An Affordable Virtual Reality Learning Framework for Children with Neurodevelopmental Disorder

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ABSTRACT

Our research explores wearable Immersive Virtual Reality (IVR) to support new forms of intervention for children with Neuro-Developmental Disorder (NDD). In cooperation with therapists at a local rehabilitation center, we developed and evaluated Wildcard, a system that exploits a low cost VR visor and enables the child to "feel immersed" in 3D worlds, using eye focus and head/body movements to interact with the virtual items. Wildcard includes a set of functionalities for the therapists to monitor children's interaction, to customize the virtual space for the specific needs of each subject, and to automatically collect data.

Keywords

Accessibility, Neurodevelopmental Disorder, Virtual Reality

1. INTRODUCTION

Headsets for experiencing Immersive Virtual Reality (IVR) are commercially available today at affordable cost, triggering the development of a wide number of wearable IVR applications in different domains such as entertainment, tourism, and healthcare. Our research explores the potential of this technology to support new forms of interventions for children with Neurodevelopmental Disorder (NDD). NDD is an umbrella term for a group of disorders often co-occurring deficits in the cognitive, social, and emotional spheres that severely affect adaptive behavior and the basic capabilities needed in everyday life. NDD includes, among others, Intellectual Disability, ADHD (Attention Deficit Hyperactivity Disorder), and ASD (Autistic Spectrum Disorder). Digital interactive technologies are increasingly used in the NDD domain because they provide multisensory stimuli that are more engaging, predictable, and replicable than those offered by conventional therapeutic tools [1] and wearable IVR technology can bring additional benefits [3]. The wearable device occludes the field of view and immersivity leaves a subject to deal with the stimuli of the virtual world and can alleviate the symptoms of the sensory integration dysfunction that characterizes persons with NDD [2][4]. Still, wearable IVR involves a number of potential drawbacks [5]. The headset might not be accepted by children with NDD and the interaction mechanisms might not be easy to understand and use; immersivity may increase the risk of self-isolation, with the child sticking to the virtual imaginary world and unwilling to return to the "real" world. As such, creating wearable IVR applications that are usable and effective for this specific target group is a challenge. The paper describes an IVR system for children with NDD called Wildcard, which has been designed and evaluated in cooperation with a local therapeutic center, and reports the main lessons learned and latest results.

2. WILDCARD

Many therapeutic practices include storytelling activities for NDD children to work on different developmental spheres: communicative, social, emotional, imaginative and cognitive. Our goal is to help children improve various competences: selective, sustained, and alternating attention; communication and socialization; comprehension and memory; discrimination of visual and audio stimuli; problem solving; and visuo-spatial perception by offering wearable immersive storytelling experiences. Wildcard platform exploits a low cost visor - Google Cardboard - and a smartphone placed inside it. The virtual spaces are digital interactive transpositions of paper-based stories that therapists use in their regular therapeutic practice. The child can explore the virtual environment and interact with story characters and elements using eye focus and head movements (sensed by the smartphone sensors). Several progressive prototypes of Wildcard have been designed and iteratively tested with therapists and children. In its current version, Wildcard supports 3 interaction modes. In Exploration mode, the child explores a set of story-related interactive contents arranged along a 3D maze path. In Story360 mode, the child is required to focus her attention on the main virtual character in order to proceed in the story. In Research mode, a number of items are randomly placed in the virtual world and the child must find and "collect" them (an item is "collected when the child maintains her eye focus on it for a pre-defined time).
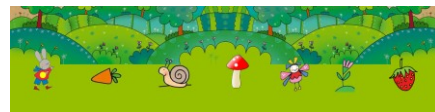

Figure 1. Unfolded Virtual World: 360° flat overview of *Story360* environments (1 character [left] + 6 items [right])

The IVR application is integrated with an external screen that, by showing the replica of what is rendered inside the visor, the therapists can observe how the child behaves in the immersive space and directs his flow of interactions. To address the specific needs of each child, the therapists can customize the digital contents and some interaction features, using a library of build-in visual elements and setting different parameters. For example, they can select the visual theme or the background environment for each interaction mode; they can adjust time variables such as the minimum eye focus duration for an item to be "selected"; they can replace the main character and define its speed of movement or its animation effects; they can place any number of dynamic objects anywhere in the 360 view, and create fading effects when an item is selected. In addition, Wildcard automatically collects data on children's interaction that are automatically transformed into indicators of performance, attention and concentration, and can be used for live and ex-post monitoring, diagnosis and assessment.
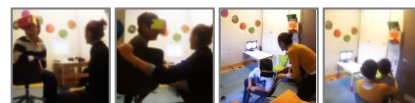

Figure 2. Children using Wildcard with their therapist

3. EVALUATION

The current system has been evaluated during an empirical study aimed at assessing the degree at which the integration of Wildcard in the regular therapeutic practice achieves some of the benefits stated in the previous section (as shown in Figure 2). The study involved 3 therapists and 10 medium-low functioning subjects (8 males and 2 females, aged 6-10 years, who had had never been exposed to IVR before). Children used Wildcard individually, once a week, for 2-months, attending from 4 to 8 sessions of 30 minutes each, according to their own non-study related availabilities. Before the study, children participated in "familiarization" sessions, comprising storytelling activities with the paper-based counterpart of the stories implemented in Wildcard and play with hand-crafted cardboard-based masks. During the study, the therapists were customizing the session to suit each child, proposing tasks that had increasing levels of complexity. A vast amount of information of different nature was collected: therapists' notes, videos, surveys, and interaction logs.

Qualitative data - from therapist's observations and video recordings - pinpoint that Wildcard was willingly accepted by the children. The engagement level maintained by all children in all sessions, even in the last ones where the novelty effect had less "impact", was judged "exceptional" by the therapists. Two children were particularly amazed about how they could play with their favorite hero as protagonist, and asked to play with the same story four times within the same session. Therapists were enthusiast of both the personalization features of Wildcard and the possibility of real-time supervision during sessions. For the first time, they could use autonomously an innovative digital technology, define IVR-empowered interventions and tailor them to each child's needs without depending from external technicians. The adjustment of virtual world parameters was the most used add-ons in the personalization process. As Wildcard allowed therapists to see the virtual world through the children's eyes and tracked participants' attention and performance levels (see below), caregivers could supervise each entire session seamlessly and receive continuous feedback. This enabled them to provide specific encouragements to a child when needed, to discuss what she was experiencing, and to understand what elements were disturbing.

Quantitative results - from the data automatically collected by Wildcard - are encouraging, particularly in relationship to Performance and Attention. Performance refers to the child's ability of using the system and accomplishing the assigned tasks, and is measured by task Accomplishment Time (AT). Attention comprises selective and maintained attention (respectively, the capability to focus on an important stimulus ignoring competing distractions and the capability to capability to hold the focus for the time needed to conclude a task). It is computed as the sum of the instants spent by the child to look at the "right" virtual item, i.e., the most meaningful one for the current task. AT is inversely proportional to Attention (the more the child points the right element and maintains eye focus, the less is the time spent for task accomplishment). Even if each session was customized for each child and the increasing difficulty of the sessions was not comparable between participants, our data show a decrement of AT for all children. This result is stronger in the subjects who attended at least 7 sessions, and is weaker, but still evident, in the subjects who skipped 2 or more sessions. Figure 2 provides an example of Attention measures in tasks involving Story360 interaction mode (lasting around 2 minutes), and enables a comparison between the 1st and the 3rd session of Child 2.

In Fig. 3 attention levels plot "1" (green line) if the player is staring at the protagonist in a given instant, and "0" (red line) otherwise.
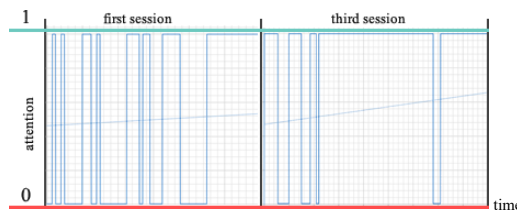

Figure 3. Attention measures for Child 2: session S1 vs. S3

During session 1 (left Fig. 3), the child initially explored the story environment somehow randomly, without concentrating on the main character as requested by the therapist. Eventually, he started focusing on the protagonist and progressively increased his attention on it as the story evolved. After only 2 sessions the child shows an evident improvement (right Fig. 3): he continued to explore the story environment, at the beginning by focusing more on the protagonist and then sustaining his attention for a much longer time, pausing just for few seconds until the story ends. Our data show a similar trend during the following 4 sessions, indicating that the improved attention skill was maintained.

4. CONCLUSIONS

Combining low-cost wearable immersive virtual reality with storytelling and strong customization features, Wildcard offers a unique set of features that have only been initially explored but have already shown their potential for the treatment of children with NDD. In addition, the combination of an inexpensive visor, a smartphone and an "app" that anyone can download, gives to Wildcard an enormous potential for large scale adoption, within therapeutic centers and beyond (e.g. families and schools). Additional benefits arise from Wildcard customization features, which empower caregivers and given them a control at a degree which is not allowed by any other existing tool. Our next steps are in various directions. We are planning wider controlled empirical studies to provide more rigorous evidence of the therapeutic benefits. We are adding content management features to the customization tool and expanding the platform with new experiences (e.g. 360 social stories). Finally, we are working on the integration of machine learning approaches that exploit the progressively increasing amount of data automatically gathered by Wildcard both for diagnostic purposes and to support self-adaptation of the IVR interactive space.

5. REFERENCES

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