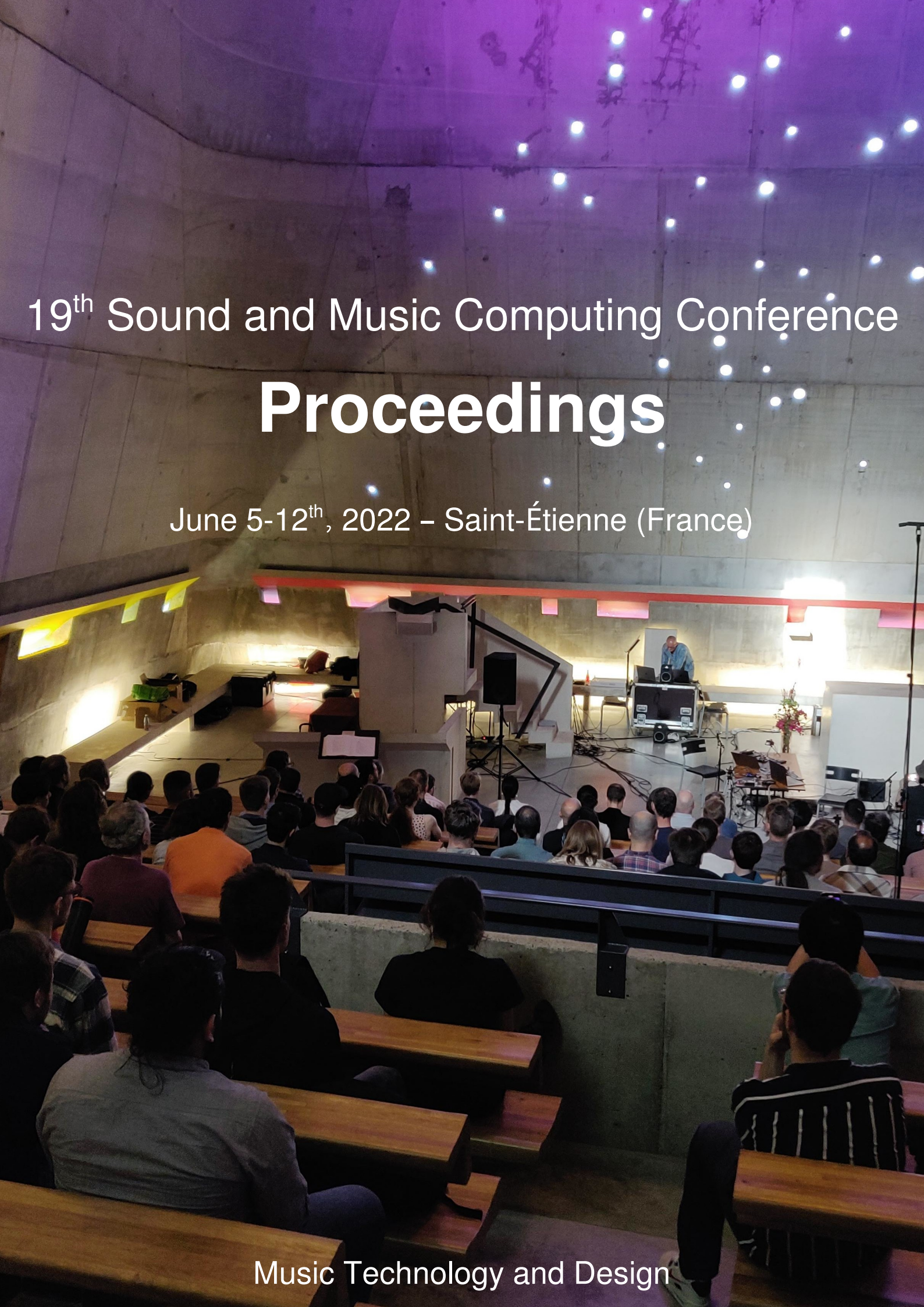

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Exploring the Possibilities of Music Therapy in Virtual Reality: Social Skills Training for Adolescents with Autism Spectrum Disorder

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ABSTRACT

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterised by profound communication and social interaction deficits. It can lead to social anxiety and depressive thought patterns, leaving the individual unable to be a productive member of society. Music therapy is a method that applies musical experiences and the relationships that develop through the sessions to train communication skills, thus addressing one of the core difficulties of ASD. However, music therapy requires musical instruments that are not always easily accessible and can be an anxiety-inducing experience. This paper presents a multiplayer virtual reality application designed to allow a music therapist to help a child develop social skills in a virtual environment through musical activities. The application is designed in collaboration with two music therapists and two psychologists and includes a qualitative evaluation of the application.

1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that is mainly characterised by social communication and interaction difficulties [1]. These deficits can lead to social anxiety [2], isolation [3], and depression [4]. Music therapy (MT) has shown potential in increasing social communications skills in individuals on the autism spectrum [1]. More specifically, MT successfully trains verbal and non-verbal communication, especially if the intervention starts during the childhood of autistic individuals [7].

Compared to verbal stimuli, music-based interventions can increase the child's engagement, attention, as well as their self-esteem [8–10]. However, MT can be a socially anxiety-inducing experience for autistic children [2], as well as time-consuming for the parents, thus risks discouraging families to continue the MT sessions due to not seeing immediate progress [7].

By replacing the users' physical sensory information with virtually created ones, Virtual Reality (VR) can be used to place the users inside a relevant, interactive virtual environment (VE) within which they can receive appropriate interventions [11]. This enables the opportunity to perform MT from the social safety of the user's home and without the need for resources to access physical MT sessions and instruments. So far, most research on VR interventions for autism has focused on training target behaviours through simulated real-life situations [12, 13], including costly or potentially threatening scenarios [14].

However, the potential of VR to extend MT sessions for autistic children by alleviating social interaction difficulties [15], remains largely unexplored. To the authors' knowledge only few VR MT studies have been performed so far [16–18]. Shahab et al. [16] tested a VR environment consisting of a robot avatar and a virtual xylophone with five children, suggesting promising outcomes regarding musical ability and cognitive skills. Bryce et al. [17] exposed four children to a 360° video of a children's choir, but findings were inconclusive. Brungardt et al. [18] conducted a pilot study with 17 patients in palliative care. The intervention received positive feedback and was accepted and found usable by the patients.

When using VR applications for individuals with ASD, approaches have to be individualised according to the specific needs, to increase the overall acceptability [17, 19]. To that respect, involving stakeholders in the design process while offering collaborative designs is advised [19].

This project follows the philosophy of user-centered design [20], meaning that therapists working with autistic individuals on a daily basis are included early in the design process. In this paper, we present the design process and validation of a collaborative MT multiplayer platform that aims at allowing music therapists to perform MT sessions with an autistic child in VR. The overall design process is divided into four segments, which are successively described in the following sections. First, to create the initial design of the VE, an informal preliminary interview was conducted with two music therapists. (section 2). Second, one of the music therapists who participated in the preliminary interview took part in the evaluation of this first design version (section 3). Third, frequent meetings were organised with two psychologists over four consecutive months, to further refine the design and validate the possibility to conduct future testing with them (section 4). All interviews were conducted remotely with respect to the COVID-19 regulations. At last, a pre-test was orchestrated with 25 non-autistic children to validate the possibility to use the developed VR platform in the two real-world clini-

[1] 'Autistic person' and 'person on the autism spectrum' are endorsed terms by autistic adults and stakeholders, i.e., parents [5, 6].

cal settings evoked above with autistic children, i.e., music therapists' and psychologists' sessions (section 5).

2. INITIAL DESIGN PROCESS WITH TWO MUSIC THERAPISTS

2.1 Method for the First Design Iteration

To acquire fundamental knowledge about designing for MT and children on the autism spectrum, initial design guidelines were derived from the literature. In particular, Baltaxe-Admony et al. [21] investigated the reasons behind the deficiency of technology in MT by interviewing six music therapists from around the world. When inquiring about what the therapists were missing from their previous experiences with technological solutions, five design considerations emerged: 1) versatility, 2) ease to travel with, 3) easy to set up, 4) a stand-alone technology, and 5) possibility for data collection. Points 2 to 4 led to choose the Head-Mounted Display (HMD) Oculus Quest 2 for developing the application, as it is wireless, portable, and has relative ease of setting up. Point 1, versatility, was included as a discussion topic for planned interviews. Point 5, data collection, was omitted due to being irrelevant for the time being.

Building on these design guidelines, an interview with two music therapists was conducted to understand their specific needs when working with autistic children. One had a 6-year education in the MT field and 13 years of professional experience, including a diverse clientele. Her typical sessions last around 45 minutes for children and 2 hours for adults. They usually take place at the client's home, and can be individual or group sessions. The second music therapist is a professor with vast experience in researching how MT can be used to help autistic children [22, 23]. The interview lasted about an hour. The researchers asked questions about the design of the VE, the interaction with the instruments, and the possibilities for training social and communication skills.

2.2 Findings from the Preliminary Interview

2.2.1 Designing the Music Activity

The music therapists first suggested making the VE familiar and simple. Thus a classroom was designed, as it is a common location for MT sessions. To make it resemble a typical classroom, items such as a bookcase, a blackboard, school lockers, and a row of school desk chairs were added to the VE.

The instruments should also be familiar while also taking advantage of VR and the ability to make elements that are otherwise not physically possible. Thus, two VR Musical Instruments (VRMIs) were created: a virtual xylophone as the familiar instrument, and *The Looper* as the specific VRMI (Figure 1). Their designs draw upon guidelines outlined by Serafin et al. [24]. In particular, both natural and 'magical' interaction possibilities were added, where the xylophone was promoting natural interaction and the Looper the 'magical'. Other guidelines were considered,

Figure 1. *A view of the classroom. In the front, the play area with the two instruments, the Looper (left) and the xylophone (right).*

such as using appropriate feedback and mapping, implementing for minimal latency, and preventing cybersickness [24]. Last but not least, the experience had to be social, which is also often highlighted in technology-based autism research [19]. To do so, the Looper was inspired by the social interaction occurring during board games. Hence, the therapist and child would both be interacting with the Looper across the table, thus prompting joint attention. At last, the therapist could construct rules such as turn-taking or other rules that can be customised to the child's needs.

The Looper consisted of an oval track with an RGB wave effect to make the instrument salient and attract the child's attention. A small black ball was looping the track, the speed of which could be controlled by adjusting a handle on the side of the Looper. When passing by one of the white dots on the track, a bass drum sound played, functioning as a backbeat. Then, the user could add cubes on the track with different sound modes. When the ball passed through the cubes, they would play a sound and provide visual feedback, consisting of a brief change in colour (white to yellow) and a simple particle system with pink sprinkles. The different sound modes were a snare drum, kick drum, crash cymbal, and a 'wobbling' sound. To support predictability, they are all indicated by fitting icons on the cubes.

To avoid cybersickness, it is advised to minimise the amount of acceleration while being mindful of the locomotion techniques available [24]; continuous locomotion techniques were implemented for a seated experience. To that end, translation was enacted by using the left thumbstick, while a 45° rotation was performed by moving the right thumbstick to the right and left. When initiating movement, the user would instantly reach max speed and likewise stop immediately, avoiding inducing cybersickness. Real-walking was also possible for traversing the VE.

2.2.2 Design of the Avatar

The representation of the player's body can influence the VRMI interaction [24], thus the design of the avatar was discussed with respect to the autistic perception. Some studies have shown improvements in social skills when

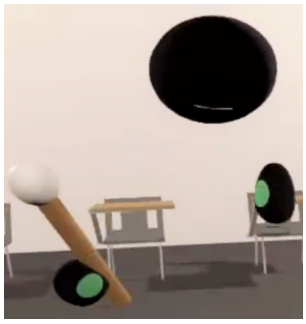

Figure 2. *The default Normcore avatar used to represent the users in the VE.*

using a highly realistic-looking avatar, especially regarding the use of realistic facial expressions [25]. Yet, others find that the individual can struggle when too many stimuli are present, i.e., to recognize and distinguish facial expressions from one another [26]. Moreover, when asked about the avatar design, the therapists were concerned about using a realistic avatar, being potentially intimidating. Because of the conflicting views and with the feedback from the therapists, we decided to utilise the default Normcore avatar, which is a simple iconic-looking avatar (Figure 2), to keep with our user-centered approach. The avatar had a black sphere for the head with a white, smiling mouth. The mouth changed size based on the microphone input. Remotely, the users would see other users' hands as simple mittens to reduce the amount of data needed to be sent and thus the overall latency, which also minimises the risk of cybersickness [24]. Locally, the mittens were exchanged with two five-fingered hand models, created in Autodesk Maya. This change drew upon the VRMI interaction [24] and also aimed at adding avatar-realism, to induce a higher level of perceived presence [27], and thus to increase the ecological validity of the environment that is of importance for social neuroscience.

2.2.3 Implementing the First Iteration

The application was developed in Unity 2019.4.19f1, with the SteamVR plug-in and the multiplayer framework Normcore. With Normcore, the therapist and their client can connect to the same room, which is defined by an app key. For voice communication, Normcore uses a VoIP (voice over internet protocol) that is optimized for minimal latency. This feature can for instance allow the music therapist to also sing with the child during the sessions.

3. EVALUATION BY A MUSIC THERAPIST

This evaluation had two objectives: gathering design insights to improve the application, and validating the potential use of the application in the music therapist's sessions. The following subsections first present the method used, then the experiment's findings, and finally detail the respective design adjustments that were made.

3.1 Method for the Evaluation

A remote VR experiment was conducted with a music therapist from the preliminary interview. Without the opportunity to provide the music therapist with an HMD, the experiment was conducted via videocall, where a researcher shared their view from VR. The therapist was asked to 'puppeteer' the researcher to interact within the VE, and to vocalise her thought about what she saw, in line with the thinking aloud method [28]. The experiment lasted about an hour. Likewise the preliminary interview, the researchers inquired about the design, the interaction with the instruments, and the possibilities for training social and communication skills. Data were analysed with traditional coding; the feedback from the therapist was transcribed and categorised into emerging themes by three researchers [29]. The categories were compared and discussed between the researchers which led to the final categories, from where data was interpreted.

3.2 Findings from the Experiment

Three themes emerged from the data, namely, usability, social interaction, and functionality, as well as seven categories (Table 1). They are described hereafter.

THEMES	CATEGORIES
Usability	• Ease of use • Versatility • Familiarity
Social interaction	• User expression • Clear participation
Functionality	• Instruments • Environmental purpose

Table 1. *Overview of the emerging themes with their definitions and related categories from the experiment with the music therapist.*

Beginning with **usability**, the therapist found the instruments intuitive to interact with and familiar, which could be perceived as reassuring and engaging. Indeed, the xylophone was easily recognisable, and for the Looper, she said "*...even if I had never seen it before, there is still something intuitive and familiar, about this table with this ball that is going around. It kind of reminds [me] of air hockey or something similar. You get an urge to approach [it] and do something with it*". Furthermore, she highlighted the positive effects of the Looper's gaming-like features. Yet, concern about its versatility arose due to the idiosyncratic preferences and needs of autistic individuals, making it potentially too advanced for some children.

In terms of **social interaction**, what contributions each user had made was unclear, possibly hindering the perceived sense of agency. To that respect, displaying more easily distinguishable sounds was advised to better hear one's contributions. Though, she highlighted the strong social potential of the application. For instance, a simple gesture such as asking the other player for a cube that

could be of reach could constitute a great exercise for training social interaction skills. At last, the therapist found the avatar design too simplistic, as only the mouth was reacting to the microphone input, which could be perceived as unsafe. Indeed, facial expressions are important during non-VR therapists' sessions to adapt their behaviour according to the child's state. However, she added still being able to read their client's body language, which is another viable method for understanding their mood, and to adjust the soundscape accordingly.

Regarding **functionality** she warned about potential unnecessary distractions. She specifically mentioned that stacking the cubes could take over the child's attention and be perceived as the main task, thus removing the focus from creating sounds together. Moreover, the colourful items and furniture could also grab the child's attention. Hence, the therapist proposed two solutions: using more neutral colours for the furniture or making the salient items into VRMIs. Regarding this second possibility, the lockers could produce a sound whenever opened, and musical drawings could be created by drawing on the blackboard. Furthermore, the therapist suggested to exploiting more the virtuality of the xylophone, by adding visual feedback or switching colours in line with the different soundmodes of the cubes. At last, regarding the Looper, more soundmodes were desired, as well as simplifying the backbeat and its relation to the white dots on the track more obvious.

The therapist concluded that the application would be used in their sessions with the mentioned adjustments. "*There are some elements that will be lost [in VR], but what other things can we then add? It is the gestures and intuition and mood that we need to compromise because there is something other, that [VR] can do, which is interesting. And it will be exciting to find out what that is. So, it can be an extension of what you otherwise can do in the musical room*". She added being excited to participate in future iterations and tests to discover how to properly use it and maybe to expand the application even more.

3.3 Redesigning the Instrument

Based on the therapist' feedback it was decided to enhance the Looper and remove the xylophone, which was considered unnecessary. To that end, brainstorming sessions were conducted between the authors. This process led to replacing the Looper's track with a railroad, as autistic children often enjoy trains [30]. Hence, a locomotive was used instead of a ball to loop over rails. Gates replaced the cubes to remove attention from stacking the objects. The gates could be placed across the rails so that the locomotive could drive through and activate the corresponding sound and additional visual effect (music notes jumping out from the gate). Authors hypothesised that these changes would make the Looper more usable and discoverable - and thus more adapted to the target group previously described by the therapist in section 3.

In addition to these changes, interaction possibilities were added to provide more control over the created soundscape. The controls are summarised in Table 2. Controllers were assembled in a control panel (see Figure 4). More distinguishable sound modes were also implemented, i.e., marimba, drums, 'magic' sounds (whistle, plings, and whooshes). The VE resulting from this redesign is displayed in Figure 3.

Controller	**Purpose**	**Other feedback**
Lever	Train drives faster/slower.	-
+/- buttons	Volume of the gate sounds is decreased/increased.	Transparency of the smoke is decreased/increased.
Rotator	Pitch of the gate sounds is decreased/increased.	Size of the smoke is increased/decreased.
Whistle	Whistles and the train makes a horn sound.	Smoke colour changes to one of the avatar colours.

Table 2. *Controllers' functions and related feedback.*

4. CONTINUED DESIGN PROCESS WITH TWO PSYCHOLOGISTS

A second design iteration was conducted with two psychologists with two objectives: refining the design according to their specific needs and validating the potential use of this application in their sessions. This section will first present the method that was used, and then the design insights that emerged and led to several design adjustments.

4.1 Method for the Second Design Iteration

The psychologists are autism experts working in a day hospital and use digital tools in their daily interventions (i.e., video games with a projected screen, tablet, and robots). Also, they have previously worked with third author, and thus have experience with evaluating the use of augmented reality technologies in sessions with autistic children [31]. With their expertise and cooperation, future testing with the target group was planned (more about this in section 6.2).

For iterating the VR application, the psychologists participated in three online meetings, where the first author would share their screen to showcase the VR application.

4.2 Design Insights from the Psychologists

Similar to the music therapist's feedback (in section 3), notes were made about the avatar design and the ability to better see each others' contributions. Additional comments were made about the design of the VE, potential interaction and locomotion difficulties, audio effects, as well as the training and introduction to the system for the children. Their different insights are described hereafter.

4.2.1 The Avatar Design

The psychologists suggested making the avatar more expressive. Hence, we added eyes and a nose and made it

Figure 3. *The VE and the interaction stations. Top left to right: the gates, the avatar, and colour buttons. Bottom: the railroad system with control panel on the side.*

Figure 4. *The control panel for the railroad system. From left to right; lever, +/- buttons, rotator, and whistle.*

Figure 5. *The flags on the gates change colours depending on the colour of the player who last interacted with it. Also, to the left; the revised avatar design in red.*

possible to change the avatar colour by pressing one of the colour buttons placed on the wall. The colour allowed to better visualise what contributions each user made. When interacting with one of the gates, the flag on top of the gate changed colour corresponding to the interactor's avatar colour (Figure 5).

4.2.2 Adaptation to Autism Perception

To adapt to the specific autism perception, the psychologists asked to simplify the space and to avoid unnecessary distractions, similar to the music therapists. Thus, only objects meant for interaction were kept (the colour buttons, the gates, the railroad and its control panel). Then, as ASD can lead to mobility issues, the interactions were further discussed. To minimise errors while operating the instrument, big buttons and handles were suggested for the control panel. Also, the gates were given a relatively big size and mass, making sure that they would not easily tip over. Psychologists also asked that the session could be performed from a seated position. At last, paying attention to sound modes that the gates are given was deemed important, as people on the autism spectrum typically have difficulties processing sensory inputs [1]. It was then advised to avoid high-pitched sounds, resulting in replacing some of the sounds with low-pitched instruments (e.g., marimba, drums, and rhodes).

4.2.3 Virtuality

The psychologists stressed the importance of using salient elements of virtuality, to help the children to separate the virtual from the real world. Here, the non-realistic avatar and visual effects could serve as useful signals.

4.2.4 Other

The psychologists suggested adding items that the children could break or throw around, as this is common in their experience and could be used for communicating. This was noted as future work. Tutorials for the VR tool were also suggested; however, it was later mentioned to be unnecessary as the therapist could guide the child in the VE.

4.2.5 Implementation of Second Iteration

The application was developed in Unity 2020.3.18f1 for the Oculus Quest 2. The framework used for setting up VR interaction was XR Interaction Toolkit, and Normcore was used to provide multiplayer functionality.

5. PRE-TESTS WITH NON-AUTISTIC CHILDREN

Pre-tests were conducted with non-autistic children to assess their acceptability, usability, and perception of the VR application, We considered that gathering positive feedback about the acceptability and usability of the application with non-autistic children could validate both of the future testing with the psychologists.

5.1 Method for the Pre-tests

A parent from author's professional network invited his child's class to visit the *Multisensory Experience Lab* at Aalborg University in Copenhagen. In connection with the visit, the 25 children (age 9) were recruited as proxy participants for evaluating the VR artefact. The children came

in groups of 4 or 5, accompanied by their respective teachers. Each child was given about 3 minutes to explore the environment alone. They were aided to wear the HMD and asked if the image that they saw was blurred. Based on their answer, the HMD was further adjusted until the child agreed. Children were provided with guidance if they asked questions or stood still. The view from the HMD was streamed to a PC monitor so that the researcher could observe the child's behaviour in relation to their actions in VR.

During the testing, the first author took notes of the child's behaviour, interaction (ease of use), and motivation, both in real life with the HMD, and by looking at the screen. Comments from the other children were also taken into account. As the pre-test mainly aimed at evaluating the acceptability and usability when wearing the HMD, the bias created by the other children observing and commenting on the child testing the environment was considered as not having a non-significant impact.

5.2 Findings from the Observations

Findings suggested that more guidance was needed. This could be done by having a guide with them in VR or including tutorials for the different features.

The need for small adjustments to the control panel appeared; a heavier hinge joint for the lever would decrease the sensitivity of the tempo of the locomotive, and greater rotational sensitivity for the rotator, to decrease the risk of straining the wrist. The sizing of the furniture also had to be decreased, as many children found it difficult to reach some of the items on the tables. Also, to promote cooperation between the users, the size of the railroad had to be reduced so that the ends of the table could be closer. This feature has to be included for future testing with autistic children to prompt the social VR experience.

Some children tried methods to 'break the system', which aligns with psychologists' views about how autistic children would interact with the application. For instance, children threw the gates around the virtual room, which seemed enjoyable to them. Others tried to exit the room, which at times resulted in the virtual player clipping through the walls of the room and in an endless fall. This did not scare the children. It was clear that prevention of clipping through the virtual walls, as well as a reset or 'clean up' button, were needed. Indeed, the alternative would be to terminate the VR experience and restart the app, which could break the flow in the session.

On the technical side, the Oculus Quest 2 did not seem too heavy or uncomfortable for the children. The battery lasted for about 2 hours, which is sufficient for one or two full sessions of MT.

6. DISCUSSION AND FUTURE WORKS

The VR-based MT application presented in this paper is based on feedback from professionals experienced in working with children and adolescents diagnosed with ASD, thereby creating the foundation for future studies investigating its efficiency to increase the social capabilities of the target group. The application allows a child on the autism spectrum to log into an online VE without physically interacting with a music therapist, thereby reducing the risk for social anxiety. Additionally, VR enables the music therapist to access virtual instruments that are not accessible in real life and are potentially easy for an autistic child to interact with.

6.1 Adapting to the Autistic Perception

Both the music therapist and the psychologists encouraged to simplify the VE to adapt to the autism perception. More specifically, only meaningful virtual objects should be kept visible to not potentially catch the child's attention, removing focus from the social interaction.

According to the participating experts, the designed Looper instrument could potentially offer sufficient usability for an autistic child to use - with certain adjustments. Clarifying the perception of what contributions each user had made, was deemed fundamental to facilitate social interaction features (e.g., joint attention). More distinguishable sounds were suggested by the music therapist to feature as the separator of user contributions. This resulted in marimba, drums, and 'magic' sounds (whistle, plings, and whooshes) sounds. In contrast, the psychologists requested low-pitched sounds as these are more easily processed by individuals on the autism spectrum, which were, therefore, implemented for the second iteration. In future work, the sounds could be customised to their preferences and need to allow for a more versatile tool.

Concerning the avatar, all the therapists advocated for using a simplified model rather than realistic. Though, findings from a recent VR study conducted with 7 children with mild autism show improvements in social skills when using highly realistic-looking avatars [25]. We can hypothesize that this contrast may be due to the fact that the therapists in this paper commonly work with children with severe to moderate autism, contrary to this study's participants. This discrepancy calls for further research to evaluate if therapists' needs regarding the avatar design are correlated to autism severity.

It should be noted that there are limitations to the VR system. As mentioned by both music therapists and psychologists, facial expressions can be an important aspect of recognising the child's emotions. With body language being the alternative, as noted by the music therapist, two types of avatars could convey more expressive movements: an avatar with inverse kinematics - and a full-body avatar with additional equipment such as sensors attached to hips and feet. However, with the design consideration of using a stand-alone technology, adding equipment could be an issue, as well as possibly hinder the child's acceptance.

As the psychologists had suggested, it was found that some non-autistic children who tested the application would throw around with the virtual objects or 'break the system' by moving outside the room's boundaries. Such behaviours could indicate a strong excitement or a will to examine the limits of the system. Moreover, the psychologists noted that trying to break the system could be understood in communicative ways and could be beneficial

to incorporate.

6.2 Limitations and Future Works

With the COVID-19 regulations that were enforced during the design process, neither the music therapists nor psychologists could try the VR application for themselves. Thus, additional evaluations must be conducted with the autism experts in VR before an evaluation can be conducted with autistic children.

In a previous augmented reality study [31], before experiencing the VE, the practitioners were worried of feeling enclosed within the HMD and that it would not be adapted for autistic children. However, neither the practitioners or non-autistic children mentioned this in the present study.

It should be mentioned that the application is developed by and in co-operation with non-autistic people. Although the pre-test with school children provided valuable insights, it only considered the perception of non-autistic users. Thus, the VE has not yet been tested with autistic participants and cannot account for potential hypersensitivity that some autistic children display. Especially, the choice of the audiovisual effects generated by an activated gate may receive negative feedback from children on the autism spectrum. While we do not question that practitioners could teach the children how to interact in VR, conducting tutorials with both practitioners and children could help to minimize potential risks due to hypersensitivity. Indeed, it could gradually allow them to get used to the VE or to individualize the VE based on their perception.

Previous work show that VR can prompt social interaction [7–10], yet question remains about the ecological validity of VR interventions. As MT is time consuming and thus require months or years before noticeable results are showing [7, 23], longitudinal studies are necessary to evaluate this question.

This paper focused on designing a multiplayer VR tool to meet the needs of some primary users, i.e., music therapists and psychologists. Future focus will be on whether they can promote social and communications skills by adding the tool in common autism interventions. To that end, the VR application will be evaluated at the day hospital in collaboration with the two psychologists, with six children (+11 years) with severe to moderate ASD. The children will do a 20-minute session once a week over several weeks to assess their acceptability, usability, and the evolution of the social interaction.

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