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# Validation of an Upgraded Virtual Reality Platform Designed for Real-Time Dialogical Psychotherapies

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**Abstract: Background:** The advent of virtual reality in psychiatry presents a wealth of opportunities for a variety of psychopathologies. Avatar Interventions are dialogic and experiential treatments integrating personalized medicine with virtual reality (VR), which have shown promising results by enhancing the emotional regulation of their participants. Notably, Avatar Therapy for the treatment of auditory hallucinations (i.e., voices) allows patients to engage in dialogue with an avatar representing their most persecutory voice. In addition, Avatar Intervention for cannabis use disorder involves an avatar representing a significant person in the patient's consumption. In both cases, the main goal is to modify the problematic relationship and allow patients to regain control over their symptoms. While results are promising, its potential to be applied to other psychopathologies, such as major depression, is an exciting area for further exploration. In an era where VR interventions are gaining popularity, the present study aims to investigate whether technological advancements could overcome current limitations, such as avatar realism, and foster a deeper immersion into virtual environments, thereby enhancing participants' sense of presence within the virtual world. A newly developed virtual reality platform was compared to the current platform used by our research team in past and ongoing studies. **Methods:** This study involved 43 subjects: 20 healthy subjects and 23 subjects diagnosed with severe mental disorders. Each participant interacted with an avatar using both platforms. After each immersive session, questionnaires were administered by a graduate student in a double-blind manner to evaluate technological advancements and user experiences. **Results:** The findings indicate that the new technological improvements allow the new platform to significantly surpass the current platform as per multiple subjective parameters. Notably, the new platform was associated with superior realism of the avatar (d = 0.574; $p < 0.001$) and the voice (d = 1.035; $p < 0.001$), as well as enhanced lip synchronization (d = 0.693; $p < 0.001$). Participants reported a significantly heightened sense of presence (d = 0.520; $p = 0.002$) and an overall better immersive experience (d = 0.756; $p < 0.001$) with the new VR platform. These observations were true in both healthy subjects and participants with severe mental disorders. **Conclusions:** The technological improvements generated a heightened sense of presence among participants, thus improving their immersive experience. These two parameters could be associated with the effectiveness of VR interventions and future studies should be undertaken to evaluate their impact on outcomes.

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## 1. Introduction

An emerging use of virtual reality (VR) in many medical fields has recently been observed. This is especially true for psychiatry, as it seems to be a promising technology to offer personalized treatments to specific populations [1–3]. VR consists of a computer-generated simulation of a three-dimensional image or environment, which can usually be interacted with by a person using special electronic equipment such as a head-mounted display. Indeed, VR allows for the creation of an environment targeting a multitude of symptoms (e.g., stressful social context) by exposing participants to immersive emotion-inducing life contexts in a secure environment supported by a physician or therapist [1,4]. This tool was initially designed to help treat phobia and other anxiety disorders, which was deemed to be at least as efficient and more practical than in vivo exposure [5,6]. Still, its use has been extended since then to several mental disorders, such as substance use disorders (SUD), eating disorders, and post-traumatic stress disorder [1]. The primary approach used in VR interventions is exposure-based therapy, which uses pre-recorded scenarios to expose patients to different difficult situations [1]. However, it does not allow personalization for each patient, the interaction with the avatars is predetermined, and the therapist's feedback is not carried out in real-time. Studies have proposed that the more the virtual experience corresponds to people's real-life experiences, the more they will be able to transpose the responses learned to their daily lives and thus could improve intervention effectiveness [7,8].

Dialogical approaches have emerged in response to these concerns within the last few years. Outside the field of VR, dialogical therapy is used to benefit patients' relationships and learn real-time skills while building assertive interactions [9]. Empty-chair work and role-play are some examples of known dialogical interventions [9,10]. Avatar therapy is a dialogical intervention that was first developed in the context of the treatment of auditory verbal hallucinations [11–14]. Considering that hallucinations are invisible entities, Leff's team proposed recreating the avatar (synthetic character) representing the patient's voice [15]. In this approach, the patient is invited to dialogue with the avatar of his voice, which is animated in real-time by the therapist, to better regulate the negative emotions generated by the threatening or denigrating remarks of the voice. Recently, our team integrated VR into this therapeutic approach, yielding significant reductions in frequency and distress associated with auditory verbal hallucinations that are experienced by individuals with treatment-resistant schizophrenia [12,13]. In addition, this therapy was found to improve quality of life and reduce some voice-associated beliefs [12,13]. Considering these promising results, the idea of translating a similar relational approach to other pathologies emerged, resulting in the development of a new VR intervention to treat cannabis use disorder in individuals with comorbid severe mental disorders [(SMD), including chronic psychotic and mood disorders] [16]. According to the National Institute of Mental Health, a severe mental disorder is defined as a mental, behavioural, or emotional disorder resulting in serious functional impairment that substantially interferes with or limits one or more major life activities [17]. In this case, the avatar created by the patient was a synthetic representation of a person with significance in the patient's consumption history. In doing so, the therapist targeted notably an increase in motivation to change, a better ability to manage stress and cravings, or even a better ability to manage interpersonal conflicts [16,18,19]. Results showed significant reductions in the quantity of cannabis consumed and severity of cannabis use disorder, as well as an improvement in quality of life and psychiatric symptoms maintained until the 12-month follow-up [19].

Whether a dialogic approach is taken, VR therapies require the virtual environment to generate a certain sense of presence. Sense of presence refers to feeling present in a virtual environment [20,21]. Previous studies suggest that the sense of presence could be linked to efficacy in patients undergoing avatar therapy [7,22]. Although the precise elements that contribute to the sense of presence remain to be clarified, specific evidence suggests that the realism of the environments plays an important role [23,24]. Research has shown that the perceived realism of the visual display of VR environments increases with their level of detail and better aesthetic preferences [25,26]. One of the most replicated findings is that the level of emotion evoked facilitates a sense of presence in the VR environment [22,27–30]. It has been hypothesized that personalizing emotional narratives increases the sense of presence in VR environments [31,32]. Specific avatar characteristics appear to increase the sense of presence and/or enjoyable overall quality of experience [33]. Such factors include realistic facial features over cartoon-like and body characteristics (entire body versus upper body) [33–36]. Also, it has been proposed that the increased movement realism of the avatar (i.e., breathing, eye blinking) increases the feeling of social presence and improves participant interactions in VR environments [37,38].

In the specific context of the Avatar Intervention (i.e., Avatar Therapy for the treatment of auditory verbal hallucinations and Avatar Intervention for cannabis use disorder), it remains unclear whether precise elements of the platform contribute to the sense of presence. This type of platform requires the transformation of the voice of the therapist so that it resembles that of the character chosen by the participant, creating an avatar whose emotional expressions can be modified in real-time and, in the case of Avatar Intervention for cannabis use disorder, selecting a proper environment to discuss with the avatar [12,13,16]. Throughout previous clinical trials, anecdotal feedback about the main technological obstacles encountered has been gathered in a non-systematic manner. Notably, many patients have mentioned the lack of cultural diversity in the avatars, the lack of realism of the transformed voice, the lack of accessories available in the personalization of the avatars, the lack of a lower body and body movements, more choice of virtual environment, and a robotic non-realistic appearance of the avatar and its lip movements. With the aim of reproducing each participant's experience as faithfully as possible and enhancing the efficacy of VR treatments, improvements in each of these parameters have been undertaken.

The objective of this article was to compare the current VR platform to a new one developed to optimize the quality of immersive experience. Based on the feedback obtained from previous participants and a literature search of factors favouring a sense of presence, this new application includes adding features for avatar personalization, avatar mobility, wide-range facial expression, realistic voice modification, elaborate lip synchronization, and detailed environments. This cross-sectional study represents the first exploration of these various parameters on the immersive experience in healthy participants and participants with SMD to bring this validation study closer to the reality of clinical intervention. The hypothesis is that the new optimized platform will show superior realism and elicit a higher sense of presence than the Avatar platform used in previous and current clinical trials.

## 2. Materials and Methods

### 2.1. Participants

A total of 50 French-speaking participants were recruited at the University Institute in Mental Health of Montreal (individuals with SMD) and in the community (healthy controls). We recruited participants with these two profiles to gain insight into the perceptions of healthy individuals and those with SMD, meaning a self-reported mental disorder diagnosis consistent with Diagnostic and Statistical Manual of Mental Disorders 5-TR categories F22, F23, F20, F25, F31, F32, and F33 [39]. All participants were required to be 18 years or older for inclusion in this study. Participants were excluded if they had already used or experienced the current VR platform, were unstable, or had a physical limitation (e.g., blindness) that prevented them from using a VR headset. The ethics committee of the CIUSSS de l'Est-de-l'Île-de-Montréal approved the study. Informed written consent was obtained from all participants (ethical approval code: 2021-2556).

### 2.2. Design and Procedures

This cross-sectional study consisted of one visit that lasted one hour and thirty minutes. The visit consisted of presenting the study, obtaining written consent, testing both VR platforms, and completing questionnaires. The design was double-blind as both participants and the evaluators did not know which platform was the current vs. the new one. The two VR platforms were tested in a random order (assigned by a team member who ensured that the number of participants starting with each platform was the same) to ensure the evaluators remained blinded and to minimize test–retest bias. The participants would randomly test one platform, answer questionnaires about the tested platform (i.e., sense of presence, emotions, avatar realism, voice transformer's realism, lip synchronization quality, and global experience), test the second platform, and answer the same questionnaires about the second platform.

The evaluation was double-blinded, as both the evaluator passing the questionnaires and the participants testing the platforms did not know which platform was the current or the new VR platform. A graduate student who was not present in the VR room administered the questionnaires in a separate room.

### 2.3. Experimentation

Each participant had to create an avatar of someone they judged as close to them; they had to choose someone they could feel comfortable talking to and make this same person in both VR platforms. The participant had to prepare two scenarios, one for each platform, which caused them a tolerable negative emotion (e.g., anger, sadness). The scenario had to be linked to the COVID-19 pandemic so that the discussions could be comparable for all the study participants. The COVID-19 topic was chosen as a universally challenging situation. Scenarios causing great distress or strong negative emotions were not retained, considering that this exposure to VR did not consist of an intervention. The objective of the study was only to validate a new VR platform. The current platform was the one used for the Avatar Intervention for cannabis use disorder. The participants could choose from 3 environments: a bar, an apartment kitchen, or a park. These 3 environments were selected as they were available on the current platform (Figure 1). Although more environments are available on the new platform, participants remained in the same chosen environment on both platforms. The immersive part of the visit lasted between 5 and 7 min.


**Figure 1.** Example of avatars in VR environment in the current platform (**1**) park, (**2**) apartment, and (**3**) bar, and in the new platform (**4**) park, (**5**) apartment, and (**6**) bar.

### *2.4. Set Up Material*

With the current platform, the VR environment was created using a custom-made Unity 3D game engine, including unique avatars generated with the Morph3D Character System (https://unity.com/fr, accessed on 5 January 2025). Voices are modified by the Roland AIRA voice modulator 7 VT-3. The Oculus Rift head-mounted display VR headset allows immersion in the virtual world. The bi-directionality of sound between the therapist's headset and microphone and the patient's headset and microphone is obtained with a Behringer U-PHORIA UMC22. The avatar's lips were synchronized using Simple Automated Lip Sync Approximation (SALSA), version 2014 (https://crazyminnowstudio.com/unity-3d/lip-sync-salsa/, accessed on 7 January 2025). Audacity was used to record the immersion sessions (https://www.audacityteam.org/, accessed on 7 January 2025). Figure 2 demonstrates the setup for the current VR platform. Inspired by the facial action coding system, the avatars' facial expressions in the current VR platform were programmed to reflect the following four emotions: happy, excited, angry, and sad [40]. The new platform was designed from scratch via a partnership with the Centre de Développement et de Recherche en Intelligence Numérique (CDRIN). The avatars were created with Unity's Morph 3D software, version:2021.3.38, their voices were modified with the Morph Vox application extension (https://screamingbee.com/morphvox-voice-changer, accessed on 5 January 2025) and the Oculus Rift-s head-mounted display VR headset allows immersion in the virtual world. Voicemeeter Banana was used to record the immersion sessions (https://vb-audio.com/Voicemeeter/banana.htm, accessed on 7 January 2025). Figure 3 demonstrates the setup for the new VR platform. The avatars' lips were synchronized using the artificial intelligence sound-matching system developed by modelling complex lip movements using deep learning algorithms owned by a third party (not publicly available). The Sound-matching system was developed by Ubisoft in the context of game playing and was adapted by the CDRIN for the needs of the VR platform. In addition, the new platform also used a higher number of the universal emotions of Paul Ekman, such as angriness, contempt, disgust, happiness, fear, sadness, and surprise [41]. The new platform also offered more environments, such as a park, a balcony, two bedrooms, two kitchens, and a bar, compared to the current platform, which only had a bar, a kitchen, and a park. In addition to having more environments, the new platform had more realistic environments (e.g., background avatars were added). The new platform also offered more ethnic choices for creating an avatar, and it also offered more modulation of the avatar. For example, the new platform offered more realistic skin tone choices, more starting ethnic faces, and more sliders to help change the size and place of each facial feature compared to the current platform, which had few skin colours to choose from, only one starting face and the choice to modify only certain facial components with predetermined assets. Finally, in the new platform, avatars were modified so that they displayed body movements (breathing, eye blinking).

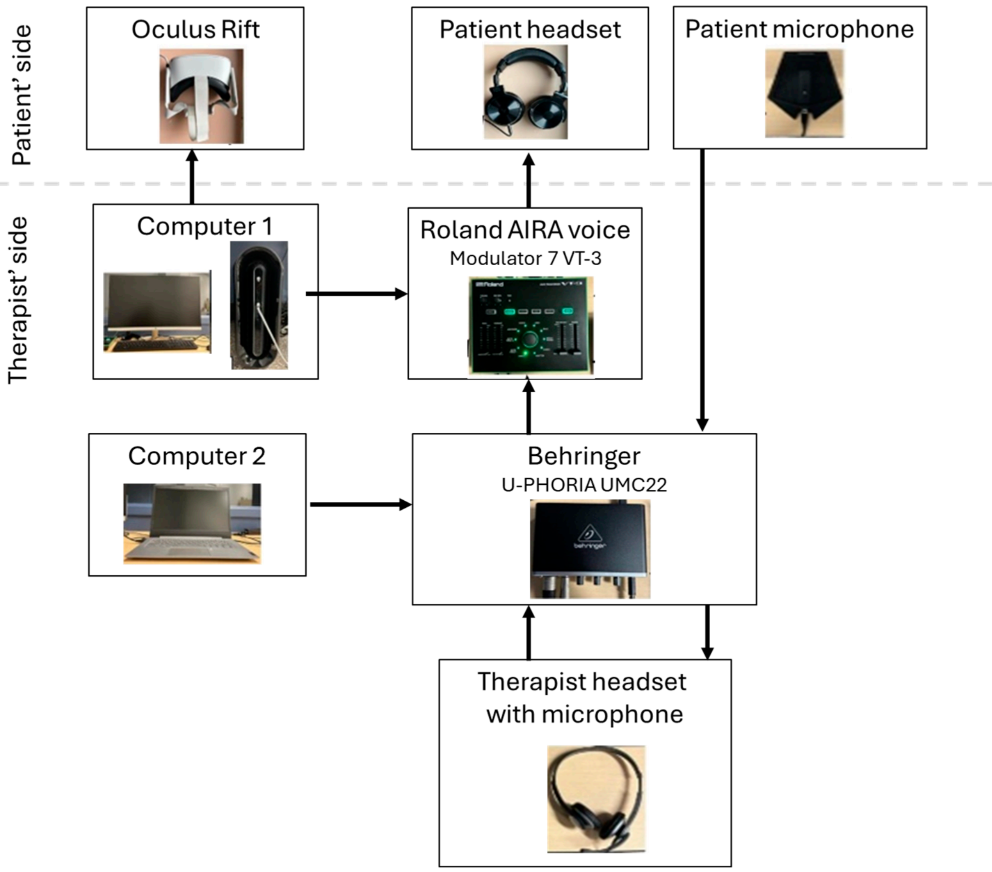


**Figure 2. Set-up for the current VR platform.** Computer 1 was responsible for accessing the Unity Morph 3D application that managed the avatars. Computer 2 was responsible for the sound recording on the Audacity application. The Roland was responsible for transforming the therapist's voice and the Behringer was responsible for the bidirectionality of sound.

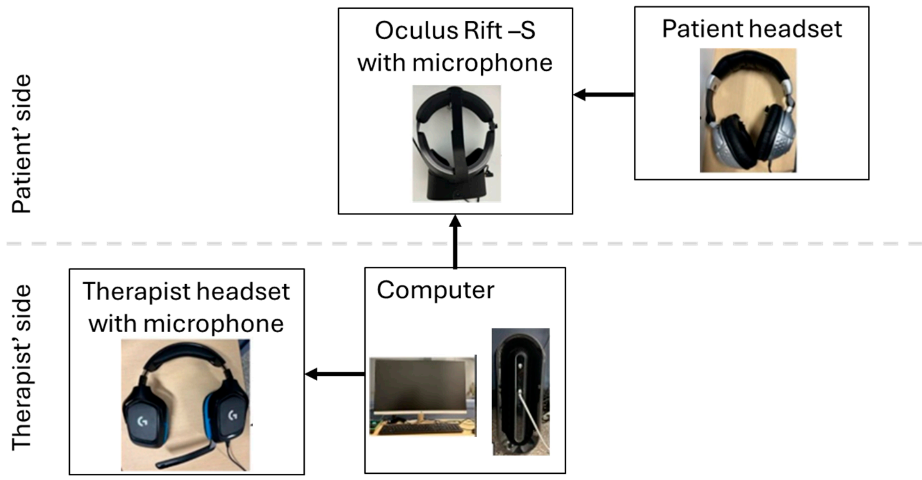


**Figure 3. Set-up for the new VR platform.** In this case, the singular computer was responsible for accessing the Unity Morph 3D application, which managed the avatars and allowed for bidirectional sound. It held a Voicemeeter banana for the sound recording and used the Morph Vox application to transform the therapist's voice.

### *2.5. Assessments*

The questionnaires were administered to both the healthy group and the severe mental disorders group. First, the sense of presence was measured using the Temple Presence Inventory. This validated questionnaire is lengthy (42 items) and is subdivided into 8 presence subscales (spatial presence, social presence-actor, passive social presence, active social presence, presence as engagement, presence as social richness, presence as social realism, and presence as perceptual realism) [42]. Like many studies that have used sense of presence questionnaires in the past, we adapted and simplified the Temple Presence Inventory based on the requirements of the current study [43–45]. Therefore, for each subscale, only the top 2 items with the highest Cronbach's alpha ranking were used. In addition, the last subscale (presence as perceptual realism) was removed as the questions did not apply to the study setting; indeed, the VR environments do not allow movements. The final adapted questionnaire comprised 14 items with a scale ranging from 1 to 7 (score range from 14 to 78). The Cronbach's Alpha was 0.871 for the total questionnaire. The questionnaire has also a comparable satisfactory internal consistency for healthy participants as well as those with SMD. No item significantly changed the Cronbach's alpha statistics. The second questionnaire was the Positive and Negative Affect Schedule (PANAS), which was initially validated in a non-clinical sample [46]. Internal consistencies were high (0.89 and 0.85 for positive and negative affect respectively). Although previous studies used this questionnaire in a population with a severe mental disorder, it had not been validated with this group at the time of writing these lines [47,48]. Paul Ekman's 10 primary and secondary emotions were selected: interest, excitement, anger, nervousness, attention, irritability, shame, guilt, fear, and hostility for a total of 10 items [40,41,49]. This questionnaire measured, on a scale from 1 to 5, the intensity of the above-mentioned emotions. In addition, for the present study, questions were specifically developed to evaluate the aspects related to the improvements made to the new platform (not previously validated). The avatar realism, the voice transformer's realism, and the lip synchronization quality were measured using a subjective Likert-type scale ranging from 0 to 10 (0 being the worst quality and 10 being the best quality). Finally, global experience was measured using a Likert-type scale ranging from 0 to 100 (0 being very poor and 100 being very good). See Supplementary Materials for French and English versions of questionnaires and questions developed for the study.

*2.6. Analyses*

Descriptive statistics for continuous variables were reported as mean and standard deviation, while dichotomous variables were reported as frequencies and percentages. In order to compare the new VR platform to the current VR platform, Wilcoxon tests were performed to analyze differences between platforms for all subjects. The same tests were performed to investigate potential differences separately in healthy subjects and participants with mental health disorders to compare the level of realism and sense of presence evoked by the current and the new VR platforms. The Wilcoxon test was preferred over a paired *t*-test as most of the data did not follow a normal distribution. To reduce the likelihood of type I errors, a Bonferroni correction was applied to the standard *p*-value threshold of $p < 0.05$; therefore, the threshold was set to $p < 0.01$ for aesthetic measures and $p < 0.005$ for emotional measures. Effect sizes were also calculated using Cohen's D statistics; [0.2–0.5] was associated with a small effect size, [0.5–0.8] with a medium effect size, and ≥0.8 with a large effect size [50]. The analyses were performed using SPSS Statistics for Windows (Version 28, IBM).

## 3. Results

*3.1. Sample Characteristics*

From the initial 50 recruited participants, 7 participants in the group with SMD were excluded as they were not stable enough to complete the required tasks (i.e., worsening psychotic symptoms). Therefore, the study sample comprised 43 participants, 23 of which were diagnosed with a mental disorder: schizophrenia (N = 9), schizo-affective disorder (N = 4), major depressive disorder (N = 8), and bipolar disorder (N = 2). The sample included 23 women (53.5%) and 20 men (46.5%); the mean age was 35.5 ± 9.6 years, and participants were mostly Caucasians (81.4%) and employed (62.8%) (Table 1).

**Table 1.** Baseline sociodemographic and clinical characteristics (n = 43).

| Characteristics | Mean (SD) or n (%) | |
|---|---|---|
| | Healthy Subjects (n = 20) | Participant with SMD (n = 23) |
| Age (years) | 35.89 (12.32) | 37.70 (6.91) |
| Sex | | |
| Male | 4 (20.00) | 16 (69.57) |
| Female | 16 (80.00) | 7 (30.43) |
| Ethnicity | | |
| Caucasian | 14 (70.00) | 18 (78.26) |
| Others | 6 (30.00) | 1 (21.74) |
| Relationship status | | |
| Single | 10 (50.00) | 17 (73.91) |
| In a romantic relationship | 10 (50.00) | 6 (26.09) |
| Education | | |
| High school not completed | 0 (0.00) | 8 (34.78) |
| High school completed | 1 (5.00) | 6 (26.09) |
| College or trade school completed | 9 (45.00) | 7 (30.43) |
| Bachelor's degree | 4 (20.00) | 2 (8.70) |
| Master's or doctorate degree | 6 (30.00) | 0 (0.00) |
| Currently employed | 20 (100) | 9 (39.10) |
| Diagnosis | | |
| Schizophrenia | 0 (0.00) | 9 (39.13) |
| Schizo-affective disorder | 0 (0.00) | 4 (17.39) |
| Bipolar disorder | 0 (0.00) | 2 (8.70) |
| Major depressive disorder | 0 (0.00) | 8 (34.78) |

SD: standard deviation; n: number of participants; SMD: severe mental disorders.

*3.2. Comparisons of VR Platforms in All Subjects*

As presented in Table 2, several statistically significant differences were observed in favour of the new platform compared to the previous (current) one. Indeed, the new VR platform elicited a better sense of presence ($p = 0.002$), improved avatar realism ($p < 0.001$), improved voice realism ($p < 0.001$), improved lip synchronization ($p < 0.001$), and a better global experience relative to the current VR platform ($p < 0.001$). The effect sizes were large when looking at voice realism and the global experience. Finally, no significant differences were observed in the emotions elicited by both platforms.

**Table 2.** Comparison of outcomes for the current and new VR platforms in all participants.

| | Current Platform | | | New Platform | | | Comparisons | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Median | Q | N | Median | Q | Z | *p* Value | Cohen's d |
| Sense of presence | 42 | 69.5 | 56–76 | 42 | 73.0 | 75–83 | −3.1 | 0.002 * | 0.520 |
| Avatar realism | 43 | 6.0 | 5–7 | 43 | 6.0 | 6–8 | −3.4 | <0.001 * | 0.574 |
| Voice realism | 42 | 3.0 | 1–5 | 42 | 5 | 4–7 | −4.9 | <0.001 * | 1.035 |
| Lip synchronization | 38 | 4.5 | 2–6 | 42 | 7.0 | 5–8 | −3.7 | <0.001 * | 0.693 |
| Global experience | 42 | 65.0 | 50–73 | 42 | 75.0 | 70–80 | −4.1 | <0.001 * | 0.756 |
| Emotions | | | | | | | | | |
| Interested | 42 | 4.0 | 4–5 | 42 | 4.0 | 4–5 | −1.3 | 0.196 | 0.199 |
| Excited | 42 | 3.0 | 1–4 | 42 | 3.0 | 2–4 | −1.0 | 0.332 | 0.134 |
| Upset | 42 | 1.0 | 1–1 | 42 | 1.0 | 1–2 | −0.4 | 0.666 | 0.023 |
| Nervous | 42 | 1.0 | 1–2 | 42 | 1.0 | 1–2 | −0.8 | 0.417 | 0.102 |
| Attentive | 42 | 4.0 | 3–5 | 42 | 4.0 | 3–5 | −1.2 | 0.227 | 0.190 |
| Irritable | 42 | 1.0 | 1–1 | 42 | 1.0 | 1–1 | −0.2 | 0.813 | 0.037 |
| Ashamed | 42 | 1.0 | 1–1 | 42 | 1.0 | 1–1 | −1.4 | 0.166 | 0.216 |
| Guilty | 42 | 1.0 | 1–2 | 42 | 1.0 | 1–1 | −1.7 | 0.090 | 0.268 |
| Afraid | 42 | 1.0 | 1–2 | 42 | 1.0 | 1–1 | −1.4 | 0.166 | 0.216 |
| Hostile | 42 | 1.0 | 1–1 | 42 | 1.0 | 1–1 | −0.7 | 0.480 | 0.042 |

N: number of participants; Q: quartiles (25–75th); Z: Z-values; *: statistically significant ($p < 0.05$).

### *3.3. Comparison of VR Platforms in Healthy Subjects*

As presented in Table 3, statistically significant differences were observed in favour of the new platform in 20 healthy subjects. Indeed, the latest VR platform elicited higher scores for avatar realism ($p = 0.008$), voice realism ($p < 0.001$), and lip synchronization ($p = 0.007$). Moreover, trends towards a better global experience and global sense of presence were observed, with $p$-values slightly above the set threshold with the Bonferonni correction ($p = 0.011$ and $p = 0.035$, respectively). Of note, the differences in voice realism and lip synchronization yielded large effect sizes. Finally, like in the entire sample, no significant differences were observed in the emotions elicited by both platforms.

**Table 3.** Comparison of outcomes for the current and new VR platforms in healthy subjects.

| | Current Platform | | | New Platform | | | Comparisons | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Median | Q | N | Median | Q | Z | *p* Value | Cohen's d |
| Sense of presence | 20 | 73.5 | 55–79 | 20 | 74.0 | 65–88 | −2.1 | 0.035 * | 0.552 |
| Avatar realism | 20 | 5.8 | 4–7 | 20 | 6.0 | 6–7 | −2.6 | 0.008 * | 0.702 |
| Voice realism | 19 | 2.0 | 0–4 | 19 | 5.0 | 4–7 | −3.7 | <0.001 * | 1.519 |
| Lip synchronization | 18 | 5.0 | 2–6 | 18 | 6.5 | 5–8 | −2.7 | 0.007 * | 0.833 |
| Global experience | 20 | 65.0 | 50–71 | 20 | 74.0 | 70–80 | −2.5 | 0.011 * | 0.675 |
| Emotions | | | | | | | | | |
| Interested | 20 | 4.0 | 3–4 | 20 | 4.0 | 4–4 | −1.0 | 0.317 | 0.224 |
| Excited | 20 | 2.0 | 1–4 | 20 | 2.0 | 3–4 | −1.0 | 0.329 | 0.199 |
| Upset | 20 | 1.0 | 1–2 | 20 | 1.0 | 1–3 | −1.9 | 0.058 | 0.457 |
| Nervous | 20 | 1.0 | 1–2 | 20 | 1.0 | 1–2 | −1.0 | 0.327 | 0.234 |
| Attentive | 20 | 4.0 | 3–5 | 20 | 4.0 | 3–4 | −0.8 | 0.453 | 0.171 |
| Irritable | 20 | 1.0 | 1–2 | 20 | 1.0 | 1–1 | −0.7 | 0.48 | 0.156 |
| Ashamed | 20 | 1.0 | 1–1 | 20 | 1.0 | 1–1 | −0.4 | 0.705 | 0.083 |
| Guilty | 20 | 1.0 | 1–1 | 20 | 1.0 | 1–1 | 0.0 | 1.000 | 0.000 |
| Afraid | 20 | 1.0 | 1–1 | 20 | 1.0 | 1–1 | −0.6 | 0.564 | 0.127 |
| Hostile | 20 | 1.0 | 1–1 | 20 | 1.0 | 1–1 | 0.0 | 1.000 | 0.066 |

N: number of participants; Q: quartiles (25–75th); Z: Z-values; *: statistically significant ($p < 0.05$).

### *3.4. Comparison of VR Platforms in Subjects with Severe Mental Health Disorders*

As presented in Table 4, statistically significant differences in favour of the new platform were also observed in 23 participants with SMD, which were comparable with the overall groups of participants. Indeed, the new platform was associated with higher scores for voice realism ($p = 0.001$) and a better global experience than the current VR platform ($p = 0.001$). A trend towards better lip synchronization was observed, with a $p$-value just above the set threshold with the Bonferonni correction ($p = 0.013$). The sense of presence ($p = 0.027$) and avatar realism ($p = 0.026$) were not significantly different between both platforms. The effect sizes were large in terms of voice realism and global experience. Finally, similarly to healthy subjects, no significant differences were observed in the emotions elicited by both platforms.

**Table 4.** Comparison of outcomes for the current and new VR platforms in participants with severe mental disorders.

| | **Current Platform** | | | **New Platform** | | | **Comparisons** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **N** | **Median** | **Q** | **N** | **Median** | **Q** | **Z** | ***p* Value** | **Cohen's d** |
| Sense of presence | 22 | 67.5 | 55–75 | 22 | 73.0 | 64–79 | −2.2 | 0.027 * | 0.480 |
| Avatar realism | 23 | 6.0 | 5–7 | 23 | 6.5 | 6–8 | −2.2 | 0.026 * | 0.499 |
| Voice realism | 23 | 4.0 | 1–5 | 23 | 5.0 | 5–7 | −3.2 | 0.001 * | 0.769 |
| Lip synchronization | 20 | 4.0 | 2–7 | 19 | 7.0 | 6–8 | −2.5 | 0.013 * | 0.610 |
| Global experience | 22 | 67.5 | 54–76 | 22 | 80.0 | 69–91 | −3.2 | 0.001 * | 0.837 |
| Emotions | | | | | | | | | |
| Interested | 22 | 4.0 | 4–5 | 22 | 4.5 | 4–5 | −0.8 | 0.405 | 0.176 |
| Excited | 22 | 4.0 | 1–4 | 22 | 3.0 | 2–4 | −0.5 | 0.654 | 0.094 |
| Upset | 22 | 1.0 | 1–1 | 22 | 1.0 | 1–1 | −0.8 | 0.399 | 0.179 |
| Nervous | 22 | 2.0 | 1–3 | 22 | 1.0 | 1–2 | −2.5 | 0.013 * | 0.614 |
| Attentive | 22 | 4.0 | 4–5 | 22 | 4.5 | 4–5 | −1.0 | 0.317 | 0.213 |
| Irritable | 22 | 1.0 | 1–1 | 22 | 1.0 | 1–1 | −0.3 | 0.739 | 0.070 |
| Ashamed | 22 | 1.0 | 1–1 | 22 | 1.0 | 1–2 | −1.6 | 0.102 | 0.363 |
| Guilty | 22 | 1.0 | 1–2 | 22 | 1.0 | 1–1 | −2.1 | 0.035 * | 0.492 |
| Afraid | 22 | 1.0 | 1–2 | 22 | 1.0 | 1–1 | −1.9 | 0.058 | 0.432 |
| Hostile | 22 | 1.0 | 1–1 | 22 | 1.0 | 1–1 | −1.4 | 0.157 | 0.309 |

N: number of participants; Q: quartiles (25–75th); Z: Z-values; *: statistically significant ($p < 0.05$).

## 4. Discussion

This validation study evaluated whether the new optimized VR platform provided greater realism and a heightened sense of presence than the current Avatar Intervention platform. Through double-blind assessments of 43 participants, the new platform outperformed the current one in avatar realism, voice transformation, lip synchronization, overall experience, and sense of presence. Emotional measures showed no significant differences between platforms.

To date, several studies have focused on technical parameters such as the quality of 3D graphics, the efficacy of technological devices, and the availability of multisensory simulations on the feeling of presence [51–53]. Yet, few studies have evaluated the impact of customization features on the sense of presence. Thus, the comparison of results with the literature is limited. This question is nevertheless of interest in an era where VR and other immersive virtual settings are gaining in popularity. Indeed, evaluating the impact of features on the sense of presence is a first step towards determining whether such advancement has an impact on patient satisfaction and intervention efficacy. Moreover, evaluating healthy subjects and SMD patients separately showed that these features appear to be perceived in a similar manner for all individuals, regardless of their mental health status.

In the new VR platform tested in the present study, avatars displayed a more extensive range of facial expressions, were easier to personalize (e.g., accessories, clothing, cultural diversity), and displayed realistic breath movements and eye blinking. Results showed that the avatars in the new VR platform were perceived as more realistic, consistent with previous studies showing that these elements contribute to avatar realism [33–36]. Lip synchronization was also more realistic in the new VR platform. Thanks to new advances in deep learning algorithms that enable improved lip synchronization by modelling the dynamic complexities of lip movements. In the participants, the area where the most significant improvements were observed is the voice transformation. This result suggests that greater attention should be paid to this element in the future, especially in the case of VR dialogical approaches, which presumably rely closely on the quality of the transformed voice. Finally, enhancements were made to background environments, including adding additional characters in the background and more realistic environments, which may have improved the perceived realism. Coherently with the observed improvements in the realism of the avatars, the voice transformation, and lip synchronization, we observed moderate-to-large improvements in the realism of the global experience and the sense of presence, suggesting that effects may be synergistic. These results could have important clinical implications as the sense of presence appears to be linked to efficacy [7,22]. This could be due to the fact that the addition of multiple features for avatar modelling ensures that the immersive context and the avatars' representation are as close as possible to each participant's reality, which could allow for better transfer of learnings and skills into real-life situations [54,55]. In addition to being part of an era of personalized medicine tailored to patients' needs, a greater appreciation of the overall experience could enhance patient adherence to treatment. Future studies will be necessary to investigate these hypotheses as well as the association between technological advancements and treatment efficacy.

Regarding the evoked emotions, considering that the sense of presence has previously been found to be associated with positive emotions in patients with schizophrenia during Avatar therapy for the treatment of auditory verbal hallucinations, the new platform would be expected to elicit stronger positive emotions as well [22]. The lack of difference between both platforms might be due to a lack of statistical power in the context of a mild effect. Another likely reason is that the two COVID-related scenarios provided by participants were purposely chosen to elicit only moderate emotions so that dialogues could be kept reasonably short; therefore, stronger emotional responses may be necessary to highlight these differences.

The main strength of the current validation study is that both platforms were formally tested in two populations, namely healthy subjects, and participants with SMD. Many studies in the field have tested VR features in the general population [23,33,34,38,56]. Although an initial validation step in the general population is beneficial, the VR features or platforms must be tested in the populations that will eventually benefit from the VR-based interventions. Although some validation investigations have been performed in anxious and autistic populations [57,58], to the best of our knowledge, none has been conducted on participants with severe psychiatric disorders. However, some of the most promising results of VR therapies have been achieved in schizophrenia [13,14,59]. Interestingly, differences in the evoked emotions between platforms were only observed in individuals with psychiatric disorders. This is relevant considering that one of the main assumptions of the dialogical VR interventions is that a certain level of emotion needs to be elicited during therapy sessions so that emotion regulation abilities can be tried and improved [13,16]. Of note, this study allowed for the analysis of many realism aspects that could impact the sense of presence and combined them to develop an improved VR platform. In comparison, most previous validation studies in the field have focused solely on single technical VR elements [23,60–62]. Indeed, the impact of major improvements needs to be tested in order to transform the clinical use of this therapeutic tool. The type of VR platform required to conduct dialogical psychotherapies is inherently complex and necessarily multi-faceted. Thus, in addition to contributing to knowledge about the possible aspects of feeling present in VR, this study was a first step towards improving VR therapies. The next step will be to analyze which components contribute the most to the sense of presence and the overall experience. Future studies comparing the therapeutic benefits of the two platforms will also be necessary.

In addition to the previously listed strengths of this study, a few limitations must be acknowledged. First, the sample was relatively small, which limited the statistical power. Nevertheless, many past studies in the field have included similar or even smaller samples [23,27,33,34,63]. A Bonferroni correction was applied to reduce the likelihood of type 1 errors; however, it must be acknowledged that this could have reduced the number of statistically significant differences. Moreover, it must be noted that the sample size allowed for the observation of multiple significant differences between both platforms, in both groups of participants, in most of the outcome measures, apart from the emotional measures. Finally, despite the improvements in realism and sense of presence, we must acknowledge that the new VR platform might not be readily usable yet. One of the significant technological advances involved in developing the new platform had to do with the technological transfer from gaming to VR for lip synchronization. Even though the realism of lip synchronization was improved, it caused a certain delay for the experimenter (but not the participants) that might compromise the capacity of therapists to entertain a fluid dialogue with psychiatric patients undergoing VR-based therapies. Further technological advancements will be necessary to resolve this issue in the future.

## 5. Conclusions

This study showed that improvements in avatar personalization, voice transformation, lip synchronization, and environment details in the new VR platform improved the sense of presence and the global experience of healthy participants and participants with SMD. Although significant improvements in subjective aesthetics were observed, further work will need to be done to reduce the duration of the feedback delay required for lip synchronization to ensure that the new platform can be used in VR-based clinical interventions. In addition to increasing the sense of presence, ensuring that the immersive context and the avatars' representation are as close as possible to each participant's reality in a clinical setting could be linked to the effectiveness of therapy, as it would facilitate a better transfer of learning to real-life situations. Finally, among the VR elements modified in the new platform, it will need to be determined which elements contribute the most to the increased realism of the global experience and the enhanced sense of presence. Sorting out the most relevant elements will help guide future technological innovation in developing VR platforms designed to administer dialogical psychotherapies.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/biomedinformatics5010004/s1, File S1: the French and English versions of questionnaires and questions developed for the study.

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