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Preliminary evaluation of an IVR user experience design model using eye-tracking attention measurements

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Abstract

The present study drafts a simplified IVR user experience design model to guideline a preliminary evaluation of attention variance for semantically distinct elements. 27 participants (11 females) freely explored an interactive multi-user virtual setting, whilst equipped with full-body motion support and eye-tracking which procured attention duration measurements. Initial results confirm significant element attention discrepancy and provide the first indication toward a more detailed categorical organization of experience components for follow-up experimentation.

Keywords: Virtual Reality, User Experience, Eye Tracking.

Index Terms: Human-centered computing—Human computer interaction (HCI) —HCI theory, concepts, and models.

1 Introduction

The design of an Immersive Virtual Reality (IVR) experience ought to rely upon a model of the standard experiential components that transcend all IVR applications, regardless of application-specific objectives and particular tasks. Broadly, this may be correlated to Hassenzahl's "experience before product" notion [1]. Past attempts [2, 3] to address user experience in an immersive setting came in the form of proposed structural models, but little attention has been given to the issue since.

The present study, having examined past approaches [4, 5], drafts a simplified model consisting of four fundamental elements that inform any IVR experience; those elements are, the environment, the self, other entities, and functional objects. Prior to introducing any specific task, users arrange said elements as per to their degree of emotional and/or cognitive impact, thus a baseline of the IVR experience may be detected and eventually help generate a more detailed IVR Experience Design model. In this study we conduct a preliminary evaluation and assess element impact based on user attention measurements with the use of eye-tracking technology.

2 Fundamental elements of the IVR experience

According to Experience Design principles every medium-based experience develops upon a Story, a Narrative, and the Objectives set for users by the designer [1, 6]. Users attempt to reach the in-application objectives by going through information pertaining to place and time, entities, interaction, modalities, etc. Drawing a simple situational map of those and many more informative pieces and basic properties (e.g., situated vs abstract, dynamic vs static, etc.) [1] allowed for a semantic arrangement that revealed how they associate with four main elements: the Environment, the Self, the Héteros, and the Object.

The Environment consists of what we label as Cosmos, which pertains to the evident or assumed cosmology, and which also governs the second sub element of the Environment; Space. Space is better understood along the second fundamental element of the experience which is the Self.

The Self is twofold relating to literal representation (i.e., avatars), and locomotive and interactive modalities, but it also pertains to socio-cognitive processes based on semiotics, social relations, and social context, following interaction with objects or other entities. The Space contains anything that the Self may associate with spatially. Héteros (from the Greek *ἕτερος*: the other one; second; different), can refer to any entity with evident agency. For the sake of this simplified model, here it refers to other anthropomorphic entities, bearing human modalities (e.g., body, speech, etc.). Therefore, this element may also assume a literal representation in the form of an avatar and pertain to social interaction with the Self, while the Environment defines social context. All visible objects are part of the Space, unless they possess a pre-designed and visually or otherwise immediately evident function.

The Environment and the Self are fundamental, structural components of any experience, especially an egocentric [7] IVR experience, hence, they are unavoidable. The Héteros and Object elements give the illusion of creative control and in practice can be absent, but their fundamentality relates to the cognitive associations drawn regardless of the experience presented; since users will often reflect on, review, or even look for sentience and functionality in their surroundings.

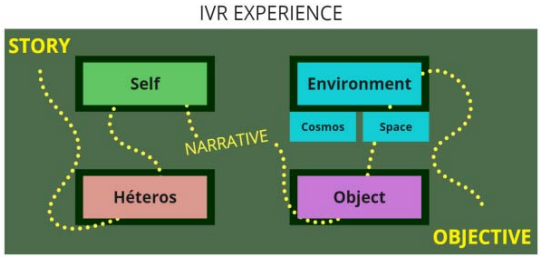

Figure 1: Preliminary structural model of the fundamental elements of the IVR experience.

In summary, the IVR experience is constituted by: a) what users know before-hand (in the form of preconceived notions and general truths), b) what they discover through interaction and locomotion, therefore gradually expanding their perception of the Space, and the Héteros and the Object (or in absence of those), c) what they discover or presume about the Cosmos, and d) how all of these and their nuances, correlated to the experience design properties, unfold the Narrative and lead toward an internal Objective realizing the Story.

3 Experimental design

This study, based on user attention measurements, assesses element impact for a preliminary evaluation. 27 individuals (11

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females), 18 to 50 years old (avg. 28), were asked to freely explore a virtual environment (VE) and interact with its elements. The final VE (see Figure 2) was a 12m^2 room wherein each 3D model was representing the element to which it related the most semantically. The room, along with its simple objects, was the participants' immediate Space and was represented by the decorative objects lying around. On one of the walls a virtual window provided a view of the outside world, based on which participants gathered variant information regarding the Cosmos (e.g., time of day/year, presumed physical laws, location). Therefore, the window model represented the Cosmos. The Self was represented by the mirror and participants' avatar.

Figure 2 illustrates system architecture. Using Unity[1], two remote locations equipped with Vicon[2] motion capture systems were interconnected, tracking the head, hands, and feet of the researcher on one location and participants on another. Tracking data were solved onto human 3D models via Inverse Kinematics (IK), providing the research and the participants with real-time full-body motion. Whereas the Salsa LipSync Suite[3] automated lip-syncing allowed for realistic lip movements of the researcher's and participants' avatars which represented the Héteros and the Self elements respectively. Participants could interact with the researcher via Photon Voice[4] during individual sessions, and both used Vive Pro HMDs. HMDs were equipped with the Pupil Labs Eye Tracking addon[5] allowing for realistic gaze direction solving in the virtual setting, as well as participant gaze direction data collection. Finally, only at the participant location, a simple cardboard box (15cm^3) was being tracked, using Vicon motion capture system, to solve motion onto its virtual replica, thus introducing a MR experience and representing the Object element.

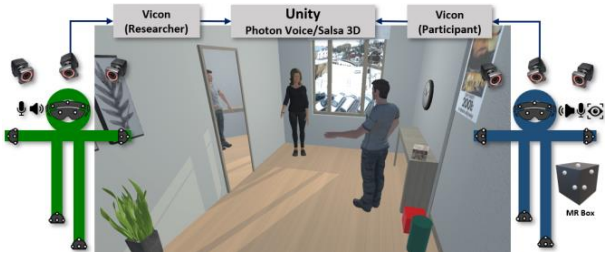

Figure 2: System architecture and the VE.

Evaluation Results

Figure 3a illustrates the number of seconds that participants spent looking directly at each 3D model of the virtual setting. Figure 3b correlates absolute measures to per participant session duration (average session duration was ~12.5′). Since models were categorized as per their relation to each element, the final values denote *attention* per element. Therefore, walls and decorative 3D models represent Space, the Window represents Cosmos, and together they constitute Environment *attention*. Similarly, the MR Box values are data for the Object element, H-Avatar values for the Héteros, and Mirror values are for the Self, including recorded data when participants directly looked at their body parts. A one-way ANOVA (analysis of variance) was performed between per category/element mean values and resulted in high statistical significance ($p=0.001<0.05$) disputing the H_0 of element attention invariance.

[1] https://unity.com/
[2] https://www.vicon.com/
[3] https://crazyminnowstudio.com/
[4] https://www.photonengine.com/voice
[5] https://docs.pupil-labs.com/vr-ar/htc-vive/

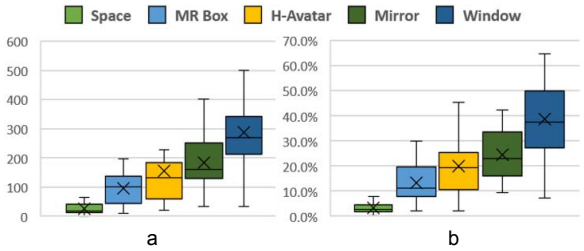

Figure 3: (a) Absolute *attention* distribution; (b) Percentile *attention* distribution.

Based on these results, the first conclusion confirms that there is a baseline of affectiveness which can be directly correlated to specific components of an IVR experience. The above ordinal arrangement is a preliminary indication that produces a blueprint that may inform follow up experimentation. More specifically, even though the H_0 refers to attention invariance, there was expectation for the most interactive elements to score the higher values. In short, we expected that the social richness provided by the researcher's avatar and the haptic stimulation and interactivity of the MR box would draw greater attention compared to the Environment.

In addition, the final values of the Environment's sub elements show a bizarre disparity with the Cosmos finishing ahead of all elements, yet the Space coming last. This is valuable information because, not only it calls for a re-evaluation of overall element organization but reveals a possible flaw in element drafting, which was expected to a degree considering how broad and complex the Environment element was to begin with. But there is now clear indication that the broader universe of an experience holds entirely different importance compared to its more tangible parameters. An issue that is important to probe in future experimentation.

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