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► To cite this version:

Valentin Bauer, Tifanie Bouchara Bouchara, Patrick Bourdot. Designing an Extended Reality Application to Expand Clinic-Based Sensory Strategies for Autistic Children Requiring Substantial Support: Participation of Practitioners. 2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), Oct 2021, Bari, France. pp.254-259, 10.1109/ISMAR-Adjunct54149.2021.00059 . hal-03817662

HAL Id: hal-03817662

<https://hal.science/hal-03817662v1>

Submitted on 17 Oct 2022

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Designing an Extended Reality Application to Expand Clinic-Based Sensory Strategies for Autistic Children Requiring Substantial Support: Participation of Practitioners

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ABSTRACT

Extended Reality (XR) has already been used to support interventions for autistic children, but mainly focuses on training the socio-emotional abilities of children requiring low support. To also consider children requiring substantial support, this paper examines how to design XR applications in order to expand clinic-based sensory strategies that are often used by practitioners to put them in a secure state, and how to maximize the acceptability of such applications among practitioners. To that respect, a "Mixed Reality platform for Engagement and Relaxation of Autistic children" was designed and developed, which allows to add audio, visual and haptic individualized or common stimuli onto reality. A first Augmented Reality free-play use case called Magic Bubbles was created based on interviews with stakeholders and on a collaboration with three practitioners. A preliminary study with eleven practitioners confirmed its well-being potential and acceptability. XR design guidelines are finally derived.

Keywords: Autism Spectrum Disorder, design, multi-sensorimotor, augmented reality, mediation, well-being.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality; Human-centered computing—Interaction design—Interaction design process and methods—User centered design; Social and professional topics—User characteristics—People with disabilities—

1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a pervasive neurodevelopmental condition with a worldwide prevalence of around one percent [16]. Autistic people¹ belong to a spectrum, meaning that they display various sensorimotor and cognitive abilities, as well as co-occurring conditions, e.g. attention disorder [16]. Autism is characterized by three main features: social and interaction disorders, focused interests, and sensory disorders. In particular, sensory disorders concern 90% of people over the different sensory channels, including hypersensitivities and hyposensitivities [25]. While some individuals need little support (e.g. to conduct academic work), others need substantial support for performing daily tasks (e.g. being non-verbal and displaying intellectual disability) [16]. This paper uses the terms Autistic requiring Low Support (ALS) and High Support (AHS) to respectively refer to them. Since AHS children often experience distress, this paper focuses on using digital tools to support practitioners' interventions aimed at making them feel secure.

Three complementary clinic-based sensory strategies are often used with autistic children, and in particular AHS children: *Sensory Integration Therapy* [2, 9], *Snoezelen* [15] and *Music Therapy* [17]. They display positive outcomes to put children in an optimal state then allowing to perform challenging tasks (e.g. communication), by

creating a secure context, regarding the physical space and the child-practitioner relationship. In particular, *Sensory Integration Therapy* posits the role of the user's body to integrate multisensory interactive processes so that to gradually enhance cognitive abilities. It relies on playful sensory activities (e.g. swinging or brushing) [2, 9]. *Snoezelen* aims at making the child feel secure and strengthening the dyadic child-practitioner relationship, through multisensory spaces often including bubble columns [15]. *Music Therapy* gathers a broad range of activities. It includes *active techniques* where the child directly makes music, and *passive techniques* where the child listens to the music presented by the practitioner [17]. Yet, challenges appear regarding these three interventions: equipment may not be flexible enough, which may bore the child over the long term; and *Snoezelen* equipment may be too expensive for practitioners to afford.

Extended Reality² (XR) is promising to expand common autism interventions, as proved by recent Virtual Reality (VR) [18] and Augmented Reality (AR) [5] reviews. Indeed, autistic children are often attracted by digital tools [13], and XR allows to display secure, individualizable, and precisely controllable multisensory environments. Moreover, the Head-Mounted Display (HMD) technology is well-accepted by autistic children [26], and may be affordable for health structures. Yet, many practitioners remain reluctant to using XR, due to possible risks linked with over-exposition to screens [14], e.g. risks of addiction [5]. Hence, including practitioners during the design process is advised to maximize their acceptability [23]. This paper adopts such a design process to leverage the HMD potential in order to expand common practitioners' interventions.

Previous XR studies mainly focused on training socio-emotional abilities, leaving sensory strategies unexplored [5, 18]. Thus, they mainly concerned ALS individuals who can work on such skills [7]. Yet, contrary to other mediums (e.g. desktop computer, tablet), XR displays high multisensory immersive capabilities, leading stakeholders to advocate for creating XR well-being and sensory-based strategies [4]. For instance, in Newbutt et al. [20]'s study, 29 autistic children answered "It relaxes me and I feel calm" to the question "What could or would you use VR HMDs for?". To our knowledge, this paper presents the first HMD-based XR design focusing on expanding clinic-based sensory strategies for AHS children.

So far, a few digitally-augmented multisensory environments targeting autistic children have been designed in collaboration with clinical teams, with positive effects over well-being, engagement and the child-practitioner relationship [11, 22, 24]. In such spaces, most physical items were augmented to trigger sensory stimuli based on users' body movements and manipulations. Children could see and act with other people around, including practitioners. While *Mediate* [22] used free-play activities, the *Magic Room* [11] and *Sensory Paint* were mainly task-oriented. In terms of contexts,

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¹This paper uses autism stakeholders' preferences in terms of terminology, e.g. identity first-language, with terms such as "autistic individual" [6].

²Within the Milgram and Kishino [19]'s Virtuality continuum, Mixed Reality (MR) covers systems from Augmented Reality (AR) to Augmented Virtuality (AV). Related to the same continuum, we use Extended Reality (XR) terminology to target not only MR, but also Virtual Reality (VR).

Mediate and the *Magic Room* were conducted in large spaces, and *Sensory Paint* used a projected screen, a tangible ball and a Kinect camera. Yet, since these bespoke projects were designed for specific clinical contexts, they may not be suitable for stakeholders due to their low portability and potentially expensive price [23]. Thus, this paper leverages the XR multisensory potential to expand them by using the affordable and portable HMD technology.

The main contribution of this paper is to offer insights about the design of XR applications which aim at expanding clinic-based sensory strategies that are commonly used to make AHS children feel secure. To explore this under-studied aspect, it presents the design of the HMD-based XR application called *Magic Bubbles* which was developed with the Mixed Reality platform for Engagement and Relaxation of AHS children (MiRERA). The iterative design process conducted in collaboration with practitioners is first detailed. Then, a user study carried out with eleven practitioners is presented, which led to design improvements. XR design guidelines are finally derived. This paper addresses two research questions:

- RQ1: According to practitioners, how to design XR applications in order to expand clinic-based sensory strategies which are commonly used with AHS children?
- RQ2: How to maximize practitioners' acceptability of XR applications which aim at complementing clinic-based sensory strategies for AHS children?

2 DESIGN PROCESS WITH PRACTITIONERS

The initial XR use case is first presented, and then its adaption and development for a clinical context in collaboration with practitioners.

2.1 Methodology

A first use case scenario emerged from interviews that were conducted with 34 autism stakeholders, i.e. 29 practitioners, 4 autistic people and/or their families, and 1 researcher [4]. It aims at calming and engaging AHS individuals through a free-play multisensory interaction space, drawing from Sensory Integration Therapy, Snoezelen, and music-therapy interventions. Two main technological possibilities were imagined, i.e. VR vs. AR environments. The latter allowed to adjust the proportion of real and virtual elements based on the practitioner's needs. To be adapted to a real-life clinical context, this main use case was then presented to two psychologists and one psychiatrist. All of them are autism experts working in a day hospital and use digital tools in their daily interventions. This approach thus follows presumptive design principles [10], i.e. speeding up the design process by presenting advanced ideas to help practitioners to validate them and generate new ones. In addition to discussions, and also to better understand the specific needs of autistic children, the first author attended three solo sessions and two group sessions conducted by the psychologists and using digital tools (tablet, projected screen, robot), which included three AHS children.

2.2 Initial use case

2.2.1 Environment

Two types of stimuli are presented, i.e. generic and individualized. Generic visuals are bubble columns, moving audio bubbles, and water ponds. Indeed, interviews with stakeholders [4], the project called *Magic Room* [11], and the positive outcomes of the Snoezelen approach [15] suggest that autistic children often like bubbles and bubble columns. Bubbles emerge from water ponds, then explode and reappear, since appearing/disappearing patterns are often appealing [4]. All visuals are simple geometric shapes for simplification purposes [7]. Generic audio stimuli are short musical sounds (e.g. marimba, percussions), inspired from previous studies [11], interviews with stakeholders [4] and music-therapy activities [17].

Individualized stimuli are used to create a secure space with familiar objects. Hence, a pink "music" bubble can host the child's preferred music tracks, and an "image" panel can host visuals, e.g. drawings. The practitioner has to add them prior to start the session.

Four sensory interactions are available: psychomotor, audio, visual, and tactile with the controllers' vibrations. Children can move in space and touch virtual objects by using the controllers and/or their body [3]. To prompt exploration, moving in space changes the environmental lighting color, drawing upon the audio floor in *Mediate* [22]. Interactions do not require hitting the controllers' buttons, due to possible fine motor skills disorders. Hitting objects can trigger five types of reactions: (1) audio bubbles to trigger their bubble sounds; (2) bubble column to change the color of all columns and panels, in line with the *Impression Wall* in *Mediate*; (3) panels to change the sounds of the bubbles; (4) ponds to trigger a water splash; and (5) music bubble to trigger the individualized music. Simple feedbacks also show that actions are taken into account, by using controllers' vibrations and/or hovering the surface of objects.

Objects are organized according to their roles to create clutter-free scenes with little information [7]. They are identified by using simple shapes and colors, as displayed on subfigures 1 A, B, C, D, and include the: bubble columns, audio bubbles, water ponds, panels, music bubble, and image panel. The number of bubbles, panels and columns, can respectively be adjusted from zero to eight, three, and three. To give a sense of agency, a yellow dot shows the direction of sight [12]. A gradual real-virtual transition helps to prevent anxiety by making the virtual space neutral at the start/end of the experience. To prompt collaboration, children can always see the practitioner (i.e. directly or through an avatar), who can remain physically close to them and use physical guidance. At last, foam carpets delimit the interaction space to enhance comfort and structuration.

2.2.2 Activities

Free-play or task-oriented activities were imagined. Free-play activities consist in a free exploration of the interaction space, and were advised in the interviews previously conducted [4]. Task-oriented activities have intended outcomes, and draw from common interventions (e.g. sound lotos³) and prior studies [11].

2.2.3 Practitioner's Interface

Practitioners can monitor and adjust all stimuli at the start or at run-time, or even stop the experience, through a User-Interface (UI) on a large screen (see subfigures 1 E, F). In particular, the UI allows to: add/remove objects (orange), trigger stimuli (green), add/remove simple feedback (blue), and display contextual information (grey). Feedback include controllers' vibrations, since tactile hypersensitivity is a common autistic trait, and a visual timer to support predictability. Contextual information for instance concerns the time spent while using the application. To prompt exploration, the UI can also be used to trigger unexpected events [1].

2.3 Use case adaptation for a day hospital context

To adapt the initial use case for a day hospital context, practitioners made design requirements leading to changes summarized in table 1.

2.3.1 Environment

To prevent sensory overloads, the speed of the bubbles in the column was decreased. Their size and speed were made controllable by stooping/standing, or using the practitioner's UI. To enhance sensory stimulation and generate surprise, a rectangular panel was added to trigger sounds from the controllers with two short melodies created on purpose. To clarify the structuration of space, psychomotricity cones were added to delimit the interaction space.

³Sound lotos are listening games used to identify daily noises, e.g. animals or objects.

Table 1: Practitioners' needs about using XR at the day hospital

Categories	Needs from the practitioners (<i>Change Adopted (A); Already Planned in the existing design (AP)</i>)
Environment	<p><i>Collaboration</i>: The child can perceive the real environment and act with his/her practitioner. (A)</p> <p><i>Meaningful environment</i>: The virtual space has to be connected to the real space and to the other child's activities. (A)</p> <p><i>Practitioner's role</i>: Practitioners can provide physical guidance. (AP)</p> <p><i>Sensoriality</i>: The child can move, perceive controllers' vibrations, and possibly interact without controllers. (AP)</p> <p><i>Common autism guidelines</i>: The environment has to be individualized, fun, and predictable. (AP)</p> <p><i>Sense of agency</i>: The child/practitioner can control the speed and size of the bubbles. (A)</p> <p><i>Little information</i>: Movements have to be slow and only a few objects with clear roles have to be displayed. (AP)</p>
Activities	<i>Free vs. Directed Play</i> : Free-play activities are preferred for AHS children. (A)
Practitioner's UI	<i>Practitioner's Interface</i> : Practitioners can monitor and adjust all environmental stimuli. (AP)
Equipment	<i>Equipment</i> : Equipment has to be affordable, resistive, portable, non-tethered, and allow to remove the earphones. (A)

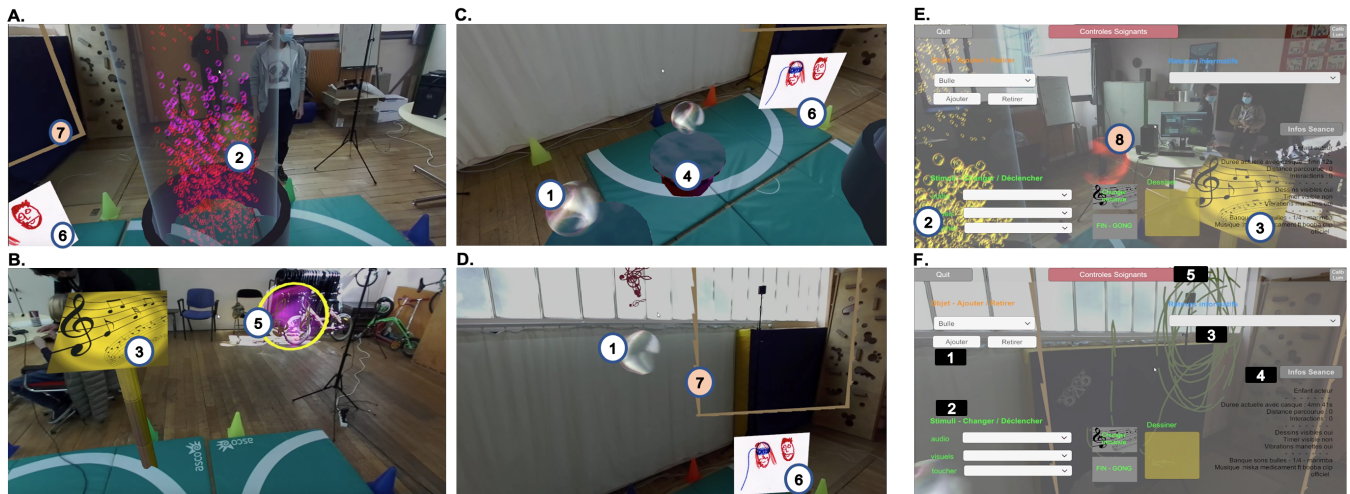


Figure 1: Design of *Magic Bubbles* Game – Content: 1 Bubble; 2 Bubble Column; 3 Panel; 4 Water Pond; 5 Music Bubble; 6 Image Panel; 7 Drawing panel (added after the user testing); 8 Recording Bubble (added after the user testing) – Practitioner's UI (E,F): 1 Add/Remove objects; 2 Trigger stimuli; 3 Add/Remove simple feedback; 4 Display contextual information; 5 Show/Display the UI.

2.3.2 Activities - Actor vs. Spectator conditions

Free-play AR activities were chosen to best suit AHS children, make the environment meaningful, support collaboration, and make a smooth transition between real and virtual spaces. In this context, a psychologist specified that it was not a problem for the child to see the practitioner's monitoring screen, and may even be reassuring.

Two conditions were added, i.e. *spectator* or *actor*, drawing from passive and active practices in Snoezelen and music therapy interventions. When spectator, the child can move in space, but not interact with objects. All stimuli are triggered by the practitioner and/or automatically. When actor, the child can move in space and interact with all virtual objects. The practitioner can only physically guide them, and trigger stimuli when supporting their actions.

2.3.3 Practitioner's Interface

As the UI suited most practitioners' needs, only a small change was added to support visibility. Indeed, the buttons "Controle soignant" and "Infos Seance" were respectively added to show/hide the main pane and only see the child's view, and to show/hide the informational pane (see subfigures 1 E, F).

2.3.4 Equipment

Equipment choices are detailed in section 2.4, and were mostly driven by the possible behaviours of AHS children, e.g. aggressiveness, or covering their ears with their hands. Since autistic children

are often used to wear protection headsets, wearing an HMD was considered to be possible for most of them. For the others who may display tactile hypersensitivity, using a gradual sensory habituation to the HMD may be needed to allow them to wear it.

2.4 Apparatus & Development

Magic Bubbles uses the AR see-through platform called MiRERA, which means that a stereoscopic camera is plugged onto the HMD, captures a live feed of the real environment, and then makes it visible inside the HMD, supplemented by virtual objects. The HTC Vive Pro headset was chosen with a Zed Mini camera⁴ to get a non-perceivable visual latency of 60ms, a correct resolution of 720 p per camera, and an immersive 90° horizontal Field of View (FoV). The front cameras of the HTC Vive Pro were previously tried but abandoned because they achieved lower results in terms of resolution and latency, being possibly detrimental for autistic children. Other HMD see-through devices were excluded because they displayed a narrower horizontal FoV, e.g. 52° for the HoloLens 2⁵. While bandwidth technical limitations did not allow to use non-tethered AR, practitioners still preferred using tethered AR rather than non-tethered VR. Indeed, perceiving the real surroundings and practitioner was a major requirement, and alternatives such as including the practi-

⁴<https://www.stereolabs.com/zed-mini/>

⁵<https://www.microsoft.com/fr-fr/hololens>



Figure 2: Left: AR setting at the day hospital - Right - a practitioner testing the application.

tioner's face inside a VR environment on a virtual television screen was deemed impossible for some children who would misunderstand the link between the image and practitioner. The total weight of the system of 563g was not considered to be a problem for autistic children aged more than 11 since it was well accepted in Newbutt et al.'s study [20]. Two HTC Vive controllers are used. Four Vive lighthouse outside-in tracking systems cover the interaction space to avoid tracking loss due to the practitioner being close to the child. Hence, trade-offs were made regarding the portability of the system in relation to its other features. The HMD runs on a desktop computer Dell Precision 3630, with i7 CPU, 32Go of RAM, and the Nvidia Geforce RTX2080. A 27-inch screen allows to monitor child's activities while being far from it.

A video presentation of the software, consisting in a screen capture of the practitioner's UI while hiding the main pane when the application is running, can be found online⁶. Development was done using Unity3D software, Google Resonance Audio for the 3D audio rendering, Steam VR SDK for the AR handling, and ZED SDK to work with the ZED Mini camera. A game control script allows actions to be triggered by the child or practitioner, by handling the main features (e.g. visible/hidden aspects) based on state machines which manage the states of objects. It communicates with other managers: audiovisual manager to handle all audiovisual aspects; player manager to handle user movements and interactions; log manager, which writes in external files the actions of the child and practitioner. Every object sends events to the corresponding manager if an interaction occurs. Unity physics engine handles all collisions.

3 EVALUATION WITH A CLINICAL TEAM

Pre-tests were conducted with a team of practitioners at a day hospital through two sessions (i.e. pre-test 1 and 2), including nine practitioners who did not participate to the initial design process. This pre-study was required to: validate if the application was consistent regarding their interventions with AHS children, gather design insights to refine the application, and get their approval to then be able to work with AHS children. This section first presents the demographics and method used, and then insights which emerged about the user experience and design.

3.1 Participants

Participants include eight women and three men: educators (n=5), clinical psychologists (n=2), co-head of the day hospital (n=1), nurse (n=1), secretary (n=1), and psychology intern (n=1). Two had little XR experience with VR games. Four were 20-30 years old, three were 30-40, one was 40-50 and three were 50-60. Seven participants did the pre-test 1, and the four others did the pre-test 2.

3.2 Method

3.2.1 Protocol

Only the actor condition was tested, since this pre-study mainly targeted the suitability of the existing design and interactions used

⁶Link to the video presentation: valentinbauer.com/research/doctorat/

for AHS children, as well as possible improvements to that respect.

Practitioners freely tested the application during five minutes or more, in the psychomotricity room of the day hospital (see figure 2). To observe their discovery of the space, no detailed explanation about how the environment works was given prior to start. The two psychologists who participated to the initial design observed their colleagues during the testing, to: think about new AR needs with respect to AHS children; imagine how they could guide the children wearing the HMD; and precise the observable parameters that could be used to assess the state of the children. Due to the sanitary Covid situation, a strict cleaning protocol was used: face masks kept during the experiment, equipment cleaned between participants using disposable wipes, windows regularly opened, and two sessions with different participants separated by ten minutes at least.

3.2.2 Data collection and analysis

During the experience, subjective insights were gathered about the practitioners' experience, through note-taking of their behaviors and comments (the three last sessions were filmed), i.e. smiles/laughs, movement quantity, or type of movements. After the experience, seven semi-directed questions addressed demographics (i.e. age, profession, past XR experience), user experience (i.e. feeling of connection with the real space, comfort, feeling of dizziness), and preferences (i.e. object preferred). Three final open questions concerned: general feelings, possible design improvements, or additional elements that practitioners would like to say.

A descriptive qualitative analysis allowed to identify phrasings and observations representing key aspects of the user experience. They were then grouped into concepts drawing from the prior grounded theory analysis of the interviews conducted with autism stakeholders [4]. The number X of participants mentioning each concept will be mentioned inside parenthesis using (n=X).

3.3 User experience: Subjective results

All participants enjoyed the experience, which was spontaneously compared to Snoezelen (n=4), even if two of them were anxious prior to start. All participants liked hitting the bubbles, which were the preferred elements along with the water ponds. A psychologist said: "you can play squash if you send the bubbles strong enough against the cupboard". Participants were often surprised, and smiled/laughed when realizing that they could interact with elements.

Most participants felt connected to their real surroundings (n=10), even if they were concerned about feeling "enclosed" in the virtual space prior to start. Hence, this experience reassured them about future testing with AHS children, and made a psychologist confirm that AR has more potential to be accepted by practitioners than VR. Some behaviors suggested a possible feeling of presence (n=4): one participant made a bubble bounce on a psychologist and asked "did you see it?"; two participants hit the ponds with their feet; and one participant described being "in another world".

Sensorimotor behaviors vary between participants, from being very stiff to moving a lot (stooping, jumping etc.), with the whole body being engaged. The experience can potentially be hypo or hyper stimulating, depending on its use with children (n=9).

Most participants felt comfortable with the device (n=8), apart from three of them who: found it heavy (n=1), perceived a discomfort on the nose (n=1), or due to their face mask (n=1). A psychologist ensured that "these issues are not a problem with children since they would directly express [non-verbally] their discomfort if they have any". One participant felt a bit dizzy at the end, due to the HMD not being screwed enough, thus making the image a bit blurry.

3.4 Design insights from practitioners

The insights about the suitability of the design for AHS children are first detailed. Then, the insights which were integrated to improve the application are mentioned, and are summarized in table 2.

Table 2: Design insights from the testing with practitioners

Concept	Participant proposals
Structuration	Connect all sessions with drawings (n=4) Use a gong sound to end the sessions (n=3) Hide the chaperone (n=7)
Sensoriality	Only interact with controllers (n=3) Vary interactions with the bubbles (n=3) Simplify action-reaction principles (n=3) Prevent from entering inside the column (n=1)
Agency	Add recording possibilities (n=3) Add drawing possibilities (n=4)
Equipment	Pay attention to the wire of the HMD (n=11)

3.4.1 Suitability of the design for AHS children

Psychologists who participated to the initial design found consistent the use of a screen to monitor what the child perceives. Indeed, since they remembered the positions of virtual objects in the real space between sessions, they deemed it suitable to guide children. They also stressed to always keep the same number of elements due to the ritualization of children. To that respect, a basic setup with three bubbles, one bubble column and one panel appeared to be a good trade-off in terms of number of elements. All participants noted that attention has to be paid to the wire between the computer and HMD, so that to not hinder the child. Since non-tethered AR could not be used due to technical constraints (see section 2.4), they again stressed that tethered AR was better suited than non-tethered VR.

3.4.2 New design insights

To support structuration, we added the possibility at the end of the session for the child to make a real drawing that would then be included in the image panel for the next session. The psychologists who participated to the initial design said that it could connect sessions by “leaving traces that they will see again”, offer a sense of agency, ritualize sessions, and may allow to infer the child’s experience. Thus, hitting the image panel was added to navigate through all of the drawings. We also added a gong sound that the practitioner can trigger to announce the end of the sessions. Also, the grid boundaries of the interaction space (i.e. chaperone) were removed after pre-test 1, as they were described as a “prison” (n=7).

About sensoriality, only controllers’ interaction was kept after pre-test 1, since it was more intuitive than body interaction. Three types of interaction were added to the simple “hit” for the bubbles to make children more aware of their movements’ velocity: grabbing, throwing, or exploding them. The panel which was used to change the bubbles’ sounds was removed after pre-test 1, because it did not display a clear action-reaction relationship. Though, sounds can still be changed through the UI. Making the bubbles disappear when approaching the column was also added to prevent over-stimulation.

To give a sense of agency, one recording and one playback bubbles were added to the actor condition after pre-test 1. They allowed to hear back one’s voice as in some appealing video games for autistic children (n=1), e.g. *Talking Tom Cat* [21]. As simplifying action/reaction principles was advised during pre-test 2, only one bubble was finally kept for both actions. Drawing on a large panel was also added after pre-test 2, with controllers or through the UI.

4 DISCUSSION & RECOMMENDATIONS

In the two first subsections, findings are discussed to address: how to design XR applications to expand clinic-based sensory strategies with AHS children, according to practitioners (RQ1), and how to maximize practitioners’ acceptability (RQ2). Table 3 summarizes the main findings. Limits and perspectives are then discussed.

4.1 XR design guidelines to support sensory strategies

As in the previous XR multisensory designs focusing on well-being [11, 22, 24], practitioners recommended to include the possibility for the child to act and collaborate with them, so that to reinforce the child-practitioner relationship. Hence, an HMD-based AR see-through system was chosen to maximize immersion while perceiving the practitioner and real surroundings. This paper suggests that AR is well-suited to support clinic-based sensory strategies for AHS children, whereas VR could possibly isolate them. Thus, it extends the AR cognitive-behavioral potential previously outlined [5], “to cope anxiety, fear and phobias in social situations” [26].

Practitioners insisted on using free-play activities with AHS children, to provide room for playful and creative experiences, as in the project called *Mediate* [22]. Indeed, contrary to other multisensory projects [11, 24] which focused more on task-oriented games, our design choices came from three causes: users are AHS children; practitioners have a psychoanalytic background, and encourage emergent behaviors to arise to then work on them; free-play connects with other mediation activities used at the day hospital. Hence, *Magic Bubble* could be considered as a *malleable medium*, i.e. a concept commonly used by practitioners to describe open-ended sensorimotor mediation activities, which includes the materials, digital devices, and the practitioner [8]. To our knowledge, this is the first HMD-based AR design for mediation purposes with AHS children.

A secure multisensory AR space was designed to handle the variety of autistic sensory profiles. To this end, the design process was informed by the overall clinical context of the children. This led the psychologists who participated to the initial design to consider the *Magic Bubbles*’ environment as potentially *holding*, i.e. a concept commonly used by practitioners to describe a nurturing space for generating and supporting exchanges with the practitioner [27].

Whereas *Magic Bubbles* supports various interaction types as in previous multisensory projects [11, 22, 24], it is the first to our knowledge to be such flexible and adaptable to clinical contexts, in line with stakeholders’ needs [23]. This feature is particularly due to the affordability and portability of HMD technology. Hence, the platform only uses audiovisual interactive elements and no smart objects to be quickly mounted/dismounted in spaces where permanent installation would be impossible. With the current development of HMD technology, these features will become even more prominent in the next few years. The impact of mainly using audiovisual elements on the child’s experience will have to be assessed in comparison with previous projects which mainly used tactile inputs.

4.2 Maximizing practitioners’ acceptability of XR

Whereas most practitioners had no previous XR experience, *Magic Bubbles* was well-accepted. They were engaged and agreed to future testing with AHS children. While being concerned about feeling “enclosed” prior to start, because non-appropriate for AHS children, they felt connected with their real surroundings during the experiment. To that respect, this is the first paper to our knowledge which suggests that AR is more suited than VR to expand clinic-based sensory strategies with AHS children, according to practitioners.

Table 3: Main design insights for using XR with AHS children

RQ1	<ul style="list-style-type: none"> • Use AR rather than VR to prompt collaboration • Use free-play activities • Make the general context secure • Use flexible and portable XR designs
RQ2	<ul style="list-style-type: none"> • Use AR rather than VR for clinical contexts • Consider XR as other mediation tools • Design XR applications within clinical contexts • Use XR in controlled environments to prevent any risks

The acceptability of *Magic Bubbles* is also due to the fact that it complements other sensory-based mediation activities at the day hospital, e.g. painting, theatre, music making, or video games. In particular, the success of such mediation activities is due to the sensory qualities of the medium in relation to the child sensorimotor abilities, and child-practitioner relationship [8]. Hence, AR is well suited to extend them due to its multisensory potential.

The psychologists who participated to the initial design were enthusiastic, as the project would then be used in a real-life clinical context. Indeed, they stressed that most technology-based approaches are currently tested in laboratories, which raises possible concerns about: biases due to the strong ritualization of AHS children, and non-adaptability of such designs within real-life clinical contexts. While XR reviews [5, 18] do not clearly mention which studies were conducted in clinical contexts, this paper suggests to take more into account the ecological context when designing autism studies.

Contrary to many practitioners who still remain reluctant to using technology-based approaches [14], practitioners from our study stressed that using XR with AHS children may be positive if used in a controlled way. Hence, they advise using XR within a secure context, i.e. under the control of a practitioner and with a time limit.

4.3 Limits and Work in Progress

Only practitioners' feedback were gathered because the Covid-19 pandemic prevented us from conducting tests with AHS children at the time of this design process. Then, only subjective insights were collected to gather information about the user experience and existing design. At last, gradually asking questions to practitioners about ideas that emerged over time could have offered further insights.

Magic Bubbles is currently being evaluated at a day hospital in collaboration with practitioners, with seven AHS children, i.e. six boys and one girl, aged more than 11. Experimental procedures were approved by the Pol  this Ethics Research Committee of Universit   Paris-Saclay under reference 226. Children do the 20-minute experience once a week over six weeks, four being actor and three being spectator. Indeed, practitioners deemed that the evolution between spectator and actor conditions could otherwise be frustrating.

ACKNOWLEDGMENTS

We would like to thank all the practitioners who tested the application, and particularly Marie-No  lle Cl  ment, Olivier Duris, and Charlotte Labossiere for their valuable design insights. This work was supported by a MESRI Funding from Universit   Paris-Saclay.

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