Improving the daily autonomy of people with Autism Spectrum Disorder through Virtual and Augmented Reality

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Autism Spectrum Disorder is a developmental disability characterised by cognitive rigidity and communication and behavioural deficits. These deficits negatively impact the lives of people with ASD by making them unable to complete daily activities and even communicate with others. In order to support persons with ASD in their everyday life, facilitate their social inclusion, and improve their quality of life, we developed 5A. 5A provides innovative tools based on smartphones and wearable headsets that integrate Virtual Reality (VR), Augmented Reality (AR), and Conversational Agents (CA). These applications help persons with ASD understand the environmental and socio-organizational characteristics of everyday life scenarios and correctly perform related activities. Experiences in VR allow simulating typical tasks of such scenarios, e.g., taking the subway. When people find themselves in similar situations in real life, AR helps them generalise the skills acquired in VR by superimposing interactive multimedia elements on the view of the surrounding physical world. In both VR and AR, a personalised Conversational Assistant provides prompts and personalised feedback.

CCS Concepts: • **Human-centered computing** → *Virtual reality*; *Mixed / augmented reality*.

Additional Key Words and Phrases: Augmented Reality, Virtual Reality, Public Transportation, Autism Spectrum Disorder

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1 INTRODUCTION

Autism spectrum disorder (ASD) is a developmental disability characterised by social communication deficits, cognitive rigidity , and deficits in adaptive behaviour [1]. These limitations impact the ability to independently manage daily activities and respond to environmental changes, with dramatic effects on the quality of life of ASD people and their families. From the therapeutic point of view, the main rehabilitation methodologies consist of behavioural training activities to consolidate functional behaviours. This approach effectively develops adaptive attitudes, but it can be experienced in a few contexts, thus aggravating the difficulty of transferability of the learned conduct. To improve ASD people's autonomy and promote their social inclusion, we developed 5A. 5A, short for "Autonomie per l'Autismo Attraverso realtà virtuale, realtà Aumentata e Agenti conversazionali", provides a set of innovative and interactive tools based on smartphones and wearable headsets that move within the virtual continuum [5], integrating Virtual

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Reality (VR), Augmented Reality (AR), and Conversational Agents (CA). These applications assist persons with ASD with comprehending the environmental and socio-organizational features of everyday life scenarios (e.g., taking the subway) and performing associated activities appropriately. Experiences in VR allow simulating tasks of such scenarios (following the previous example: identifying the subway entrance, acquiring a ticket, validating it, getting on the train, and exiting at the right stop). When people find themselves in similar situations in real life, AR helps them generalise the skills acquired in VR by superimposing multimedia elements on the view of the surrounding physical world (e.g., which button to press on the ticket machine, where to insert the ticket for validation). In both VR and AR, a Virtual Conversational Assistant (VCA) provides stimuli (e.g., "Look At the turnstile"), prompts (e.g., "Search the subway sign"), and voice feedback (e.g., "Great, you've done it!"). As a first use case, we focused on public transportation developing Cross-Reality (CR) applications designed to help users taking the subway.

2 RELATED WORK

5A is inspired by therapeutic practices for building appropriate behavioural modalities: Social Stories (for understanding interpersonal communication situations) and Video Modelling (for imitative learning aspects). Much empirical research is ongoing on VR, AR, and CA for people with ASD, but the combination of these three paradigms is unexplored.In the last few years, many VR solutions have been developed to teach ASD people how to use public transportation, e.g., planes and buses. The works of [6], [7] focus on the plane scenario. They recreate 360 video simulations where users are explained how to take a flight. A narrative script based on Social Stories guides each intervention, but users cannot interact with the elements in the scene and can only pause the video. In addition, there is no CA that the user could refer to in case of need. In [8] an interactive experience let ASD people learn what to do in an airport by freely moving into the scene, interacting with objects, and performing actions as they were in the real world. The experience presented in [3] made the users perform all the necessary tasks in order to reach a specific destination by bus: planning a route, waiting for the right bus, choosing a place to sit, and deciding when to press the STOP button to get off the bus. About the impact of AR on ASD, research shows its effects to be positive in different ways: it can increase motivation, attention, and the learning of new tasks [2]. However, a few examples in the literature related to AR support ASD people in public transportation. The most representative is the work of [4] who designed a navigation app using visually-oriented navigation. It collects Google Street View images of a calculated route to identify specific landmarks associated with waypoints, presenting a more human-centric visually-oriented navigation app. No examples have been found of AR applications to help ASD people in the subway scenario.

3 DESIGN OF THE EXPERIENCE

The design of the experiences was carried out in collaboration with therapists from two therapeutic centres specialising in treatment of individuals with ASD. In order to better design each experience, three focus groups were organised with the therapists. The approach followed in each meeting was as follows: the therapists were presented with ideas, some of which had already been implemented, in order to give them a better understanding of what they wanted to do and how they would interact in the applications. There was then a discussion on the feasibility and usability of the proposals made. Finally, the choices taken were implemented and shown during the next meeting.The first meeting discussed the general requirements that virtual and augmented reality applications should share. As they are linked experiences, the users have to feel that they are having the same experience so that they can put into practice what they have learned. The VR in this case is used as a safe and controlled space where the actions to be performed when using the underground are shown. When users switch to the AR application (in the real underground) they will have

Fig. 1. VR co-design session: therapists working on the task flow of the experience

Fig. 2. An example of sketch made during the AR co-design session

to be able to redo the same tasks learned in VR assisted by the digital hints that the AR will make appear. A key role in this shift between technologies is played by transmedial elements. These elements are found in both applications and can facilitate task learning. The main transmedial elements are the VCA, the interaction key elements (e.g. ticket machine, turnstiles) and the supporting elements (arrows, highlighted areas) that can suggest to the user what to do or where to go. The second meeting was dedicated to the virtual reality experience. In particular, the tasks flow, the interaction modalities with which the user can move forward in the experience were discussed, as well as the support modalities that the conversational assistant has to offer during the experience (Fig.1). The third meeting focused on the AR application. The design of this experience was more complex because the UI to be created had to integrate real and virtual elements in a consistent way. To do so, the therapists were given pictures representing scenes in the underground to which they could add the virtual elements using transparent sheets, as shown in Fig.2. The final design choices made during the meetings with therapists are presented in the next section where the two use cases are illustrated.

4 5A SUBWAY - USE CASE

4.1 5A Subway VR

The VR experience has been divided into three main moments corresponding to a specific virtual environment. These are the outside of the subway, the inside of the subway, and the inside of the train. Each of these moments contains, in turn, tasks, which are the actions that must be carried out in order to reach the goal. For example, inside the underground, the user has to buy a ticket, pass through the turnstiles, and find the correct direction to take. Each task is divided into sub-tasks that correspond to the atomic VR interactions: gaze, select and move. Combining those makes it possible to create the whole flow of the experience. For example, if the goal is to teach the user how to pass the turnstile, the interactions to be performed are: 1) Observe any open turnstile (GAZE); 2) Select the chosen turnstile (SELECT); 3) Reach the turnstile (MOVE); 4) Select where to insert the ticket to validate it (SELECT); 5) Select ticket after validation (SELECT); 6) Move past the turnstile within 30 seconds (MOVE). At any time, the user can ask the VCA for further instructions either to help or leave the experience. The VCA can also show some facilitators to help the user.

4.2 5A Subway AR

The AR experience is composed by the same moments as in VR. The design, instead, is more complex because system has a very small control over the user. Our engine needs to understand what the user is doing, what has been done by

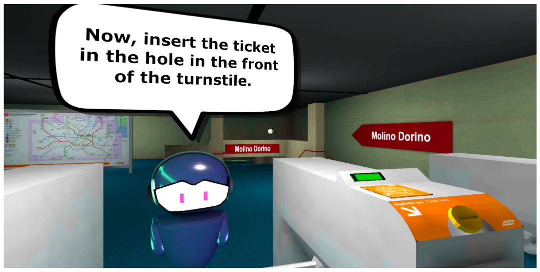

Fig. 3. Screenshot of the VR subway experience. The VCA asks the user to insert the ticket in the turnstile.

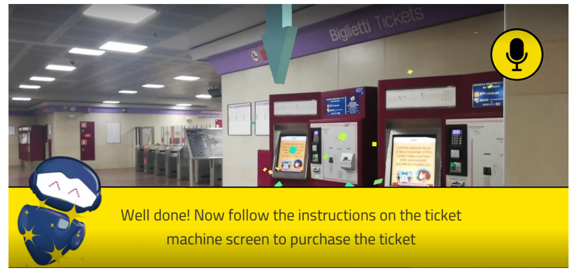

Fig. 4. Screenshot of the AR subway experience. The VCA asks the user to reach the ticket machine.

error or what has been done without the help of the application. For this reason the user can interact in two modes: object recognition and dialogue with the VCA. A user interface was created so that the virtual assistant, its message to the user, a button to allow the user to record voice messages and the hint of the object to be found are always visible. By sharing the same tasks as in VR, the user has already learned which objects s/he has to interact with while being in the subway. Using the same example, the user frames one of the turnstiles, and an AR animation will appear to show the user where to insert the ticket and where to collect it. Then the user is prompted to pass the turnstile. While in VR the experience can be completely monitored, in AR the VCA has to ask the user the needed information that the system cannot collect autonomously. (e.g., tasks completed by the user without the app's use). Given its importance, all major communication can also be activated by clicking modal UI elements dynamically generated to offer the user a way of contacting the VCA even in loud environments where voice recognition can be problematic.

5 CONCLUSION AND FUTURE STUDY

This paper presents the initial step toward exploring interactive CR applications to support ASD people in achieving everyday life tasks. Unfortunately research on this topic remains unexplored and to address this issue, we created a system based on VR, AR, and VCA applications in which the user can learn simple actions of everyday life in a digital simulation in VR and then try to replicate the task in the real world supported by the use of AR. The VCA offers a continuum between the two experiences and remains a reference point for the user to offer help in case of need.

The 5A system will be used in the next months as the core of a study involving 30 users diagnosed with high functioning ASD from Sacra Famiglia ans Nostra Famiglia, the two local therapeutic centres who participated actively during the design of the VR and AR experiences. The experimental design is a within subject study. Inclusion criteria will be IQ > 60, significant difficulties in complete autonomously the task, normal sensibility to auditory stimuli, and a sufficient level of cooperation and verbal skills. Each subject will have to undergo a pre-test session, in which inclusion criteria will be verified, then 10 biweekly session with the VR-Metro experience will be performed, followed by 1 sessions in AR and finally the last evaluation session. During each session the subject will be accompanied by a specialised therapist. Sessions in VR will be taken in the local care centre, while the AR experience will be taken in a familiar stop of the underground line in Milan close to the care centre. In the final evaluation session, users will also be tested in an unfamiliar stop of the same underground line. We will measure both the usability and engagement of users, together with questionnaires on the learnability of the task (take autonomously the underground. A pre-post evaluation will be conducted for each user on the reported difficulties in completing the task autonomously to measure an indication of the effectiveness of the solution.

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