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A Questionnaire to Measure the User Experience in Immersive Virtual Environments

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ABSTRACT

Most of the models of User eXperience (UX) in Immersive Virtual Environment (IVE) are partial due to the components and the measuring methods they suggest. We have presented in a previous work a holistic UX in IVE model, combining key components and influencing factors from the most common fields of Virtual Reality (education, entertainment and edutainment). We do not doubt that the best way to measure the UX in IVEs is to gather and compare results from the appropriate subjective methods with the appropriate objective methods. Nevertheless, in this paper, we chose to focus only on the questionnaire method. Indeed, most of components can be measured through questionnaires. The objective of this paper is to rely on the components of our UX model to select appropriate existing questionnaires and finally choose the more suitable items to create our own mixed questionnaire. First, this paper reviews the questionnaires chosen to create our own. Finally, it proposes an elaboration of the final questionnaire.

CCS Concepts

• Software and its engineering→Virtual worlds training simulations • Computing methodologies→Virtual reality.

Keywords

Virtual Environment; User Experience; Subjective Methods; Non-Instrumental Measures; Questionnaire; Model.

1. INTRODUCTION

There are several definitions of the User eXperience (UX), nevertheless, a large number of researchers agree with the general UX definition given by the norm ISO 9241-210 being: “The user’s perceptions and responses resulting from the use of a system or a service”. Depending on the research fields, “perceptions” and “responses” are presented as a construct of specific components of UX, each component defining a facet of the user’s experience (e.g. usability, flow, engagement, emotion …). An Immersive Virtual Environment (IVE) is an interactive smart computer-based system that provides a three-dimensional virtual world. The virtual world may be imaginary, symbolic or a simulation of an aspect of the real world.

There are numerous studies on UX, and meanwhile, Virtual Reality (VR) applications increasingly emerge. However, few studies combine UX and IVEs.

In the Virtual Reality (VR) field, the actual studies on UX in IVEs can be described under the following two headings:

- On the one hand, few researchers propose a model taking into account the various facets of the UX in an IVE. We have proposed in a previous paper [16], a holistic UX model (Figure 1) including the various facets of the UX in IVE. We combined key components and influencing factors from two of the most common VR fields that are education, entertainment and edutainment.

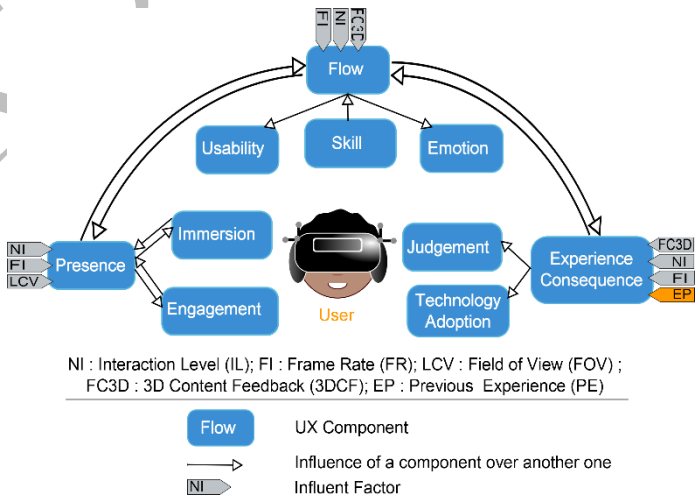

Figure 1. Our holistic User Experience in Immersive Virtual Environment model

In VR education applications, the user learns a notion or trains to acquire a practice in the virtual world in order to prepare for a situation in real life (e.g. simulation VR tools for students in psychology [14], in chemistry [4], in surgery [20]below, in history [5], …). In VR entertainment applications the user decides to have fun or to relax in a virtual reality game (e.g. EVE : Valkyrie [21], Second Life [22], …). In VR edutainment applications, the user learns a notion or trains to acquire a practice by the means of a Serious VR game in order to prepare for a situation in real life (e.g. EON Sports [23], VR-ENGAGE [18], …).

The goal of our general and therefore holistic model is to help measure and create an optimal UX inside the type of VR applications we listed above.

- On the second hand, few complete methodological frameworks are presented to measure the components of the UX in IVE.

Several studies on UX in Virtual Environment (VE), measure the UX only by means of a presence questionnaire [7]. Presence is "the sense of being there" [15], it is a state within which the user forgets about the real world and reacts in the virtual world as if it was real. Therefore, presence is an essential component of the UX in VEs. Nonetheless, considering our holistic model of 10 UX components (presence, immersion, engagement, flow, usability, skill, emotion, experience consequence, judgement, and technology adoption), the presence questionnaire may be an incomplete method to measure the UX in IVE.

There are commonly two ways to measure UX in IVEs, either by objective methods or subjective methods. Yet a combination of both methods might provide more reliable results. Objective methods (instrumental measures) provide results through experimental evidence, whereas subjective methods (non-instrumental measures) provides results through the user's point of view. The subjective methods are often used to understand the user's subjective opinions, attitudes or preferences. There are several subjective methods such as interviews (open questions that help the user talk about the specific detail of his activity), focus groups (technique that help problems and concerns to surface through the group interaction) and questionnaires (set of items designed to obtained the user's opinion, beliefs or preferences).

This questionnaire method is the main subject of our paper. In fact, as well as our holistic UX model we would like to create a complete appropriate subjective method taking into account the whole 10 components of our model. Proposing a questionnaire for each of the components (that is to say 9 questionnaires with an average of 45 items each) to the user at the time of the experimentations would be unthinkable. That is why we propose a mixed (we take into account all the components of our model) but synthetic (we select the appropriate items from each questionnaire for our own) approach for the creation of our questionnaire. To do so, first of all, we would like to identify an existing questionnaire for each of the 10 components of our model. The selection criteria for the questionnaires are:

- Accessibility of the questionnaire (i.e. the whole validation process of the questionnaire is published in a paper).
- Frequent use of the questionnaire or the questionnaire is based or inspired by a frequent used questionnaire.
- Existence of several translations of the questionnaire, at least in French. If not, the translation process needs to be easy (few items to translate, the real meaning is kept after the translation).

Secondly we would like to select the suitable items from these questionnaires to finally create our own UX questionnaire.

2. USER EXPERIENCE QUESTIONNAIRES REVIEW

2.1 Presence, Engagement and Immersion

Presence is defined as "the user's 'sense of being there' in the virtual environment". The concept of presence can be grouped in two categories : physical presence and social presence in collective virtual environments [12]. Most measures of presence try to address both. Engagement is defined as "the energy in action, the connection between a person and its activity consisting of a behavioral, emotional and cognitive form". Immersion is defined as the "illusion" that "the virtual environment technology replaces the user's sensory stimuli by the virtual sensory stimuli". The 3 components of presence, engagement and immersion can be measured by 2 questionnaires created by Witmer and Singer [19]. These questionnaires are a reference in the VR field. The Presence Questionnaire (PQ) measures the degree to which individuals experience presence in VE. This questionnaire is composed of 24 items divided in 5 subscales: involved/control, natural, auditory, resolution and interface quality. Items 4, 6, 10, 13, 20 actually measure the engagement component of our model. The Immersive Tendency Questionnaire (ITQ) measures the tendency of individuals to be immersed. This questionnaire is composed of 16 items divided in 3 subscales: involvement, focus and game. The authors have included in this questionnaire several items that in fact measure the engagement of the user.

2.2 Flow

Flow is defined as "a pleasant psychological state of sense of control, fun and joy" that the user feels when interacting with the virtual environment. The flow component can be measured by the Flow4D16 questionnaire created by Heutte in 2011 [9]. It is used to assess the degree with which the user is absorbed by his task. This questionnaire is inspired by previous flow questionnaires: FSS2-36 [6], ECF10 French version of the Flow-Kurzskala [9], DH13 [3][2], CM09 [2]. The questionnaire consists of 16 items divided in 4 subscales: cognitive absorption, altered time perception, lack of self-preoccupation, well-being.

2.3 Skill

Skill is defined as the knowledge the user gain in mastering his activity in the virtual environment. The skill component can be measured by the Computer Self-Efficacy (CSE) questionnaire created by Murphy in 1989 [11]. This questionnaire is a reference in the education field to evaluate adult student's computer skills. This questionnaire helps understand the attitude of a user toward a computer technology, the degree with which he feels comfortable with a computer. The questionnaire consists of 32 items with 3 subscales representing different levels assessment of computer skills: beginning, advanced, mainframe.

2.4 Emotion

Emotion is defined as the feelings (of joy, pleasure, satisfaction, frustration, disappointment, anxiety, …) of the user in the virtual environment. The emotion component can be measured by the Achievement Emotions Questionnaire (AEQ) created by Pekrun in 2002 [13]. This questionnaire is used to assess emotion experience in achievement situations. There are 3 subscales representing 3 situations: class-related, learning-related and test-related. This questionnaire is based on 9 emotions: enjoyment, hope, pride, relief, anger, anxiety, shame, hopelessness, boredom. The questionnaire consists of 232 items. It proposes a large number of situations that matches or that can be easily translated in a situation such as a user being in a VE.

This questionnaire does not address a particular field, although some authors has developed a specific AEQ for Mathematics (AEQ-M) or for Language (AEQ-L).

2.5 Usability

Usability is defined as the ease of learning (learnability and memorizing) and the ease of using (efficiency, effectiveness and satisfaction) the virtual environment. The usability component can be measured by the System Usability Scale (SUS) created by Brooke in 1996 [1]. This scale has been created on a base of 50 usability questionnaires. It is used to assess "the appropriateness of a purpose", in other words, to evaluate if the way we propose to use our VE is appropriate. The questionnaire consists of 10 items. No subscales were identified in this questionnaire.

2.6 Technology Adoption

Technology adoption is defined as the actions and decisions taken by the user for a future use or intention to use the virtual environment.

The technology adoption component can be measured by the Unified Technology Acceptance and Use of Technology (UTAUT) questionnaire created by Venkatesh in 2003 [17]. It is used to assess the degree with which the user will adopt and use the system, in other words, the likelihood of success for new technology introduction. This questionnaire consists of 31 items divided in 8 subscales: performance expectancy, effort expectancy, social influence, facilitating conditions, attitude toward using technology, self-efficacy, anxiety, behavioral intention to use the system.

2.7 Judgement

Judgement is defined as the overall judgment of the experience in the virtual environment. The judgement component can be measured by the AttracDiff 2 questionnaire created by Hassenzahl, Burmester and Koller in 2003 [8]. It is used to assess the user's attraction in a pragmatic and hedonic way towards the system. This questionnaire consists of 28 items divided in 4 subscales: perceived pragmatic quality, perceived hedonic quality-stimulation, perceived hedonic quality-identification, attractiveness.

2.8 Experience Consequence

Experience consequence is defined as the symptoms (e.g. the "simulator sickness", stress, dizziness, headache, …) the user can experience in the virtual environment. The experience consequence component can be measured by the Simulator Sickness Questionnaire (SSQ) created by Kennedy in 1993 [10]. It is used to evaluate the negative consequences the user can have while using the IVE. These negative consequences are assessed through 16 items divided in 3 subscales: nausea, oculomotor problems, disorientation.

3. ELABORATION OF OUR OWN QUESTIONNAIRE

To be able to conduct experiments, to measure the UX in an IVE and to finally validate our holistic UX in IVE model, we need to create our own measurement tool (Table 1). Indeed, most of the existing questionnaires measure at the same time only one or two components of our model. It is an incomplete way in our situation to measure the UX in IVE.

The idea is to propose to the user one unique questionnaire that measures the whole 10 components of our model. As such questionnaire do not exist, we needed to elaborate our own questionnaire. The questionnaire elaboration consists of choosing suitable items from the original questionnaires. We relied on 4 criteria for the item selection:

1) The chosen items have been translated in several languages (at least in french).
2) The chosen items that have not been translated in french are easy to translate. The real meaning of the translated item is not modified.
3) The meaning of the chosen items is different enough from each other (even if they measure the same component), so that the user does not find the items redundant.
4) The chosen items are not ambiguous. Their meaning is easy to understand for the user.

By choosing to keep at most 3 items by subscale, in the end, our questionnaire consists of 79 items. We added 3 open questions at the end of the questionnaire to allow the user express the positive as well as the negative experience he wish to share and the improvements he wish to provide to the environment.

To make sure the items of our questionnaire are well correlated we will be conducting experiments with users playing a game in a VE. We collect data, in the first instance, to verify the intern reliability of our final questionnaire with the Cronbach's alpha[1]. As a second step, the results of the experiments obtained through the questionnaire will help in the validation process of our UX in IVE model.

4. FITTING THE QUESTIONNAIRE TO THE CONTEXT

We made some arrangement in order to create a questionnaire better related to VE. The criteria for these arrangement is to make sure the "Virtual Environment" words appear or fit well in the item proposed:

- In the PQ, some subscales (e.g. IFQUAL: Interface Quality; NATRL: Natural, AUD: Auditory, RESOL: Resolution) only had 2 or 3 items, in that case we did not have to make a selection and picked all of the items of the subscale (e.g. AUD: 14: "I correctly identified sounds produced by the virtual environment"; 15: "I correctly localized sounds produced by the virtual environment").
- In the ITQ, one item from the game subscale could hardly apply to VE. The items from the involvement and focus subscales did not apply right away to our context. Therefore, we chose items that could easily be adjusted to our context, and rewrote the items (e.g. "How mentally alert do you feel at the present time?" becomes "16: I felt mentally alert in the virtual environment", "How frequently do you find yourself closely identifying with the characters in a story line?" becomes "18: I identified to the character I played in the virtual environment" …).
- In the AEQ, one subscale could hardly apply to VE (i.e. Relief). For the 2 remaining subscales we chose to select 3 items, one for each emotion category (positive activating: enjoyment, negative activating: anxiety, negative deactivating: boredom) [13].

[1] According to the Statistical Package for the Social Sciences (SPSS), Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability.

- In the UTAUT questionnaire, 5 direct determinants of intention subscales could hardly apply to VE or were redundant (i.e. performance expectancy, social influence, self-efficacy, anxiety, behavioral intention to use the system). 3 of the subscale did apply to VE (i.e. Effort expectancy, attitude toward using technology, facilitating conditions).
- We adjust most of the items we selected so that they could fit perfectly to VE. In some cases, changing the words "system" to "virtual environment" was enough, in other cases we did adjust the item to apply for VE (e.g. "I enjoy being in class" becomes "37: I enjoyed being in the virtual environment").

Table 1. Items selected from the original questionnaires for our own UX in IVE questionnaire

UX Component	Original questionnaire	Subscale	Item ID in the original questionnaire
Presence	Presence Questionnaire (PQ)	INV/C	2, 9, 16
		NATRL	3, 5
		AUD	20, 21
		IFQUAL	17, 18, 19
		RESOL	11, 12
Engagement	Presence Questionnaire (PQ)	INV/C	4, 10, 13
Immersion	Immersive Tendency Questionnaire (ITQ)	FOCUS	3, 7, 18
		INVOL	4, 5, 16
		GAMES	6
Flow	Flow4D16	Cognitive absorption	D1b, D1c, D1d
		Altered time perception	D2a, D2b, D2c
		Lack of self-preoccupa-tion	D3b, D3d
		Well-being	D4a, D4c, D4d
Usability	System Usability Scale (SUS)	N/A	3, 6, 8
Skill	Computer self-efficacy Scale (CSE)	Beginning	15, 21, 23
		Advanced	10, 14, 24
Emotion	Achievement Emotions Questionnaire (AEQ)	Class-Related	JOY : 24, 41, 49; ANX : 35, 50, 56
		Learning-Related	JOY : 124, 131, 117; ANX : 125, 102, 96; BORE : 112, 119, 109

Table 1. Items selected from the original questionnaires for our own UX in IVE questionnaire (continued)

UX Component	Original questionnaire	Subscale	Item ID in the original questionnaire
Experience Consequence	Simulator Sickness Questionnaire (SSQ)	Nausea	6, 7, 8
		Oculomo-tor	2, 3, 4
		Disorienta-tion	10, 12, 14
Judgement	AttracDiff 2	Pragmatic Quality	QP(QP3, QP6, QP7)
		Hedonic Quality-Stimulation	HQS(HQS1, HQS5, HQS6)
		Hedonic Quality-Identifica-tion	HQI(HQI2, HQI3, HQI7)
		Attractive-ness	ATT2, ATT3, ATT7
Technology Adoption	Unified Technology Acceptance and Use of Technology (UTAUT)	Effort Expectancy	EOU3, EOU5, EU4
		Attitude toward using technology	A1, AF1, Affect1
		Facilitating conditions	PBC2, PBC3, PBC5

5. CONCLUSION

In previous work [16] we have proposed a UX in IVE model that defines in a holistic way the UX. Our model is generic and can be used in most of the fields of VR (simulation for education and learning, virtual worlds for entertainment, realistic situations for edutainment or serious games). This paper presents the next step of our work that consists of creating a suitable tool to measure the UX in VE according to our model. The first tool we propose and described in this paper is an exhaustive (all dimensions are considered), and synthetic questionnaire (82 items).

This paper described a questionnaire which is a first step for a methodological framework aiming to measure the UX in IVE. A first research perspective is to conduct experiments and use our questionnaire to evaluate the user experience in several virtual environments. The first experiment using our questionnaire has actually begun. The virtual environment that is used for the experiments is an edutainment virtual application. We collect data from the user, in the first instance, to verify the intern reliability of our final questionnaire and as a second step, we validate our UX in IVE model thanks to the results of the experiments obtained through the questionnaire.

Moreover, UX in IVE should be measured both through subjective and objective methods. So, even if this paper focus on a subjective method, future works aim at the elaboration and the validation of our methodological framework by proposing objective methods as well.

In the experiments we actually conduct, we gather both subjective results (components measures by questionnaire) and objective results through physiological measures such as skin conductance and heart rate and performance measures such as level completion time, level score, level reached, number of failure in the level.

6. ACKNOWLEDGMENTS

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