with TGD individuals to help them achieve a gender congruent voice, either as an effective alternative to surgery or as a supplementary option (Morrison et al., 2017). Depending on individual goals, gender-affirming voice and communication training with a speech–language pathologist involves modifying vocal features and communication behaviours to achieve a voice that is, perceived in the desired way (Davies et al., 2015). The prime focus of gender-affirming voice and communication training is often vocal pitch, however resonance, prosody (intonation), speech rate and gesture are also explored as they are all considered markers of gender (Davies et al., 2015; Hardy et al., 2020). Hancock et al. (2013) demonstrated the effectiveness of gender-affirming voice training in a retrospective quantitative file review of 25 participants who were in various stages of transitioning from male to female. Treatment targets included increasing fundamental frequency, using forward oral resonance, demonstrating upward and expressive intonation and focusing on non-verbal body language such as facial expression and body gestures to achieve a more feminine voice and communication style. In every case examined, improvement was made over the course of the training program, and participants showed increased fundamental frequency in sustained vowel, reading and monologue tasks by a statistically significant result of five to six semitones. Casado et al. (2017) extended these findings in a retrospective quantitative control trial that compared the effects of surgical interventions to modify the voice with and without additional gender-affirming voice training. In that study with 18 male-to-female transgender individuals, 10 participants underwent Wendler glottoplasty surgery to shorten the vocal folds with voice training post-surgery, and eight underwent Wendler glottoplasty surgery without voice training. The group who received voice training had a higher mean fundamental frequency and improved scores relating to self-perception of voice and emotional well-being post-treatment. These results illustrate that gender-affirming voice training, provided by a speech–language pathologist, is effective in helping TGD individuals to adapt their voice and communication patterns to align with their gender identity and gender expression (Hancock & Garabedian, 2013).

Although speech–language pathologists play a significant role in supporting TGD individuals to achieve a voice that enables gender euphoria, due to the demands of behaviour change, there is a need for client self-efficacy to undertake regular and ongoing practice outside of voice training sessions to achieve and maintain their ideal voice (van Leer & Connor, 2012). Adherence to treatment, and in particular regular practice outside of the clinic is critical for achieving desired outcomes. In fact, 'adherence may be a stronger predictor of outcome than the specific treatment approach used' (van Leer & Connor, 2012: 447). However, van Leer and Connor (2012) noted that adherence to gender-affirming voice training programs, in terms of session attendance and practice schedules, presents a frequent problem. While research supports that current gender-affirming voice training can lead to enhanced vocal pitch and improvement in measures of voice related quality of life scales, there are often high dropout rates from gender-affirming voice training services (Rapoport et al., 2023), a trend that is, seen in many behaviour change therapies including treatment for voice disorders (Hapner et al., 2009).

Quinn et al. (2023) investigated the effects of different service provision models on adherence to training programs. The authors found that an intensive vocal training program led to statistically significant improvements in motivation to attend sessions and adherence to home practice when compared to a traditional voice training program. Participants in Quinn et al.'s (2023) study also commented that they were motivated by having a clinician who was transgender as this helped foster a sense of trust, ease, and personal comfort. Mills et al. (2019) and Russell and Abrams (2019) also concluded that group therapy programs were more motivating than individual gender-affirming voice training due to the commonality of experience, shared learning, and peer support amongst group members. Additionally, Russell and Abrams (2019) identified that telehealth training sessions enabled a safe space to address the challenges and obstacles many TGD individuals encounter when accessing care. While these solutions may be feasible in some service delivery models, motivation and adherence to regular practice sessions remain an ongoing challenge for which speech–language pathologists and clients require solutions. Clients themselves report that, as well as lack of time, a lack of motivation, lack of feedback, having safe and supportive places to practice and people to practice with, as well as the fear of 'sounding silly' present as barriers to adherence to voice therapy practice (van Leer & Connor, 2010).

Some researchers have positioned technology applications as potential solutions to help improve motivation and adherence to training. For example, van Leer and Connor (2012), provided 13 participants with portable media

players containing videos of themselves and their voice therapists demonstrating voice exercises. For 1 week, participants used the technology-assisted practice, and for another conducted practice supported by written homework descriptions. Results showed significantly increased practice when participants had access to the media player technology. Further, when supported by technology, participants reported significantly greater commitment to practice, confidence in their ability to practice and perceived importance of practice. Similar positive results were reported in a systematic review of voice interventions using biofeedback, which were often supported by technology (Maryn et al., 2006). In 15 of the 18 studies reviewed, biofeedback-based interventions resulted in positive changes in voice production or voice quality.

While these technologies have improved overall practice, they do not create the same safe environment needed for regular practice as enabled by telehealth (Russell & Abrams, 2019). Bryant et al. (2020a, 2020b) suggested that such a safe and motivating environment for communication practice might be found in virtual reality (VR). VR provides visual, auditory and haptic input via a head-mounted display and controls, excluding other input from the physical environment. Users can interact with the virtual world using hand controls, body movement, and their voice. Voice-interactive VR games offer a particularly promising option for voice and communication interventions through responses to spoken interaction (Bryant et al., 2020a). However, the role for VR in voice therapy has not been as widely studied. One small study in patients with Parkinson's disease, a population that often seeks therapy for hypophonia, has demonstrated that VR games can lead to immediate improvement in voice measures, with the majority of users reporting satisfaction with the technology (Cruz et al., 2020). VR use in gender-affirming voice training, however, has not yet been investigated. As VR has successfully increased practice motivation in other populations (Snider et al., 2010), and has been shown to have positive effects on reducing anxiety around public speaking tasks (Takac et al., 2019), its use in gender-affirming voice and communication training clearly warrants further investigation.

Speech–language pathologists (SLPs) have actively participated as consultants for VR development for communication disorder rehabilitation, addressing aphasia, traumatic brain injury and broader communication disabilities (Bryant et al., 2020a, 2020b, 2022; Vaezipour et al., 2022; Brassel et al., 2021) as well as for development of VR for use in aphasia assessment (Garcia et al., 2007). Overall, these studies have demonstrated that SLPs are excited by the potential of VR use for clinical purposes but understand that there are barriers that must be considered, such as access to training and technical support (Brassel et al., 2021).

VR use in gender-affirming voice and communication training has not yet been considered in the literature. Consultation with those who engage in such training—TGD individuals and speech–language pathologists—would provide insight to better understand whether VR might have a place in gender-affirming voice and communication training and identify what consumers are seeking from these applications. Consultation is an important first step in participant-involved design, a necessary step in technology-based research (Kanstrup et al., 2017). Determining the perspectives of end users is a necessary step in VR design to ensure the application meets their needs, leading to a higher chance of successful uptake (Proffitt et al., 2019) and that the potential barriers and facilitators as well as risks are identified (Birckhead et al., 2019). This knowledge would demonstrate whether further research and development is warranted to establish a technology-based intervention for gender-affirming voice and communication training to support and motivate sustained home practice. Therefore, this study aimed to investigate the interest, attitudes and perspectives of TGD persons and speech–language pathologists towards (1) VR applications to support gender-affirming voice and communication training; and; (2) several types of voice-interactive VR applications.

## METHOD

This mixed-methods (i.e., collecting both qualitative and quantitative data) cross-sectional study used an online survey to investigate attitudes and perspectives of stakeholders involved in gender-affirming voice and communication training towards VR. The study received ethical approval from the UTS Human Ethics Committee (reference number: ETH-21 6034)]. The development and reporting of the study were informed by The Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guideline (Eysenbach, 2004).

### Participant recruitment

A convenience sampling approach was used to recruit participants. Individuals were eligible to participate if they: (1) were aged over 18 years; (2) identified as transgender, gender non-binary, or gender-diverse; and (3) had undertaken, were currently undertaking, or were interested in undertaking gender-affirming voice and communication training; or (4) were speech–language pathologists

who provided gender-affirming voice and communication training.

Participants were recruited through social media, and through emails to the professional and clinical networks of the second and third authors. These networks included eligible individuals who had engaged in gender-affirming voice and communication training at the speech–language pathology clinic of the university at which the authors were based. A snowball strategy was also employed as contacts were asked to forward survey information to other eligible participants in their personal networks. All advertising information included details of the research and a URL to the research participant information sheet and consent question. Participation in the study was voluntary, and participants were advised that they could withdraw from the study at any stage. No incentives were offered to take part and no personally identifying information was collected, thereby ensuring participant anonymity.

## Survey design and data collection

An open online survey was created by the researchers using the web-based platform Qualtrics (Qualtrics, Provo, UT). The survey consisted of 17 closed multiple-choice and open-ended short response questions, allowing for both quantitative and qualitative analysis, covering participant demographics (e.g., stakeholder type, gender, age), technology use and experience and attitudes and perspectives towards VR. All questions are stated in the survey tool in Supplementary File 1 in the supplemental data online. Questions were presented over five screens, with three to five questions per screen. Participants could navigate back through questions to revise their answers. Prior to being asked about VR, participants were given an image of a person wearing a VR head-mounted display, and a description of the technology. Participants were also asked about specific types of VR applications: (1) games with simple, repeatable gameplay mechanisms, (2) more complex multilevel games and (3) simulated real-world experiences. Prior to questions about each type of VR application, participants were shown a video of an example game in that category to inform their responses. All questions were asked in the same order for all participants. The survey was tested by the researchers to ensure it functioned as intended, however it was not piloted. The survey was open for responses between 23 August and 21 September 2021.

## Data analysis

Once the survey was closed, data were exported from Qualtrics to Microsoft Excel for analysis. Responses to closed questions were collated and analysed using descriptive statistics (counts and proportions). Open-ended responses were analysed using an inductive thematic analysis (Braun et al., 2019). The inductive approach consisted of five phases. First, responses were extracted from the survey into an Excel spreadsheet for two authors to review, thereby minimizing the risk of individual bias. Responses were read repeatedly so the researchers could familiarize themselves with the data. Next, content codes were identified and written alongside each response. The two authors discussed the content codes and identified potential categories across the responses. These were discussed with the third author to achieve consensus agreement. Related categories were grouped together to identify themes within the data. The themes were again discussed between all authors to minimize bias in the analysis. Finally, themes were verified against quantitative data. Illustrative quotes were used alongside the reporting of findings from the thematic analysis to enhance transparency and confirmability of the authors' interpretation.

# RESULTS

In total, 70 participants consented to the survey, and 55 completed the survey for a 78.57% completion rate. As the survey questions were not mandatory for participants to answer, participants were included if they answered at least half of the survey questions and provided a full response to at least one of the VR scenario evaluations. This exclusion process limited non-response errors in the reporting of the results (Wolf et al., 2016). A total of 57 responses (81.43%) were included in the analysis and are reported here.

## Participant characteristics

Over three-quarters of survey respondents were TGD individuals (76.36%; $n = 42$). Participants also included speech–language pathologists providing gender-affirming voice and communication training (17.54%; $n = 10$), and three respondents who identified as TGD speech–language pathologists (5.26%). Most respondents identified as female (68.42%, $n = 39$), six identified as male (10.91%), seven as non-binary or third gender (12.73%), and three participants chose to self-describe (5.26%). Those who preferred to self-describe identified as transfeminine, agender and transfeminine-autigender (i.e., perception of gender influenced by autism). More than half of the participants were aged 18–35 (60.00%, $n = 33$). A breakdown of age and gender by participant group is shown in Table 1.

**TABLE 1** Participant demographics by response group.

| | Number of participants (%) | | | | | |
|---|---|---|---|---|---|---|
| | TGD | | SLP | | Total | |
| *Gender identity* | | | | | | |
| Female | 31 | (54.39%) | 8 | (14.04%) | 39 | (68.42%) |
| Male | 4 | (7.27%) | 2 | (3.51%) | 6 | (10.91%) |
| Non-binary/third gender | 5 | (9.09%) | 2 | (3.51%) | 7 | (12.73%) |
| Self-described | 2 | (3.51%) | 1 | (1.75%) | 3 | (5.26%) |
| *Age (years)* | | | | | | |
| 18–25 | 17 | (30.91%) | 2 | (3.51%) | 19 | (34.55%) |
| 26–35 | 9 | (16.36%) | 5 | (9.09%) | 14 | (25.45%) |
| 36–45 | 4 | (7.02%) | 1 | (1.75%) | 5 | (8.77%) |
| 46–55 | 3 | (5.26%) | 4 | (7.27%) | 7 | (12.28%) |
| 56–65 | 5 | (8.77%) | 1 | (1.75%) | 6 | (10.53%) |
| 66+ | 4 | (7.02%) | 0 | (0.00%) | 4 | (7.02%) |

*Note*: SLP, speech–language pathologist; TGD, transgender and gender-diverse.

**TABLE 2** Prior technology use by participants.

| | Number of participants (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of technology | Often (weekly) | | Sometimes (monthly) | | Rarely | | Never | | No response | |
| Smart phone | 54 | (98.18%) | 0 | (0.00%) | 0 | (0.00%) | 0 | (0.00%) | 1 | (1.82%) |
| Tablet computer | 24 | (43.64%) | 8 | (14.55%) | 7 | (12.73%) | 14 | (25.45%) | 2 | (3.64%) |
| Social media | 50 | (90.91%) | 1 | (1.82%) | 1 | (1.82%) | 2 | (3.64%) | 1 | (1.82%) |
| Online gaming | 17 | (30.91%) | 4 | (7.27%) | 9 | (16.36%) | 23 | (41.82%) | 2 | (3.64%) |
| Console gaming | 15 | (27.27%) | 8 | (14.55%) | 6 | (10.91%) | 25 | (45.45%) | 1 | (1.82%) |
| Virtual reality | 1 | (1.82%) | 7 | (12.73%) | 6 | (10.91%) | 38 | (69.09%) | 3 | (5.45%) |
| Augmented reality (smart phone) | 3 | (5.45%) | 7 | (12.73%) | 13 | (23.64%) | 30 | (54.55%) | 2 | (3.64%) |
| Augmented reality (HMD) | 0 | (0.00%) | 0 | (0.00%) | 6 | (10.91%) | 47 | (85.45%) | 2 | (3.64%) |
| Smart watch | 14 | (25.45%) | 1 | (1.82%) | 2 | (3.64%) | 36 | (65.45%) | 2 | (3.64%) |
| Desktop/laptop | 53 | (96.36%) | 2 | (3.64%) | 0 | (0.00%) | 0 | (0.00%) | 0 | (0.00%) |

## History of technology use

All participants had prior experience with some technology. Most respondents reported often using smart phones (98.18%, $n = 54$), desktop or laptop computers (96.36%; $n = 53$) and social media (90.91%, $n = 50$). Approximately half of participants reported having at least rare experience of online gaming (54.55%; $n = 30$) or console gaming (52.73%; $n = 29$). However, a majority of participants reported no prior experience of VR (69.09%; $n = 38$) or augmented reality via a smart phone (54.55%; $n = 30$) or head-mounted display (HMD) (85.45%; $n = 47$). Table 2 provides a breakdown of participants' prior technology use by device.

Technology had also been used in gender-affirming voice and communication training by 69.09% of participants ($n = 38$), while the remaining participants had either not used technology in their voice training (25.45%; $n = 14$) or had not attended any gender-affirming voice training sessions (5.45%; $n = 3$). Of those who had used technology in their voice training, most reported having used mobile applications for tracking pitch (89.47%; $n = 34/38$). Respondents had also used computer programs such as PRAAT and Audacity (15.79%; $n = 6/38$), websites (5.26%; $n = 2/38$), discords (5.26%; $n = 2/38$), videoconferencing software (5.26%; $n = 2/38$), YouTube videos (2.63%; $n = 1/38$), and specific clinic platforms (2.63%; $n = 1/38$).

## General perceptions of VR use in voice training

Participants identified a range of opportunities for VR applications that could engage people in voice training.

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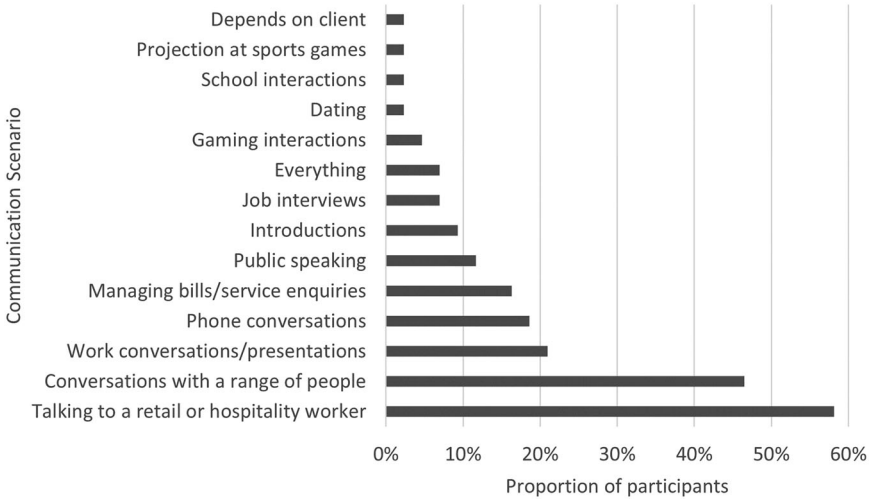


**FIGURE 1** Specific conversation scenarios that could be practiced in VR simulations.

Most participants identified that VR applications that allowed them to practice interactions with others in simulated real-life scenarios would be useful and engaging (78.18%; $n = 43$). Participants also identified potential in games that allowed them to score points and rewards (60.0%; $n = 33$), games that provided an escape into fantasy (58.18%; $n = 32$), and games that allowed them to build and create (49.09%; $n = 27$). Eight participants (14.55%) identified other opportunities including games that gave feedback on voice and non-verbal communication or worked on rhythm. Only two participants (3.64%) reported that they did not think any VR games would be engaging in voice training, and one participant (1.81%) was unsure.

Participants who identified simulated real-life scenarios as useful and engaging ($N = 43$) were asked to identify specific scenarios that could support their virtual voice practice. Participants most frequently identified interactions that involved talking to a retail or hospitality worker, for example, to order food or a coffee (48.14%; $n = 25$), general conversations with a range of people in public or private social situations (46.51%; $n = 20$), and work conversations or presentations (20.93%; $n = 9$). The full range of situations identified for simulated practice is shown in Figure 1.

Despite interest in VR applications for voice training, participants did identify that a range of existing barriers could impede their use of the technology. The expense of VR technology and applications was the most frequently noted barrier (87.27%; $n = 48$). Participants also held concerns that their use of VR in voice training could have impacts on health related to cybersickness (50.91%; $n = 28$), or could be impacted by a lack of available technical support (45.45%; $n = 25$). The lack of visual appeal and entertainment value in the game (34.55%; $n = 19$), and individual ability to use technology and follow instructions (32.73%; $n = 18$) posed additional identified barriers. Twelve participants (21.82%) suggested other concerns that could impact the success of VR in gender-affirming voice training, including comfort in using technology (3.63%, $n = 2$), the quality of feedback users received in VR (3.63%, $n = 2$), experiences of gender dysphoria when using their voice in VR (3.63%, $n = 2$) and insufficient computer hardware (3.63%, $n = 2$) or internet (1.82%, $n = 1$) to support VR at home. One participant (1.82%) expressed that they did not know what barriers may exist due to a lack of familiarity with the technology.

## Perceptions of voice-activated VR applications

Participants reviewed video examples of three types of voice-activated VR applications: simulation-based applications, games with a simple and repeatable gameplay mechanism and more complex multilevel fantasy games. These three categories of game were shown due to the current availability of an application with a voice-control mechanism within each category. Participants provided their thoughts on the potential usability and suitability of each type of application for gender-affirming voice training. The example simulation-based game was viewed most favourably by participants, with over half of the participants (58.18%, $n = 32$) reporting they would enjoy using it and 52.73% ($n = 29$) saying it would help with motivation to practice voice training exercises at home. Although many participants did indicate that they would also enjoy using and be motivated by the simple gameplay and multilevel fantasy applications, many also expressed uncertainties (Figure 2).

Participants were asked to further elaborate on their perceptions on each type of voice-activated VR application. Thematic analysis of their responses identified four main themes: (1) features of VR that contribute to or hinder

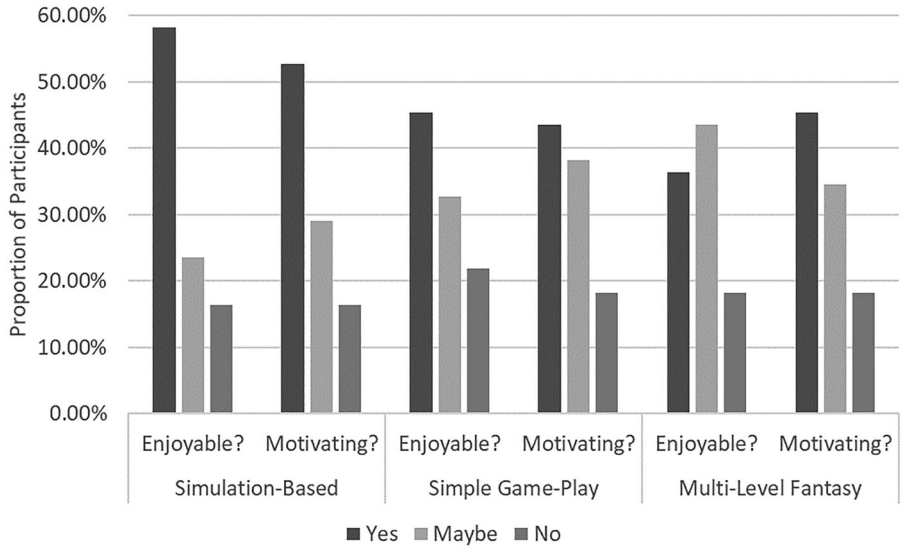


**FIGURE 2** Participant perception of whether each type of VR application help appeal for enjoyment and motivation.

audience appeal; (2) therapeutic value of VR and its relevance to gender-affirming voice and communication training; (3) exposure to or protection from harm by VR; and (4) relatability of VR to real life. Each theme is explored in detail below.

## Features of VR that contribute to or hinder audience appeal

Participants described the three different applications as fun, engaging and motivating for practice, indicating a positive sentiment towards the use of the three types of voice-activated VR applications for voice training. In doing so, participants contrasted VR applications with other methods of voice training to highlight the value of VR, with one participant stating, 'it's a much more engaging and stimulating way to train my voice!' [P11 (TGD)]. Participants referenced the strong visuals and design elements of the VR applications as key features that drew appeal, although some differing points of view highlighted that personal preference influenced opinion. For example, the simple and colourful aesthetic of the simple gameplay VR application was considered cute and interesting in design by some, while others found it to be childish and simplistic. In contrast, the neutral colour palate of the simulation-based game was either spared comment by participants, or was disliked, with one participant describing the application as, 'a bit dry or unexciting'. [P47 (TGD)]

Comments on the simulation-based game suggested that participants were more concerned with the gameplay mechanism than the aesthetic appeal where there was slightly more complexity involved. Participants were drawn to the practicality of the application and because of this, it was also considered to have the broadest demographic appeal. Highlighting this, P35, a speech–language pathologist, commented, 'I strongly feel that this caters to the older generation of patients I see as well as those from younger generations where technology use is more common and culturally embedded'. The gameplay mechanism in the fantasy, multilevel game was not as universally appealing with participants describing it as both 'very motivating and captivating' [P48 (TGD)], and 'confusing and challenging' [P26 (TGD)]. One participant postulated that prior experience with video gaming could influence appeal, with those more experienced and proficient in gaming more likely to enjoy complexity: 'I think the aesthetic/fantasy narrative and mysterious/emerging gameplay with less overt explanations might appeal more to people who play video games regularly' [P25 (TGD, SP)].

The replay value of the VR applications was another feature that affected audience appeal. For several participants, the simple and multilevel gameplay VR applications were felt to be interesting and fun to try at least once, but their ongoing appeal and longevity of use were called into question. Participants commented that they were 'not sure what would keep it engaging on an ongoing basis' [P47 (TGD)] and 'the game itself looks like it may get very repetitive … most people would not enjoy playing past the first few times' [P33 (TGD)]. Participants expressed the need to have a variety of storylines to retain a user's interest, particularly in relation to the simulation-based application, although this was considered more in the context of being able to program a range of different scenarios to tailor the content and ensure its usefulness. For example, P41, a speech–language pathologist stated:

> I think the biggest drawback would be not having the ability to program/customize/create a scenario for the client. I would have to rely

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> on an existing "library" of scenes which may or may not be useful for that person's specific goals. Or maybe they get tired of the same scene.

## Therapeutic value of VR and its relevance to gender-affirming voice and communication training

Participant responses highlighted the need for VR applications that responded to voice to have clear therapeutic or training value. For such value to be evident, participants stressed that applications would need to have transparency around the vocal characteristics being trained, and be responsive to their voice use to provide clear and meaningful feedback. Considering those factors, all three demonstrated types of voice-activated VR applications were considered valuable for discovery and exploration of broad aspects of voice, and for engaging in and promoting vocal play and vocal exercise: 'I can see people … exploring their voice, engaging in vocal play, and relaxing using this' [P25 (TGD, SP)]. However, there was an overriding sense of VR applications, particularly gameplay applications, needing to be more purposefully tailored to gender-affirming voice and communication training to be truly beneficial and worthwhile. In viewing VR games, participants expressed concern about whether they were fit-for-purpose, stating, 'it is visually appealing but doesn't feel like it has much to do with vocal training apart from the use of your own voice' [P46 (TGD)] and 'I can't understand how this assists voice feminisation' [P40 (TGD)].

To achieve therapeutic and training value, participants emphasized that applications needed to be very transparent in showing the vocal features that were targeted and trained through VR gameplay. Where this was unclear, participants did not understand why they would be using the application and noted that they therefore may not be motivated to use it. To create greater fit-for-purpose, participants suggested that applications could be personalized through a set-up menu where individuals could choose the vocal features they wanted to train, such as pitch, volume or resonance. Additionally, applications needed to provide explicit feedback on voice beyond navigation of the VR environment. Participants felt that explicit and specific feedback was distinctly lacking from the three example VR applications they were shown. Participants expressed a desire for specific metrics, including an illustration of pitch in hertz, or an audio playback of recorded samples to perceptually track change over time, to close the feedback loop and show progress. P47 (TGD), stated that the applications 'would be motivating for practice so long as … [they] could track voice training progress in meaningful ways'. However, participants also considered that VR would be unnecessary for providing such feedback when existing mobile applications could already provide these metrics, with one participant clearly making the point that, 'VR is too much of a work around for something I can just do at my desk using a pitch tracker' [P46 (TGD)]. For some, the complexity of VR animations and gameplay were viewed as a potential distraction from such explicit feedback, and therefore detrimental to their training.

## Exposure to or protection from harm by VR

Participant responses to the three types of voice-activated VR applications contained a clear theme showing participants were concerned by the potential for harm caused by VR. Some concerns were generally related to the technology, such as the risk of triggering light-sensitive epilepsy. However, other concerns related more to the contents of the applications. Specifically, participants were concerned about the risks to their voice from incorrect voice use, and the potential for psychological stress, social anxiety and gender dysphoria that could be induced by repeated use of the voice in ways required by the game that were not tailored to the user. VR responsiveness to volume was a key element of concern from voice use, with participants observing that gameplay applications at times required shouting or yelling to elicit the desired response or progression in the game. For speech–language pathologists, this raised concerns about 'causing harm to their voice if done with too much strain and effort' [P44 (SLP)], while for TGD participants, the concern included risk of psychological harm. To illustrate, one participant stated that, 'any yelling or difficult pitch to reach would trigger gender dysphoria' [P17 (TGD)].

In contrast to the potential for harm, participants also identified that VR-based voice training could be protective against harm for some users in some situations. Participants noted that practicing gender-affirming voice training techniques could be difficult without a safe space, prompting many to avoid the regular practice they needed to do. For simulation-based voice training applications in particular, participants saw a safe environment in which to hone voice skills, practice vocal techniques and build confidence in their voice before using it in their day-to-day lives:

> The use of VR in real world scenarios is exactly what some of my clients are looking for! The implementation of VR in my practice could help clients generalize strategies

> in a safe/non-threatening environment before transferring these skills into real life. [P53 (SLP)]

The anonymity offered through online platforms was seen as a key protective factor that operated alongside the safe practice environment. Participants noted that this anonymity could be achieved with avatars and usernames in existing online platforms, and that this could extend to VR. One participant highlighted this possibility, stating 'lots of my clients engage in voice practice in online communities and social networks and appreciate the safety of an anonymous avatar with the ability to disengage at any time' [P25 (SLP, TGD)].

### Relatability of VR to real life

Many participants expressed a preference for voice-activated VR experiences with clear relatability and applicability to the real world. Most participants identified that these features were most evident in the simulation-based VR applications. Through transparent links to their daily lives, participants saw relevance in training experiences, and the potential to increase practice where opportunities for physical interactions were sparse. People who were socially isolated were identified as a key target demographic to benefit from this type of VR voice training: 'this will assist people that live alone and have trouble communicating with others' [P12 (TGD)].

Not all participants felt VR simulations were relatable and suggested that limitations in the realism of the depicted environments would limit their effectiveness as training environments. The 'obvious fakeness' [16 (TGD)] of the avatars, environment, and objects promoted a sense that the simulation was more of a game than a practice environment, and so participants expressed that they were discouraged from taking the voice training element of the task seriously. The stilted and constrained nature of the conversation, caused by the voice recognition and response mechanism in the application limiting the nature and variety of responses, also affected realism.

> I didn't feel like this would give much benefit … at least not unless the café worker was significantly smarter and could throw in unexpected questions sometimes … or do something more interactive that approximated real conversations in a more meaningful way. [P47 (TGD)]

Participants were clear that greater realism in the depiction of simulated environments and interactions would significantly enhance the value of VR-based gender-affirming voice and communication training.

## DISCUSSION

A survey of TGD individuals who had engaged in, or who held an interest in, gender-affirming voice and communication training and of speech–language pathologists who had delivered such training, highlighted support for the potential of VR to enhance regular voice practice. Stakeholders identified that VR offered a likely motivating platform for voice practice. Features such as fun, enjoyable and engaging gameplay, and safe practice environments were particularly appealing.

TGD individuals and speech–language pathologists particularly drew on the motivating potential of VR, consistent with prior assertions by Bryant et al. (2020a, 2020b) that VR could encourage greater practice in safe, virtual spaces. Motivation to engage in regular voice training beyond clinical sessions is a key concern in gender-affirming voice and communication training, where regular practice is recognized as a necessity to achieve desired voice outcomes (van Leer & Connor, 2012) and to allow generalization of the gender-affirming voice into everyday use. Increased practice has been observed in research where VR is used as an adjunct to traditional therapy in other populations, including children with cerebral palsy (Snider et al., 2010), adults undergoing upper-limb rehabilitation (Laver et al., 2017) and adults with aphasia undertaking language therapy (Amaya et al., 2018). The findings of this research suggest that VR would have similar impacts on training motivation and frequency, increasing generalization of the skills taught in clinic to everyday use, leading to improved outcomes for TGD individuals undertaking gender-affirming voice training

### Features of VR that contribute to or hinder audience appeal

The technological and remote nature of VR were both identified by TGD individuals and speech–language pathologists as features that promoted safety while undertaking voice training. Participants could hone their skills in isolated simulations or engage anonymously in online communities to use their voice. There was a clear interest expressed by TGD individuals and speech–language pathologists for VR applications that simulated real-life scenarios. While gameplay applications were also considered enjoyable and motivating, simulated scenarios were deemed to have the most appeal and the most transfer potential with regards to generalization of voice skills

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to the real world. For example, an application simulating ordering a coffee at a café could provide context for voice practice before visiting a real café. Similar isolation and a degree of anonymity could be achieved through telepractice, which Russell and Abrams (2019) also perceived as enabling safe spaces for practice. By practicing at home with technology-based assistance, Russell and Abrams noted greater engagement with training programs, while van Leer and Connor (2012) also identified significant increases in practice when training was supported with technology that participants could access from home. As such, VR might be an effective way to encourage additional vocal practice and address the poor engagement rates with session attendance and home practice (van Leer & Connor, 2012).

Currently VR applications within the scope of speech–language pathology are scarce and not specifically designed for the purposes of gender-affirming voice and communication training. The findings of this study reflect that the available example VR applications required use and modification of pitch alone to achieve gameplay outcomes. However, results from this survey indicate that consumers expect a lot more from VR games if they are to be used in voice training. Participants identified that future VR games for gender-affirming voice training will need to be specific and include features such as explicit feedback on voice parameters targeted in training, including resonance, prosody, speech rate and gesture (Davies et al., 2015; Hardy et al., 2020), making use of the multimodal input mechanisms of VR systems. Tracking of progress was seen as a necessary feature, as well as the game needing to be visually appealing with colourful aesthetics, realistic and lacking in repetitive tasks.

## Therapeutic value of VR and its relevance to gender-affirming voice and communication training

As this study highlighted, technology already plays a pivotal role in the lives of TGD individuals and speech–language pathologists. Smart phones, laptops, social media and online gaming were regularly used, and for many were already a part of their gender-affirming voice and communication training. In many cases, TGD individuals used mobile applications to deliver specific and explicit biofeedback during their voice practice, to show their current pitch and changes in pitch over time. A prior systematic review of technology-supported biofeedback in voice therapy and training illustrated significant positive voice changes in 15 of 18 included studies (Maryn et al., 2006). While specific biofeedback was something that participants identified as a needed addition in VR applications, the existence of mobile applications and websites that provide such feedback did, for some, negate the need for that in VR. Extrapolating from this, the development of VR applications could represent an unnecessary expense when other platforms already provide the same solutions. However, participants identified that there was a clear need for biofeedback on more than just pitch alone, with requests for feedback on resonance, intonation, and non-verbal communication—all important factors in successful gender-affirming voice training (Davies et al., 2015; Hardy et al., 2020).

## Exposure to or protection from harm by VR

Additionally, some TGD individuals and speech–language pathologists expressed that without appropriate feedback mechanisms, voice-activated VR applications could promote the use of the voice in unsafe or damaging ways through shouting and yelling. To overcome any potential vocal harm, users may need to undertake training in clinical settings to use VR safely prior to engaging with it for home practice. As Bryant et al. (2020a, 2020b) note, this suggests that VR cannot replace, but rather should be used as an adjunct alongside traditional therapy. However, for VR to realize its true potential as a tool to promote independent home practice, it would need to be usable, at least in part, without the supervision of a trained speech–language pathologist. Within the context of clinical practice, speech–language pathologists need to carefully monitor how any technologies are used by those undergoing gender-affirming voice training to ensure there is no misuse that could negatively impact voice outcomes during necessary at-home practice (van Leer & Connor, 2012). Future research also needs to evaluate how engagement with existing voice-controlled VR applications affect voice quality.

## Relatability of VR to real life

The findings of this study showed that the scenarios depicted in VR for voice practice must be relatable to real-life and offer realistic and meaningful interactions to enable successful transfer of skills to the real world. Stakeholders expressed the need for realistic and relatable content, meaningful interactions and capacity to program or customize content to keep it fresh and engaging. This need for realism has been identified in studies investigating VR use for other communication disabilities as a key characteristic that should be leveraged for successful transfer of skills learned in VR to everyday life (Bryant et al., 2022; Garcia et al., 2007). All these considerations

emphasize the sentiment that being fit-for-purpose is more important than any aesthetic or entertainment value in any future voice-training-specific VR application. Clear thought needs to be given to the game design, its therapeutic benefit, and its relevance to gender-affirming voice and communication training to be considered as a worthwhile training tool by users.

The differences in opinion between participants regarding liked and disliked features and wants and needs in voice-activated VR applications, highlights the need for stakeholders in gender-affirming voice and communication training to be involved in any future technology design. For VR to be implemented successfully within clinical practice, applications need to be fit-for-purpose. While this survey study represents the first step in participant-involved design to engage users in product use and development (Kanstrup et al., 2017), further involvement is needed in building applications specifically for gender-affirming voice and communication training. This will require a range of user engagement and consultation methods (Slattery et al., 2020).

## Limitations and future directions

The survey used in this research provided insightful and meaningful data to support further investigation into voice-activated VR-based training tools for gender-affirming voice and communication training. The inclusion of TGD individuals and speech–language pathologists who provide gender-affirming voice and communication training ensured that this early-stage participant-involved design consultation provided valid data from all stakeholders who may be invested in tools to support training into the future. However, limitations in sampling and survey design should be taken into consideration when interpreting the findings of this research.

Survey recruitment used self-selection in the sampling, meaning that those who opted to participate in the survey may have held pre-existing knowledge of favourable views of the use of technology in gender-affirming voice and communication training, or an interest in VR. As such, responses could show bias towards a more favourable view of the technology. Given the balanced responses and ideas that were evident in the analysis and the themes, such a bias may not be present in the data. Regardless, the data does represent the views and opinions of only a small cross-section of the TGD population, and of speech–language pathologists who provide gender-affirming voice and communication training. While saturation was reached in the analysis of qualitative data, this data did still only represent a predominantly young demographic as most participants were aged 35 years or younger.

It is important to note that the three VR applications used as examples in this study, although voice-activated, were not created or designed for the purposes of gender-affirming voice and communication training. The three applications were either commercially available (in the case of the simple gameplay application), or beta prototypes sourced from within the last author's networks (for the multilevel fantasy application and simulation-based application). These applications were chosen as the only known and locatable voice-activated and controlled VR applications at the time of this research. Through observing these examples, participants were given the opportunity to consider features and characteristics of different types of applications with clear points of reference, and therefore reflect on their needs within any future application designed specifically for gender-affirming voice and communication training. The insights of participants provide valuable knowledge to future producers of gender-affirming voice and communication training VR applications.

To gain more in-depth insight into the use of VR applications in gender-affirming voice and communication training, TGD individuals must have the opportunity to trial applications, rather than viewing example videos. In doing so, tangible data can be gathered to confirm whether VR applications can be used to achieve positive voice outcomes, reduce social anxiety, improve generalization of their affirming voice, or whether gameplay mechanisms may carry risk of harm to the voice, as some participants queried in this study. Interviewing participants following VR experiences would also provide more comprehensive perspectives to inform future application design, rooted in personal experience rather than in theoretical reflection from video observation. What is clear is that co-design of VR applications that are specifically designed to provide feedback on many aspects of voice and communication skills trained in the clinic, rather than simply pitch alone needs to occur if they are to be used by TGD individuals.

## CONCLUSIONS

TGD individuals and speech–language pathologists who provide gender-affirming voice and communication training communicated a clear interest in the potential for voice-activated VR applications to support practice of voice and communication exercises and increased generalization of the gender-affirming communication skills learned in clinic. However, while interest was clear in

the majority perceiving enjoyment and motivational value in example applications, varied responses showed that such VR training tools would not appeal to everyone, and the needs of TGD individuals would need to be carefully considered, catered to, and programmed in specially designed applications for them to be truly effective in supporting gender-affirming voice and communication training.

Simulation-based VR scenarios that created safe, replicable and realistic spaces in which to practice the use of voice for daily tasks were viewed most favourably. Such environments may provide TGD individuals with spaces in which to use and become comfortable with their voices without fear of judgement, reducing anxiety around speaking in public and to non-familiar conversation partners. In using virtual worlds to practice, though, the need for ongoing and explicit feedback was clear. TGD individuals and speech–language pathologists require ways in which to monitor voice use and progress over time to maximize the therapeutic and training value of VR tools.

Ongoing participant-involved design of VR applications, and indeed any technology, will be necessary to ensure that tools can be developed that are fit-for-purpose, appealing to users and functional in the context of gender-affirming voice training. Hands-on testing of applications and clear measurement of voice outcomes will be the next step in ensuring that VR applications can be used safely in gender-affirming voice and communication training. With ongoing participant-involved design, VR offers a potential avenue to support many TGD individuals to engage in the regular practice needed to achieve gender congruence in their voice and communication.

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## CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The research presented here was completed in partial fulfilment of Charlotte Smith's Masters of Speech Pathology degree.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy or ethical restrictions.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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