HMDs and ASD - Usability evaluation results

TetaLab Research Group @ Univaq

[1] Department of Information Engineering, Computer Science, and Mathematics, University of L'Aquila, Via Vetoio, 67100 L'Aquila, Italy
[2] Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, Via Vetoio, 67100 L'Aquila, Italy

1. Introduction

The study was conducted within the framework of an experience of participatory design carried out at TetaLab (Technology-Enhanced Treatment for Autism Lab), a multidisciplinary laboratory of the University of L'Aquila cooperating with the Regional Reference Center for Autism of the Abruzzo Region. The laboratory was founded by scientists from the Department of Information Engineering, Computer Science and Mathematics and from the Department of Biotechnological and Applied Clinical Sciences, with the aim of conceiving and validating ICT-based ASD treatments specifically centered on *communication*, *social interaction*, and *autonomy*. When the study took place, the TetaLab team included three computer scientists, four psychologists, and one medical doctor; the participatory design activity involved also nine ASD young persons in the age range 15-28. Families took part as secondary stakeholders. The study included two evaluation sessions: the first one took place in Milan at the Microsoft Lab and was focused on augmented reality, while the second one took place in L'Aquila at TetaLab and was focused on immersive virtual reality.

2. Materials and Methods

2.1 Materials

Coherently with the general goal of the study, we evaluated two diffused off-the-shelf HMDs offering different interactive experiences with mixed and virtual environments:

- The HoloLens translucent visor, adding a layer of synthetic reality to the natural field of vision that gets enriched by virtual elements overlaid on top of it. Study participants experimented the HoloLens Commercial Suite, which includes the Development Edition hardware as well as enterprise features for added security and device management.
- The Oculus Rift headset, offering a 100% immersion in a virtual world generated by the computer inside the device while the field of view of the real world is cut out. In our experiment, the Oculus Rift headset was connected to a VR-ready laptop (Asus GL 502V) with Intel Core I-7 7700 HQ, 2.80GHz clock, 16GB RAM running the Windows-10 OS and a NVIDIA GTX1070 high performance GPU with 8GB of dedicated high speed GDDR5 RAM, with 1920 graphic processing cores.

2.2 Participants

Table 1. Characterization and IQ of study participants.

	P1	P2	P3	P4	P5
Age	21	21	23	21	22
Gender	M	M	M	M	M
Years of education	16	16	16	15	13
Social cognition measures					
CE-BES	30	37	34	30	25
AE-BES	43	45	39	44	38
EYES TASK	19	25	18	18	23
Advanced ToM	11	12	12	10	12
Wechsler Adult Int. Scale (WAIS)					
WAIS-VCI	110	96	69	86	98
WAIS-PRI	94	114	73	73	83
WAIS-WMI	89	89	83	92	92
WAIS-PSI	83	89	97	75	75
WAIS-IQ	**94**	**98**	**73**	**76**	**84**

2.3 Measured acceptability and usability factors

Acceptability was investigated in terms of participants' willingness to use the evaluated headsets and of a number of factors related to possible unpleasant physiological effects or discomfort (motion-sickness, double vision, digital eye strain) selected based on consolidated literature on IVR and ASD and measured as Boolean values.

Usability was investigated according to a variety of aspects (see Table 2) related to *autonomy in managing the devices* (measured with respect to support requested to operators during performances and performances in mounting the devices), *comprehension of virtual environment features* (measured with respect to interactive and non-interactive virtual elements, menu navigation elements, menu structure elements) and *interaction ability* (measured with respect to the use of game pad, remote control, gestures). These aspects were measured using a low-medium-high scale.

Table 2. The usability evaluation framework.

USABILITY FACTORS – Low (L), Medium (M), High (H) scale	
Autonomy in managing devices	measured with respect to: – support requested to operators (**SO**) during performances – autonomy in mounting devices (**MD**)
Comprehension of virtual environment features	measured with respect to: – elements (**El**) – interactivity (**In**) – menu navigation (**MN**) – menu structure (**MS**)
Interaction ability	measured with respect to the use of: – game pad (**P**) – remote control (**C**) – gestures (**G**)

2.4 IVEs scenarios

All selected scenarios contributed to the evaluation of *all acceptability factors*, *autonomy in managing devices* and *comprehension of IVE features* (usability factors). As to interaction ability, distinct scenarios provided different insights according to their characteristics:

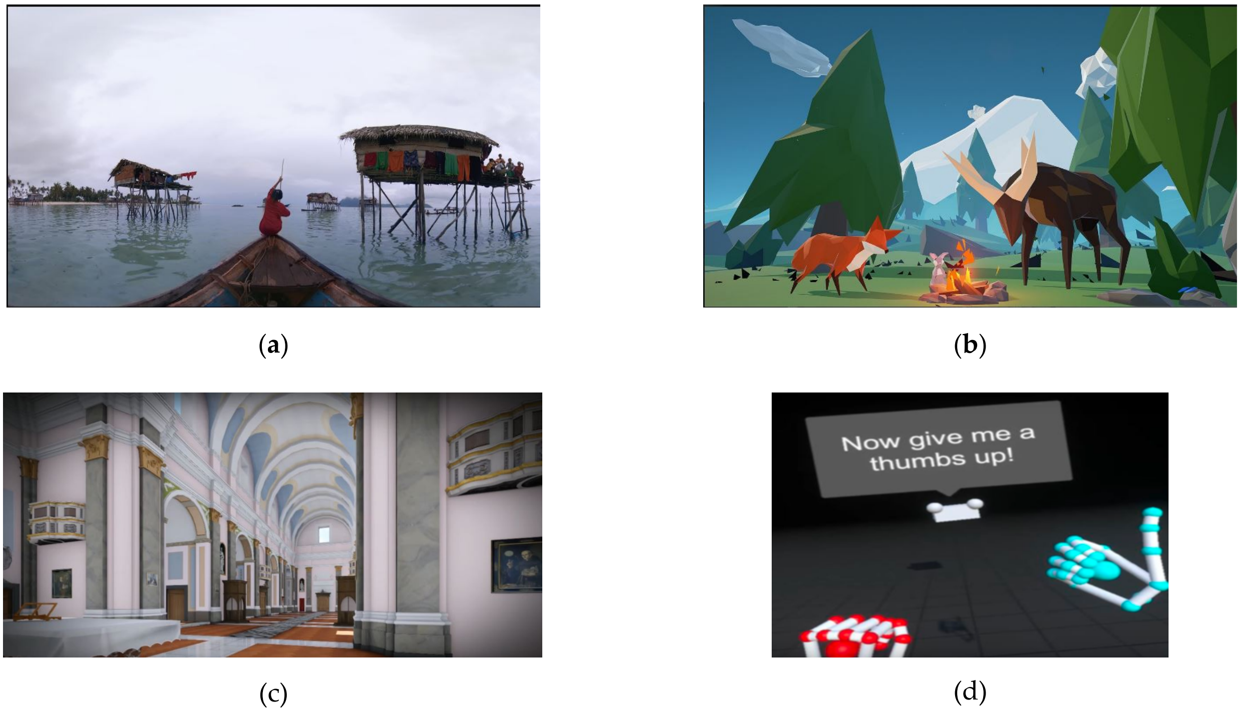

Figure 2. Sample screenshots from the demos: (**a**) A screenshot from a non-photorealistic scenario of the Dreamdeck Oculus Demo; (b) A screenshot from a non-photorealistic scenario of the Dreamdeck Oculus Demo; (**c**) A screenshot from the Santa Maria Paganica Demo; (**d**) A screenshot from the Blocks Demo.

- **E1**: the "Introduction to Virtual Reality" demo allows users to browse different scenes via remote control; for example, users can watch the world from the space as if they were an astronaut, watch the far-away lands as if they were physically in these lands, attend a Cirque du Soleil performance as if they were in the center of the performance itself, interact with a giant from a bygone era as if they were face to face with them (see a sample screenshot in Figure 1-(a)). These scenarios and associated activities contributed primarily to the evaluation of *interaction ability in using remote control* (usability factor).
- **E2**: the "Dreamdeck demos" offer a mix of photorealistic and not photorealistic scenarios in which users can, for example, talk with an alien face to face, meet forest animals, watch a city of the future standing on one on its high terrace, moving within a strange museum awaiting the T-REX coming against them (a sample screenshot is given in Figure 1-(b)).
- **E3**: the "3D virtual reality model of the Church of Santa Maria Paganica in L'Aquila", allows visitors to explore an important historic site destroyed by the earthquake of April 6th, 2009. By means of a game pad, users can approach artistic details, like the Church choir, or move away out of the church to visit the square, or magically tele transport themselves onto the platforms built to observe the cupola artistic works (a

sample screenshot is given in Figure 1-(c)). This scenario and associated activities contributed primarily to the evaluation of *interaction ability in using the game pad* (usability factor).

- **E4**: in the "Blocks game" available on Leap Motion Store, users can interact with virtual blocks, moving them, creating them in different geometric forms and magically levitating them, by using their virtual hands, thanks to the Leap motion technology (a sample screenshot is given in Figure 1-(d)). This scenario and associated activities contributed primarily to the evaluation of *interaction ability via gestures* in IVEs (usability factor).
- **E5**: In the "Michelangelos' David demo" available for the HoloLens Commercial Suite users can interact with the photorealistic hologram of the statue using their own hands: they can approach the sculpture to discover the overall artistic details, miniaturize it, restore its original size, or even change it by chiseling the marble. This scenario and associated activities contributed primarily to the evaluation of *interaction ability via gestures* (usability factor) in a mixed reality setting.

2.5 Activities

Table 3. Performed activities and associated interaction. Notice that the only way to interact with the environment perceived via the HoloLens is by *gestures*, while in the case of the Oculus Rift demos the available interaction modalities include also *remote control* and *game pad*.

Activities	Description	Oculus Rift	HoloLens
A1	Mounting the HMD	-	-
A2	Dismounting the HMD	-	-
A3	Browsing menus	remote control	gestures
A4	Watching VE	-	-
A5	Exploring VE	game pad	gestures
A6	Playing with VE	gestures	gestures

3. Results

As to *acceptability*, all factors received a positive boolean value: all the participants were able to mount and dismount the headsets without support from operators; no participant reported and/or showed negative sensory or physiological experiences. All the participants were indeed enthusiastic to participate to both sessions; this is in particular remarkable for the HoloLens session, for which they chose to face a somehow burdersome trip to Milan also overcoming physical impairments and/or social phobias.

As to *usability*, quantitative objective data in Table 5 and Table 6 were extracted from collected materials and expressed according to a Low-Medium-High scale with Low = $v \in [0\%..33\%]$, Medium = $v \in [34\%..66\%]$, High = $v \in [67\%..100\%]$, where the meaning of v depends on the particular metrics of the evaluation framework in Table 2. Specifically, for the "autonomy in managing the devices" group we determined the number of times ASD student asked for support with respect to the mean of this measure on Typical Development (TD) people and the time spent for mounting the HMD with respect to the mean of this measure on TD people (the control group included five graduated and undergraduated students from Psychology and Computer Science courses in the same age range of study participants); for metrics in the "comprehension group" v is the number of recognized elements with respect to the total requested by the activity; for metrics in the "interaction ability" group v is the number of correct actions with respect to the total requested by the activity. The Low, Medium, and High values were then mapped onto a classical F (Failure), P (Partial success) and S (Success) triad values (notice that for SO an inverted philosophy holds, since in this case the fewer the better) and the success rate calculated as

$(tot_S + 0, 5 * tot_P)/tot_O$, where tot_S is the number of occurrences of S, tot_P is the number of occurrences of P, and tot_O is the total number of occurrences. Summary results are in Table 7.

Table 4. Metrics for usability evaluation

Usab. Metrics	Meaning of Usability Metrics' Values
SO	number of times ASD student asked for support wrt the mean of this measure on TD people
MD	time spent for mounting the HMD wrt the mean of this measure on TD people
El	number of virtual elements recognized wrt the total
In	number of virtual interactive elements recognized wrt the total
MN	number of virtual menu navigation elements recognized wrt the total
MS	number of virtual menu structure elements recognized wrt the total
P	number of correct actions on the game pad wrt the total requested by the task
C	number of correct actions on the remote control wrt the total requested by the task
G	number correct gestures wrt the total requested by the task

Table 5. Results of usability evaluation - HoloLens

ID	Autonomy in managing devices		Comprehension of virtual environment features				Interaction ability		
	SO	**MD**	**EL**	**In**	**MN**	**MS**	**P**	**C**	**G**
P1	Low	High	High	Medium	Medium	Medium	-	-	High
P2	Low	High	High	Low	Low	Medium	-	-	Medium
P3	Medium	High	High	Low	Low	Low	-	-	Medium
P4	Medium	High	High	Medium	Medium	Medium	-	-	Medium
P5	Low	High	High	Medium	Medium	High	-	-	High

Table 6. Results of usability evaluation - OCULUS

ID	Autonomy in managing devices		Comprehension of virtual environment features				Interaction ability		
	SO	**MD**	**EL**	**In**	**MN**	**MS**	**P**	**C**	**G**
P1	Low	High	High	High	High	Medium	High	Medium	High
P2	Medium	High	Medium	Medium	Medium	Low	High	Medium	High
P3	Medium	High	High	Medium	Medium	Low	Medium	Medium	High
P4	Medium	Medium	Medium	Medium	Medium	Low	Medium	Low	High
P5	Low	Medium	High	High	Medium	Medium	High	High	High

Table 7. Summary of usability evaluation

Metrics	HL Activities	OR Activities
Autonomy in managing devices	0.90	0.75
Comprehension of IVE features	0.52	0.57
Interaction ability	0.7	0.76

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of University of L'Aquila (19/2016) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.