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Experimenting in virtual reality with an autistic public having language and intellectual development disorders: lessons learned and recommendations

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The possibility of virtual reality (VR) to immerse vulnerable individuals in safe and controlled environments is very attractive for training and assessing sensorimotor and cognitive skills. However, experimentation with a public with various cognitive and perceptive disorders raises ethical, ergonomic and scientific questions. In this paper, based on experiences with autistic adults with intellectual and language disorders, we provide feedback and recommendations for designing and testing a headset-based VR system for this specific population.

CCS CONCEPTS • Human-centered computing ~ Human computer interaction (HCI) ~ HCI design and evaluation methods ~ User studies • Human-centered computing ~ Accessibility ~ Accessibility design and evaluation methods

Additional Keywords and Phrases: Autism Spectrum Disorder (ASD), Virtual Reality (VR), Developmental Language Disorder (DLD), Ethics

1 INTRODUCTION

The "PII Hip-XP" collaborative research consortium aims to accompany young adults with autism and communication disorders towards a shared inclusive housing, in a perspective of autonomy and social skills. This inclusive housing project addresses the subjective well-being of the users in an anthropocentric, collaborative and systemic approach, where psycho-sensory accessibility issues come into play. It is based on a multidisciplinary approach centered on the users (autistic residents, special educational needs teacher, caregivers...), recognized as experts thanks to their experiential knowledge [8]. It is a matter of structuring a strong research community, capable of interdisciplinary work and closely connected to the sectors of activity concerned, particularly health, education, and compensatory technologies. One of the objectives of the project is the use of virtual reality (VR) artifacts to support educational strategies for a vulnerable public with Autism Spectrum Disorder (ASD), Intellectual Development Disorder (IDD) and Developmental Language Disorder (DLD) [13]. Indeed, whereas the literature on the use of VR for mental health as well as for “high functioning” autism is abundant, only a very few VR works addresses a comorbid population with these three deficiencies (ASD, IDD, DLD).

The use of VR is motivated here by the possibility for autistic residents to perform sensorimotor and cognitive activities that help empowerment in a controlled and safe environment. In addition, VR can allow for individualized consideration of the specific sensory perceptions of the person with autism, prevalent to exogenous stimuli [20]. The perceptual-motor and perceptual-cognitive systems are overwhelmed by a too rapid flow of information [4, 18]. By minimizing the intensity of acoustic and visual flows, slowing down images and speech rate, immersive technologies can promote a decrease in

behavioral disturbances and cognitive availability conducive to learning [19]. However, due to an alteration of the cognitive, relational, or physical faculties of the so-called "vulnerable" persons [21], a double problem arises:

- on the one hand, how to conceive an ethical immersive experimentation with an autistic public with specific linguistic and psycho-sensorial percepts?
- on the other hand, how to allow a scientifically valid data collection within modular and evolving scenarios, in permanent adaptation to the particular needs of users with a high degree of vulnerability?

2 FIELD OF STUDY AND METHODOLOGY

2.1 Population and context

The study cohort consists of 8 young adults (4 males, 4 females, mean age 23 years) with moderate to severe ASD, IDD and DLD. 6 out of 8 subjects cannot read and write. Clinical assessments of the subjects were based on several diagnostic scales specific to ASD: AMSE - Autism Mental Status Exam [11] (see Table 1); VINELAND-II adaptive behavior [5]; CPS-R Sensory Profile [18].

Table 1: ASME scores of the population

ITEMS (2)	POPULATION MEAN	P1	P2	P3	P4	P5	P6	P7	P8
EYE CONTACT	0.6	0	0	1	2	0	1	0	1
INTERESTS IN OTHERS	0.4	0	0	0	1	0	1	1	0
POINTING SKILLS	0.4	0	0	1	0	0	1	0	1
LANGUAGE	1.0	1	1	1	1	1	1	1	1
PRAGMATICS OF LANGUAGE	1.6	1	1	2	2	1	2	2	2
STEREOTYPY	2.0	2	2	2	2	2	2	2	2
ENCOMPASSING PREOCCUPATIONS	1.6	1	2	1	2	1	2	2	2
TOTAL/14 (TSA IF >5)	7.6	5	6	8	10	5	10	8	ç

These young adults currently live in a closed housing facility for adults with disabilities and are accompanied in their daily lives by a dedicated medical-social team. The participatory project aims to improve inclusion and autonomy of the

autistic residents, accompanied by their caregivers and teachers, and it is not part of a clinical research project. A legal consent from the guardianship has been obtained to allow the participation of autistic people.

2.2 Virtual environment

For a first experimentation, a virtual kitchen was designed in order to assess the acquisition of some motor and cognitive abilities involved in the daily use of a kitchen (preparation of simple meals, washing up...). This means that the virtual environment has not been designed as an exact reproduction of the reality but as an “enabling” environment where affordances are adapted to the psycho-sensory functioning of the population [6, 9].

The kitchen was implemented in Unity for use with a Meta Quest 2 Head Mounted Display (HMD) with hand tracking. Navigation in the kitchen is reduced to 3 degrees of freedom in rotation and interactions with objects are based on pointing with a raycast and launching predefined actions by a pinch. In view of the needs of the autistic non communicant participants, and in close relation with the experiential knowledge of the project team, different elements of remediation have been put in place to alleviate certain specificities of the autistic public. These elements are presented in Table 2.

Table 2: Issues and remedial solutions for the design of a VR system for autistic individuals

Issues	Remedial solutions
- Loss of balance with HMD	- Sitting position on a rolling chair with feet on the floor
- Exit from the safe VR area	- Physical guidance
- Difficulty to use controllers	- Hand tracking and hand interactions
- Heavy helmet and hypersensitivity	- Headgear
- DLD and non reader	- Oral guidance
- Fear	- External screen for VR streaming
- Difficulty to rotate / blocking behavior	- Oral & physical guidance
- DLD and silent attitudes	- Pictograms for consent
	- External screen for VR streaming
- Hypersensitivity	- Sensory break space inside VR environment (= window on garden)
- Concentration deficiency	

2.3 Virtual environment

The virtual kitchen environment was tested with the autistic adults in 14 sessions between June 2021 to July 2022 (Figure1). Once immersed and accustomed to the virtual environment, the subjects were accompanied in the realization of a series of tasks allowing the simple preparation of a meal: to take the prepared dish in the refrigerator, to reheat it in the microwave in a plate, to set the table with the forks and the spoons, to throw the waste in the dustbin.

During the VR tests, some experimental data were collected. The complete sessions were video recorded from the user point of view in VR and from an external point of view in the real room. Head positions and rotations as well as events (test start / end, interactions with VR objects) were recorded during the experiment. In addition, the experimenter manually coded success / fails for the different tasks requested and the pointing capabilities.



Figure 1: Experimental setup including external screen and third-party guide.

3 EXPERIENCE FEEDBACK AND DISCUSSION

From the first tests conducted with the young autistic adults, we discuss here some important points for conducting scientific experiments with vulnerable public with ASD, IDD and DSD in VR.

3.1 Guidance and modular scenario

In "classical" scientific experiments involving user testing, the protocol is often based on a defined and fixed scenario in order to facilitate data collection and comparison between different subjects. This scenario is often given in the form of written instructions, to be followed without external help.

For the activity of people with cognitive disorders, previous studies recommend a guidance [2]. We have thus set up this physical and oral guidance which allows to accompany the subject throughout the scenario and to adapt the instructions to the behavior and reactions of the participant. This requires expertise of the third-party guide in autism and a pre-existing inter-knowledge of the participant and the guide in order to maximize the trusting relationship. The installation of an external screen during the experimentation appeared essential for the guidance. It allows to visualize in synchrony what the participant is looking at. The third-party guide can thus support his activity as well as possible.

This guidance also implies an adaptation of the scenario focused on the user, fully considered as an interactive subject [3]. The initial scenario was therefore modulated and re-constructed in an iterative and incremental way throughout the experiments, allowing the experimenter to repeat the instructions, to help with the completion of a task, to move on to another task after failure or blockage, etc.

3.2 Experimental context and enrollment

For a non-communicant audience with autism, it is essential that the context of experimentation be designed in an "enabling" affordance: an environment where "the resources of the environment and those of the individual interact" [6, 9]. Thus, we carried out the experiments in their living environment, and they were integrated into daily activities in a room open to all. For this population, it is not possible to run tests at fixed timeslots in spaces dedicated to experimentation as user-labs.

In people with autism, engagement in the activity is intimately dependent on their personal interests. Upstream, downstream, and within the VR environment itself, reinforcers related to their interests and life project can support their motivation and attentional capacity; otherwise, engagement in the activity is likely to be minor or completely absent.

In addition, the use of the external screen also allowed the other participants to capture the entire scene and enter into intersubjective observation and imitation. Imitation, as advocated in the literature, is one of the levers of learning for autism [15] and, in our study, it promoted participation for all residents with autism (Figure 2).

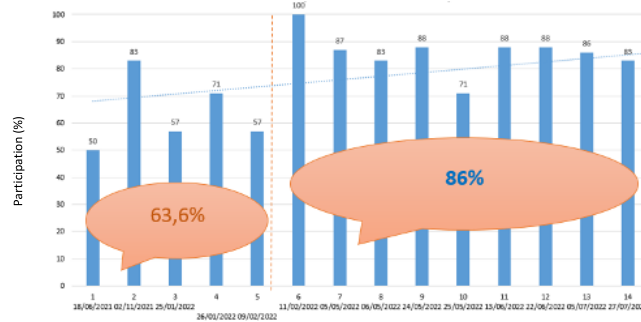


Figure 2: Differences in terms of participation before (left) and after (right) introducing an external screen in the living room during the experiments

3.3 Consent and self-determination

For ethical reasons, the assent of the participants is sought before the research begins, from the users themselves, their families or guardians. However, "it is advisable not to take for granted the consent obtained: do not lock the individual into a previous choice and make sure that the consent is up to date" [21]. To respect this principle of self-determination, different elements have been put in place.

First of all, it is the autistic participant who makes the choice of the third party who will accompany him or her. It is then the responsibility of this "third-party guide" to verify the effective agreement of the participant, before and during the immersive trial. In order to overcome the subjects' communication deficits, a pictogram system (Figure 3) was designed and implemented in the VR environment. These are presented to them before the VR session. Participants are free to point to any of the pictograms at any time during the experiment or after the actual request of the guide to continue or not. Because some people with autism suffer from echolalia or have great difficulty in reversing, the repetition of the request during the test is important.



Figure 3: The pictogram system used to collect the effective agreement of the participants.

Finally, the sensory resting space, here designed as a window on the garden that limits the sensory stimuli when viewed (Figure 4), allows participants to withdraw from the course of action at any time.



Figure 4: The sensory resting space, a window to a peaceful outer world.

3.4 Visual attention and behavioral analysis

Visual attention is essential in VR. Yet, it is often found to be deficient in people with autism. Difficulty in visually following a dynamic target has been observed [4], as has a deficit in joint attention, subsequently affecting the quality of social cognition [1]. Joint attention, an essential skill for understanding social situations, can then be the object of particular support, by soliciting communicative gestures, such as pointing to something [14]. In VR, it is therefore necessary to pay particular attention to the design of interaction metaphors based on pointing such as ray-casting, which must be adapted to the individuals' own abilities and allow them to strengthen their attentional skills (Figure 5).

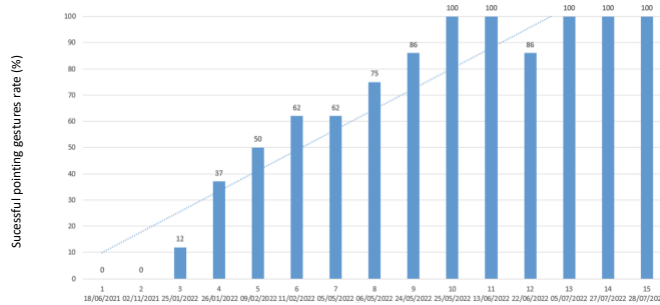


Figure 5: Evolution of the rate of successful pointing gestures throughout the different trials.

Eye-tracking analyzes are of particular interest in the study of the autistic population. They highlight a specific visual exploration style characterizing people with ASD: little or no eye contact [16], peripheral gaze, focus on details [12]. However, the deficit of visual tracking of dynamic targets indicated above makes the calibration phase of eye tracking system very difficult and must therefore be rethought. Also, the analysis of head postures or foveal gaze, "traditionally" used as a variable of attentional presence deserves to be reconsidered with regard to the mechanisms specific to autism.

Motor stereotypies are common hyperkinetic disorders in ASD [10] whose main characteristics are that they are involuntary, predictable, rhythmic, and repetitive: hand waving, body rocking, etc. Some of the motor effects related to these stereotypies can be filtered in VR to stabilize actions [7] and improve interactions [17]. At the analysis level, it is also important to develop indicators adapted to these stereotypies and their occurrence during the studied mechanisms.

4 CONCLUSION

Based on a collaborative and interdisciplinary project to support young adults with ASD, IDD and DLD toward shared inclusive housing with virtual reality (VR) artifacts, we addressed ethical, ergonomics and scientific issues for experimenting in VR with this vulnerable population. The feedback and recommendations discussed in this paper may be useful in designing and testing immersive and interactive systems for an audience with a variety of cognitive and perceptual disabilities.

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