Virtual Reality Multiplayer Experiential Training: Guiding People with Autism towards New Habits

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***Abstract*—Individuals with Autism Spectrum Disorder, at a certain point in their lives, may spend their days in Day Activity Centers. Approaching this habit for the first time is an everyday life change that can often be confusing and overwhelming. To support people during this transition, we propose a virtual reality application based on an immersive and interactive digital twin of an existing center in the city of Torino, Italy. In the virtual environment, users can try several times the experience before facing it in the physical world, following an experiential training approach, with the goal of making the adaptation smoother and alleviating anxiety. In virtual reality, users can explore the space and perform some of the activities available in the center, guided by a virtual avatar, that is controlled by a caregiver. In the current work, we report a preliminary system validation to assess usability by considering several factors, including user experience, sense of presence and negative effects. Our findings suggests positive scores for all the considered parameters.**

***Index Terms*—Virtual Reality, Autism, User Experience, Sense of Presence, ASD, Experiential Training**

I. Introduction

People presenting Autism Spectrum Disorder (ASD) are characterized by a series of impairments in social interaction and communication, along with repetitive patterns of behavior and restricted interests that begins early in life [1]. Virtual Reality (VR) offers multiple advantages for individuals in the spectrum [2], [3]. First, VR experiences can be designed ad-hoc to avoid an excess of stimuli and discomfort [4]. Second, VR allows users to repeat the experience as many times as needed, following an experiential training approach [5]. Third, individuals in the spectrum learn better when visual-spatial information is given [5], which can be easily achieved with VR applications. Last, individuals in the autism spectrum are generally tech-savvy [6], which means they are often familiar with the daily use of technology, enabling them to engage well with VR. Furthermore, according to Bozgeyikli *et. al.*, people in the spectrum ”are stated to have an affinity to technology and a strong visual memory” [2]. In Italy, there are numerous Day Activity Centers (DACs) that offer a variety of activities for individuals with ASD. However, joining these DACs for the first time can be challenging for them due to their issues related to social anxiety [7]. To address this, we propose a VR system that consists in a one-to-one reproduction of an existing DAC, allowing guests to familiarize themselves with the environment in a safe and controlled virtual scenario before their actual visit. We partnered with the DAC ”Il Margine” [1] in Torino, Italy, which hosts every day several people in the spectrum, to reconstruct their environment in VR. The goal of the project, named ”Knock Knock. It’s open” is to investigate the concept of ”gentle accompaniment” towards the center, which consists in allowing users to explore a virtual version of the spaces several times before visiting the actual center. However, while several projects propose an experiential training approach for people with ASD in different scenarios [8]–[10], to the authors’ knowledge, no one is focused on DACs. The innovative side of this project consists of a combination of design factors, that include creating a one-to-one replica of the environment, the opportunity to engage in activities within the virtual DAC, and the possibility for a caregiver to join the experience in a multiplayer session.

RQ: This project aims to reproduce a real existing DAC as a 3D collaborative environment and investigate whether the VR tour can alleviate the anxiety associated with the real-world visit for people with ASD. Additionally, we aim to examine the potential for skill transfer from tasks performed within the virtual center to their real-world reproduction.

In the current work, we present the project, focusing on the VR application design and development, together with a report of a preliminary system validation based on user experience and sense of presence. On top of that, as an original contribution, we investigated the experience of the user towards the interaction with the virtual avatar of the caregiver, that plays the role of the guide.

II. Related works

Autistic people who use VR, in particular Head Mounted Displays (HMDs), reported strongly positive experiences (see Dechsling *et al.* for a review [11]), with over 80% positive HMD-based VR experiences across 155 studies examined. Several studies also showed that VR may also facilitate the training of social skills for ASD people [12]–[14]. Kourtesis *et al.* performed a VR system validation by considering several factors, including user experience, usability and acceptability.

[1] https://www.ilmargine.it/

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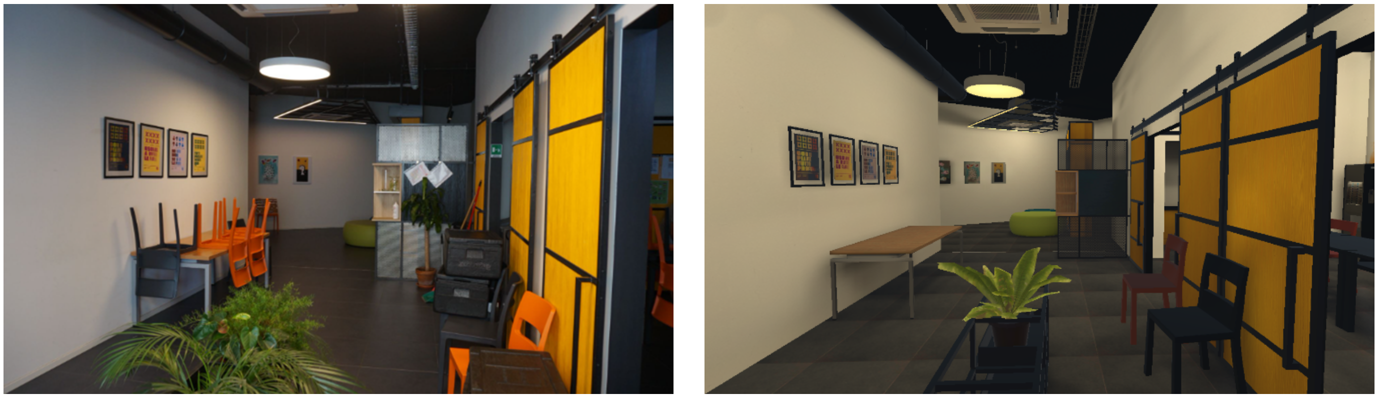


(a) (b)

Fig. 1: Real (a) and 3D reproduction (b) entrance of the day activity center.

(a) (b)

Fig. 2: Real (a) and 3D reproduction (b) silk-screen printing machine room of the day activity center.

In particular, the VR application allows ASD people to experience five real life scenarios activities (being at the gym, buying a smartphone at the phone store, going to the cinema to watch a movie, attending a seminar class and attending a job interview). Users reported encouraging outcomes on all considered categories [15]. Shaji *et al.* [16] randomly select ASD users for social skill training in VR or in real life. While both groups showed significant improvements in social interaction, participants expressed a preference for VR social skills training. Several studies showed that VR can provide a successful transfer of skills in everyday life for neurotypical people [17]–[21]. For example, Schmidt *et al.* employed VR training to help ASD children acquire street-crossing skills in real life. Results indicated successful transfer in the real environment scenario [10]. Many works aimed also to reduce the anxiety of people in the spectrum with the help of VR. Soccini *et al.* [8] provide a VR experiential training system that allows users to try several times an airport scenario before facing it in real life. Furthermore, Newbutt *et al.* [9] report that, during the COVID-19 pandemic, an HMD-based VR tour of an autism-specific school was developed in the UK, to help alleviate pressures of entering the real school once back to everyday life. However, this system consists of non-interactive 360° videos and does not include any multiplayer features.

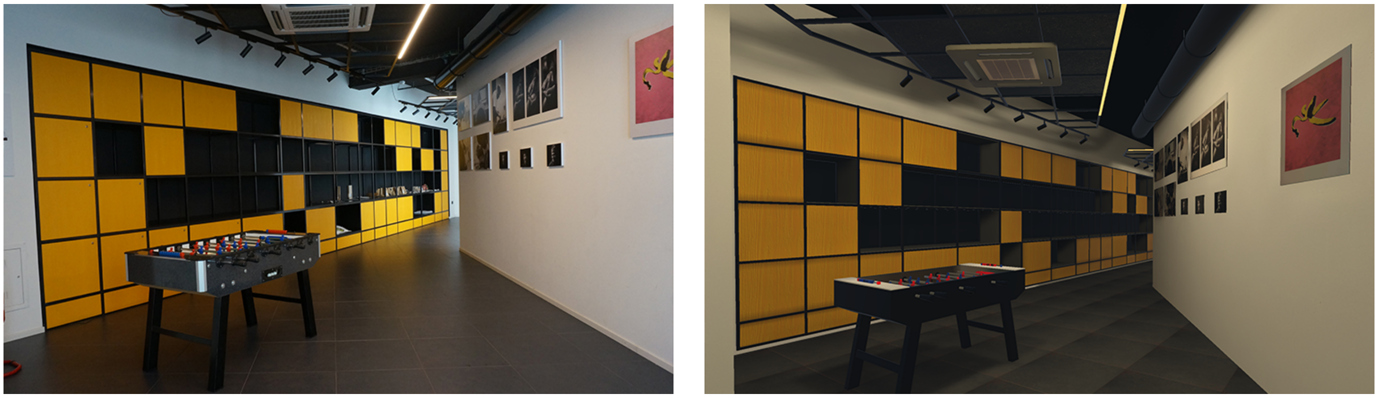
III. Project

A. Designing for people with ASD

We developed a VR application for helping individuals with ASD familiarize the environment of a DAC (Figures 1 and 3). ASD people may feel overwhelmed by the quantity and difficulty of the proposed tasks. Furthermore, they may find the experience with unknown people or in an unfamiliar environment more stressful. Addressing these issues, we present below the guidelines we followed in the design and development of the VR experience.

1) Simplification of Environments: To reduce sensory input to the users, preventing potential overwhelming [4], we aimed to reconstruct the virtual DAC with high fidelity while eliminating unnecessary elements in the rooms. For example, the virtual reproduction of the entrance (Figure 1b) presents fewer objects than the real one (Figure 1a) (e.g. boxes, sheets and chairs have been removed in the virtual scenario).

2) Task Abstraction: We abstracted real-life tasks by reducing the complexity and number of actions required to complete an activity. For example, the actions required for using the



(a) (b)

Fig. 3: Real (a) and 3D reproduction (b) of the hall of the day activity center.

silk-screen printing machine were simplified into four steps: 1) selecting the t-shirt design, 2) placing the shirt on the silkscreen machine, 3) applying the ink with a spatula and 4) drying the t-shirt with a thermal gun (Figure 2).

3) Natural Gestures Interaction: The interaction with virtual objects is designed as an abstraction of real-life movements [22], following a natural gestures interaction approach, i.e. users can perform gestures in a way that is similar to what they would do in the physical world.

4) Use of Animations: Several studies suggested that 3D animations are particularly effective for individuals in the spectrum [23]. For this reason, the proper action is suggested through 3D animation before the actual execution. For example, before using the silk-screen printing machine, some 3D animations suggest to users how the actions should be performed.

5) Navigation via teleportation: Movements in the 3D environment are based on a teleportation locomotion system. This design choice is a current standard in VR navigation of large spaces, and it is suitable to reduce the frustration that complex controls may cause for individuals with ASD [24].

6) Familiar Environment: Experiencing a VR DAC in a familiar environment was shown to be more suitable for individuals with ASD rather than experiencing it in real life [25]. A standalone VR device enables users to visit the VR environment without any location constraint. Additionally, using a headset connected to the computer via cables was reported to create safety concerns [26].

B. System

The VR application consists of a digital replica of the DAC "Il Margine". To design a 1-to-1 representation of the real environment we used as reference a 3D model captured through photogrammetry obtained with Autodesk Recap Photo 2023[2]). Then, the 3D model was designed with Autodesk Maya 2023[3] and the game mechanics were implemented with Unity3D[4] (version 2022.3). Within the virtual environment, users are represented through an avatar, provided by Meta Avatar SDK[5]. This package provides hand-tracking and face-tracking features to easily map their movement and facial expressions on a virtual avatar. Moreover, it allows to personalize the appearance of the avatar with several ready-to-use skins and clothes. A multiplayer feature was implemented to guide them through the new virtual environment as a caregiver using Unity Gaming Services[6]. In particular we chose to use Unity Relay[7] to establish a connection between users and Unity Netcode[8] to synchronize avatars and objects movements in real-time. On the hardware side, Meta Quest series[9] HMDs were used. The main benefit of these headsets is the standalone mode. In the proposed scenario, users can freely explore the virtual environment and interact with several objects. The virtual tour could be guided by an avatar remotely controlled by an operator (caregiver).

IV. Methods

While the design of the application followed several guidelines related to autistic users, we found it opportune to first validate the system with few users from a generic public to have an overall initial feedback. We defined an experimental design that consists of an exploration of the environment and an interaction with the virtual objects. The selection process was carried on to match the age and gender distribution of the target group of the individuals with ASD the system is addressed to. Seven volunteers with no diagnosis of ASD (2 females and 5 males between 26 and 35 years old) took part in the experiment.

The experience was structured as follows:

1) **Tutorial:** user familiarize with the self-avatar, the teleportation locomotion technique and the virtual caregiver;

[2] https://www.autodesk.com/products/recap/overview
[3] https://www.autodesk.it/products/maya/overview
[4] https://unity.com/
[5] https://developer.oculus.com/documentation/unity/meta-avatars-overview/
[6] https://unity.com/solutions/gaming-services
[7] https://unity.com/products/relay
[8] https://unity.com/products/netcode
[9] https://www.meta.com/quest

TABLE I: VRNQ questionnaire.

N	*Question*
User Experience	
1	What is the level of immersion you experienced?
2	What was your level of enjoyment of the VR experience?
3	How was the quality of the graphics?
4	How was the quality of the sound?
5	How was the quality of the VR technology overall (i.e. hardware & peripherals)?
Game Mechanics	
6	How easy was to use the navigation system (e.g. teleportation) in the virtual environment?
7	How easy was to physically move in the virtual environment?
8	How easy was to pick up and/or place items in the virtual environment?
9	How easy was to use items in the virtual environment?
10	How easy was the 2-handed interaction e.g., grab the tablet with the one hand, and push the button with the other hand?
In-Game Assistance	
11	How easy was to complete the tutorial(s)?
12	How helpful was/were the tutorial(s)?
13	How did you feel about the duration of the tutorial(s)?
14	How helpful were the in-game instructions for the task you needed to perform?
15	How helpful were the in-game prompts e.g. arrows showing the direction, or labels?
VRISE	
16	Did you experience nausea?
17	Did you experience disorientation?
18	Did you experience dizziness?
19	Did you experience fatigue?
20	Did you experience instability?

TABLE II: SUS questionnaire.

N	*Question*
1	Please rate your sense of being in the virtual environment, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place.
2	To what extent were there times during the experience when the virtual environment was the reality for you?
3	When you think back about your experience, do you think of the virtual environment more as images that you saw, or more as somewhere that you visited?
4	During the time of the experience, which was strongest on the whole, your sense of being in the virtual environment, or of being elsewhere?
5	Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements.
6	During the time of the experience, did you often think to yourself that you were actually in the virtual environment?

TABLE III: Avatar Guide Questionnaire.

N	*Question*
1	Did you feel like you were there with someone else?
2	Did the avatar contribute to your overall enjoyment of the VR experience?
3	Did the avatar facilitate your interaction with the environment?

2) **Objects interactions:** users are asked to place and arrange chairs in different rooms according to their colour to test the interaction system;
3) **Guided tour:** users are guided by the caregiver in an exploration of the various rooms of the DAC.

At the end of the experiment, participants were asked to fill out three questionnaires: Virtual Reality Neuroscience Questionnaire (VRNQ) [27], Slater-Usoh-Steed Questionnaire (SUS) [28] and Avatar Guide Questionnaire. The VRNQ questionnaire includes questions related to user experience, game mechanics, the quality of in-game assistance and Virtual Reality Inducted Symptoms and Effects (VRISE) (reported in Table I). The SUS questionnaire (Table II) is related to the sense of presence. Additionally, we investigated participants' reactions to the virtual avatar through the Avatar Guide Questionnaire, that is our original contribution (Table III). In all questionnaires, responses are given on a Likert scale from 1 to 7, where 1 means "Not at all" or "Extremely low", and 7 stands for "Very much" or "Extremely high". For each item i of all questionnaires, we calculated the mean score μ_i and standard deviation σ_i of all the responses $s_{u,i}$ given by user u on question i, for all the n participants (Equation 1).

$$\mu_i = \frac{1}{n}\sum_{u=1}^{n} s_{u,i} \tag{1}$$

Furthermore, in the VRNQ questionnaire, we calculated the mean value μ_c and standard deviation σ_c for each item i in category c (Equation 2).

$$\mu_c = \frac{1}{m}\sum_{i=1}^{m} \mu_{i,c} \tag{2}$$

As SUS and Avatar Guide questionnaires do not include any sub-category, they were considered as a single category.

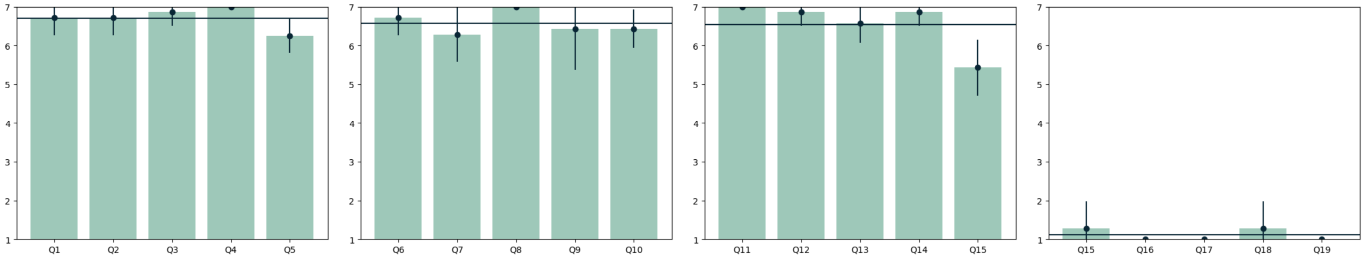
V. Results

We hereby report the results of the system validation. In general, users reported a positive feedback for all the evaluated parameters. Results related to the single questions are shown in Figure 5 and Figure 4, while Table IV reports the mean values (μ) and standard deviations (σ) of the responses given by all the users per questionnaire and per topic.

The results reveal that no VR inducted symptoms or negative effects were reported (VRISE $\mu = 1.11$, $\sigma = 0.28$).

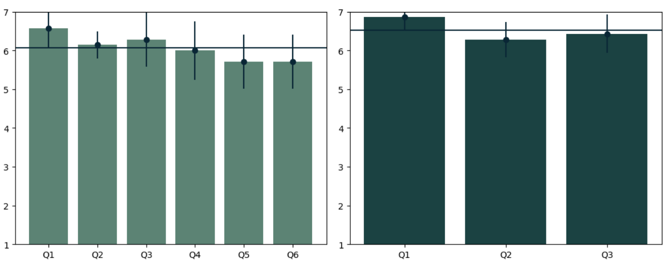
TABLE IV: Mean (μ_c) and standard deviation (σ_c) of the responses to the questionnaires.

Questionnaire	*Category*	μ_c	σ_c
VRNQ	User Experience	6.71	0.34
	Game Mechanics	6.57	0.54
	In-Game Assistance	6.54	0.39
	VRISE	1.11	0.28
SUS		6.07	0.62
Avatar Guide		6.52	0.43



(a) User Experience (b) Game Mechanics (c) In-Game Assistance (d) VRISE

Fig. 4: VRNQ results. Mean (μ_i) and standard deviation (σ_i) of each item of the questionnaires are provided. The horizontal line shows the mean score for each category (μ_c).



(a) (b)

Fig. 5: SUS (a) and Avatar Guide Questionnaire (b) items results. Mean (μ_i) and standard deviation (σ_i) of each item of the questionnaires are provided. The horizontal line shows the mean score for each category (μ_c).

The controls seem well-integrated, and the game mechanics ($\mu = 6.57$, $\sigma = 0.54$) are widely understood. The In-game assistance category also shows positive results ($\mu = 6.54$, $\sigma = 0.39$). However, the score of the final question in this category (Q15) ($\mu = 5.43$, $\sigma = 0.73$) is slightly lower than the others, probably because the guidance is given by the avatar and not provided by explicit instructions (e.g. arrows or panels). The sense of presence was also rated quite high ($\mu = 6.07$, $\sigma = 0.62$). The avatar not only was accepted but also found enjoyable, contributing positively to the overall experience.

VI. Discussion and Conclusions

In this work, we presented a VR system that allows individuals with ASD to join a virtual reproduction of a real Daily Activity Center. We conducted a preliminary system validation to evaluate the suitability for future experiential training. The experiment was conducted on neurotypical users to assess the possible occurrence of discomfort before the actual test on more sensitive neurodiverse users. Our findings seem encouraging as all participants reported great feedback. Furthermore, the interaction with the caregiver's virtual avatar was positively perceived. Considering these results, the experience will be subject only to minor changes, including improving and simplifying the initial tutorial and increasing the number of interactive objects. We expect similar positive outcomes from the experience of individuals with ASD in terms of usability and enjoyment. However, people with communication issues may find it difficult to follow the caregiver's instructions potentially reducing the benefits of the experience. During the design and development of this project, we faced some challenges. In particular, the major difficulties were encountered during the implementation of the multiplayer feature, especially in managing the avatar movements and interactive objects in a shared environment in real-time. The main limitation of this validation process is that it was conducted only on neurotypical individuals. We plan to extend the experimentation to people with ASD to validate the whole principle. We also plan to test the so-called "gentle accompaniment" by repeating the exploration in the real-world DAC to investigate whether the anxiety associated with the real visit can be reduced.

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