DESIGNING FOR THE HANDS IN VR. *DESIGNING AND ASSESSING HAPTIC AFFORDANCES FOR HAND TRACKING INTERACTION IN VR. A CASE STUDY ON EMPEROR (FRENCH AWARD WINNING VR PROJECT)*

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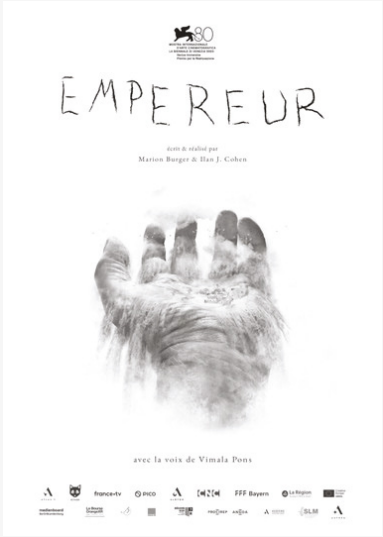

Fig1. EMPEROR french poster for Venice Festival 2023

Abstract: In this paper, we propose a simple but robust method to analyze hand tracking (HT) interactions, as haptic affordances, in Virtual Reality. In the logic of research creation, we have used EMPEROR, French VR artwork, as a ground for UX design research, with HT-based interaction design. EMPEROR offered an empirical field of research for haptic affordances, throughout the development. The aim of the study was to analyze if the users understood how to use their hands for two specific tasks. We proceeded to a blend of qualitative and quantitative methods and chronometry, to compare the performance of two groups of people (neophytes vs. acquainted VR users). The results show that performances are not better for skilled VR users, they depend on multiple factors such as analogy with IRL hand gestures, knowledge, and expectations inherited from video-games... This study could help game designers and researchers, both with UX and UI to enhance HT interaction design in VR.

Keywords: Virtual Reality (VR), hand tracking (HT), User Research (UR), interaction design, Human computer interaction (HCI), affordance

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I. Introduction

Hand tracking (HT) interactions in Virtual Reality present many technological challenges for developers and constraints for designers. All along the development of a VR project, play testing sessions offer insights to assess and improve the product to fit a target audience (Esposito, 2017; Hodent, 2018). In the context of narrative Virtual Reality (VR) experiences and games, user research is lacking quick and easy-to-use methods that offer both the scientific rigor and the adequation to an industrial schedule. This paper aims at gathering knowledge from and for the VR gaming industry and for art-based VR projects. It is an attempt to formalize a model of playtesting for any VR interactions involving HT.

By the end of 2022, most research on HT has been investigated from a tech-oriented perspective. In fact, we can find in the literature a set of technical guidelines and limitations for the development of HT interactions in VR (Abdlkarim et al., 2022; Kelly, J.W. et al.,2022). Authors have shown the limitations of HT accuracy with the Quest 2. For example, their work has demonstrated that peripheral regions have a strong impact on accuracy, but not the height. When it comes to ergonomics and behavioral psychology, both disciplines help provide models to evaluate the usability of designs. Norman's adaptation (Norman, 2004) of Gibson's concept of affordance (Gibson, 2014) is central in User Research and UX best practices. It provides a theoretical and empirical framework for improving usability in HCI. The International Standardized Organisation (ISO) offered a definition of usability as "The extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficacy, and satisfaction " (1998).

Eventually, haptic also presents some major concerns in VR as it would imply interfaces that take into account the sense of touch. Such devices are intrusive for the user, which is why manufacturers and researchers have focused on pseudo-haptic feedback, with joysticks, gamepads, or mice, for example (Lecuyer, 2001).

II. Literature review

Hand Tracking

Our survey revealed that research on HT interactions is mostly looked at technically, and we postulate this is a product-centered design approach, as opposed to a user-centered approach (Norman, 2013). In that context, new features from the manufacturer's development team (Meta, HTC Vive, Pico,etc.) often lead to object-centered design protocols (Abdlkarim et al., 2022; Kelly, J.W. et al.,2022), in which users have to adapt to the product. Design studies, on the other hand, suggest another paradigm called used-centered design. Design studies have proven to offer robust models for analyzing and improving the user experience with a product (Hodent, 2018).

Haptic

The tactile-kinesthetic perception, or haptic (Revesz G., 1934), is the stimulation of the skin from active movements of the hand while exploring its environment. This kind of perception is considered active and should be distinguished from tactile perception that is passive. The stimulation goes beyond the skin as the exploration of the hand leads to mechanical deformation of muscles, articulations, and gristles too (Lécuyer, 2001). When it comes to developing VR applications, the simulation of haptics can become rapidly complex, if only possible.

Several authors (Gentaz E. et al., 2000) explored haptic as a way to perceive objects. Lecuyer suggests the exploration and assessment of pseudo-haptic feedback, as a simulation technique, both in the sense of a computational simulation and that of a sensory illusion. In fact, pseudo-haptic feedback offers the possibility to have the illusion of textures, roughness, and mass of objects, by using properties of human perception, like visual dominance (Lecuyer, 2001). Hand tracking, though, raises the challenge to another level as there are neither controllers nor mice. Interaction design is the discipline that tries to answer those challenges, by acknowledging the importance of the User Interface (UI), in a context of visuo-dominated User Experience (UX). We should highlight that sound can also play an important role in VR for immersion (Larsson, 2002) usability, and poetic expression as well (Fuchs et al., 2003; Fuchs et al., 2006).

Affordance

Affordance has been a key concept since Norman's (Norman, 2013) adaptation for interface design, and particularly constructive for HT. Originally based upon ecological psychology theory, from J.J. Gibson (Gibson, 1979), affordance is a concept in visual perception that explains the relationship between living species and their environment. To afford is to enable, to facilitate. A chair induces sitting on it because its design affords it. A handle on a bottle or a cup affords the prehension of the fingers. Yet, few studies focus on the measurement of affordance for VR narrative games or artwork. In fact, usability has been addressed in comparison between controller-based interactions and HT interactions in VR, but not in regard to the concept of affordance (Voigt-Antons et al., 2020). VR HT-based interaction games were interrogated but with FPS (First Person Shooter) mechanics, to which Emperor experience cannot be compared (Rachevsky et al., 2018). Also, some authors addressed a similar hypothesis of affordance, called perceptual cues (He E. et al., 2021). First, these cues are considered audio or video (or both), but they do not mention haptics. Secondly, the paper raises the question of guiding users' attention. Thus, they do not address directly the usability through the lens of perceptual cues. So how to measure and assess affordance? We raise the question of usability with HT-cendered design through the lens of affordance, in the context of a narrative VR game. We postulate that for a given group of neophyte VR users, performances are expected to be weaker than for acquainted people, and that HT interactions should be designed as affording as possible. Following Gould and Lewis guidelines for further and replicable playtests, this case study occurs at the very first stages of development of the game. Our methodology is based on "empirical measurement of usage" (Gould and Lewis, 1985) as we record users performances with chronometry on task completion, as an efficient and rapid method in the video game industry.

III. Methodology

The study relies on 20 individuals (12 females, 8 males), aged from 18 to 55, without major visual deficiency. We are aware that the sample is limited and that a bigger population could prevent some biases, like gender and age. However, we assume that the protocol offered in this paper is laying the first brick for further research. The recruitment process was based on personae, upon which we elaborated socio-demographic criteria. The selected participants were sorted into two groups. Group A was the target audience, best fitting the personae, and Group B was the wider audience. In order to sort people out, we established 6 parameters as follows: 1. age/ 2. profession/ 3. location (2 and 3 were arranged as a boolean answer, either target or wider)/ 4. video game familiarity/ 5. VR familiarity/ 6. cultural pro-

gram habits. Unlike clinical studies and experimental psychology methods, the two groups underwent the same test conditions. The study was arranged over 5 days. Each session lasted an hour and a half.

Parallely, but of considerable importance, a strict protocol was respected regarding the technical equipment (*see fig2*). Good lighting conditions are primordial to any VR experience using handtracking with the Meta Quest, although some major improvements have occurred, in late 2022. We used the Meta Quest 2 head mounted display (HMD) as Emperor was designed for this headset. Here is listed the equipment used throughout the experiment.

Fig. 2: technical set up for the playtests with natural lights and 180° reflector.

- 2 lights (intensity approx. 6.2)
- 2 soft boxes
- 1 curved reflector
- 1 white cyclo
- 1 rotating chair
- 1 computer for streaming
- 1 headset without controllers

Users were expected to use their hand(s) in HT for the two following tasks:

1. Writing with your finger(s) (*fig.2*).
2. Teleport with your index finger (*fig.3*).

A tutorial was given IRL prior to the VR experiment to adopt the right teleport gesture. We also randomized the order of the features to test, to avoid bias in the performances.

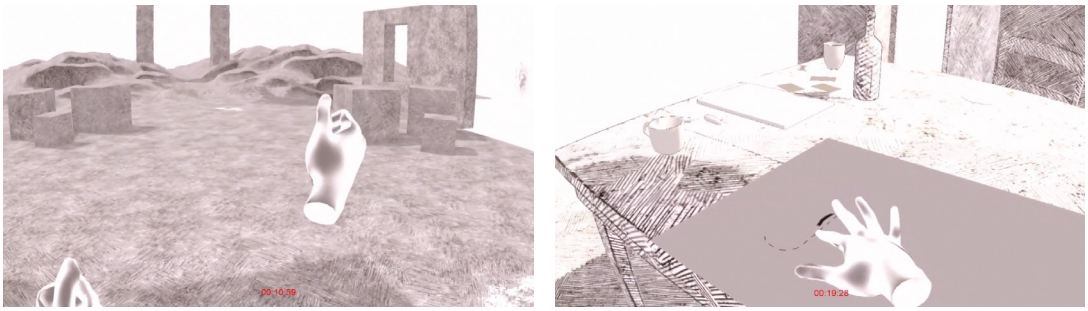

Fig. 3: screenshots from casting in real time during study, writing task (above) and teleporting task (below)

The purpose of this study is to experiment and assess a new framework for user study in Virtual Reality with a focus on usability. By using simple metrics such as chronometry to measure performance for specified tasks, we are able to acknowledge very rapidly the effectiveness, efficiency, and satisfaction of use of the designed systems.

Data processing and analyze

The data was collected from a timer we added to the stream of the playtest via OBS software (*fig. 3*), and Side Quest software for the casting of every game session. Written observation was also conducted, as part of the semi-structured interview.

The results were gathered in a tab. Then we calculated the median and interquartile range so that the performances were sorted in a rapidly comprehensive graphic. For this reason, we used boxplot (*fig. 4*). By using dispersion of results, we were able to acknowledge the differences between the two groups for both tasks. Histograms were also used for both tasks to see individual performances within their groups.

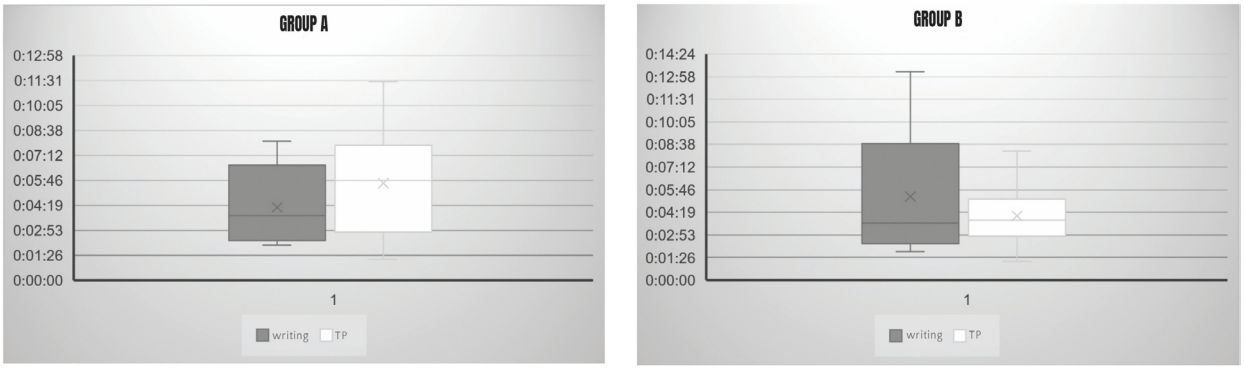

Fig. 4: dispersion of results for each group on each task

IV. Results

The experiment was mixing methods in such a way that we analyzed statistical results but also verbatim, and answers from the comprehension oral questionnaire (*Tab1*). We decided to create an ad-hoc post-test questionnaire and not to use existing UX questionnaires like the System Usability Scale (SUS), or the Game Player Experience of Need Satisfaction (PENS), for two reasons. First because the questionnaires don't fit the narrative game mechanics of *Emperor* (interactions are scarce and users are mostly passive). The second rea-

son is because they don't address the question of affordance regarding the usability of a system or a game (Johnson, D. et al., 2018).

Table 1 Oral questionnaire after experiencing all the tasks.

Condition	Question
For each task	Could you describe to me the interactions that were offered to you and what you understood from the scene?
Overall experience	• Could you tell me about the emotions you may have felt while interacting with the game? • Among all the interactions, is there one that you liked more than the others? • Is there one that you liked less than the others?

We decided to compare the two groups only for the quantitative data collected and decided to ignore the qualitative information (posture and verbatim while testing). In this chapter, we will explore objective observations from the users and how to answer our hypothesis.

Hypothesis: The target audience does not know the codes of video game storytelling, they are not familiar with VR interactions such as hand tracking and 360° environments. Interaction and handling times will be longer. The control audience will be faster because of their acquaintance with gaming and VR.

Core UX problematic: are HT interactions understandable for the audience, and do they serve the narrative?

Dispersion

The findings of this study show that for the writing task, the neophyte group (Group A) completed the task in a shorter period of time than the control group (Group B). But it is the opposite for the second task, the teleportation (TP). The first quartile (Q1) is almost equal for the two groups, and the medians (Med) are close for the writing task:

Q1 A: 0:02:21 / Q1 B: 0:02:22 *Med A: 0:03:43 / Med B: 0:03:00*

For TP, the Q3 revealed a significant difference in performances between the two groups. Group A shows a greater dispersion of results. 4 people out of 12 couldn't accomplish it.

Q3 A: 0:07:06 / Q3 B: 0:04:45

The hypothesis was only verified for the TP but not for the writing task. Dispersion is greater for Group B on the writing task, but performances with the teleportation task are more homogenous. Rather, dispersion is greater for Group A on TP, but performances on the writing task are slightly more homogenous in comparison to Group B.

V. Discussion

Evaluation

We can analyze these results from the perspective of haptic affordance and start formulating new hypotheses. Indeed, our protocol was built upon the comparison of time completion for two tasks between two groups. In the last chapter *(see IV. Results)*, the boxplot revealed surprising performance for each group. We postulate that writing with your finger is considered a more intuitive gesture, in a direct perception and that *Emperor* writing system *(see Fig. 3)* provides affording haptic interaction. As Gibson put it, perceiving affordance is an operation that neither requires further cognitive processing nor the apprenticeship of the movement (Gibson, 1979). On the contrary, teleportation, as a design decision for moving one's avatar in a 3D environment, demands the acquaintance of such mechanics. For instance, group B, which was already familiar with video games or VR environments, showed greater performances on the TP task than group A. Following our new hypothesis, we can postulate this: the design proposal for TP, in this case, the frame of a portal *(see Fig. 3)*, was affording enough for them to understand what the system was expecting from them.

Designing for the hand(s) in VR requires adapting the UI and the UX according to the target audience. For that purpose, research must be done prior to playtests on potential targets with all necessary disciplines in the humanities. Building personae as thoroughly as possible can help designers prevent the users from not understanding what is expected from them, which can cause players or viewers to stop using the game or artwork.

VI. Conclusion

This study was limited by the version of the executable program, which showed a lack of narrative context like helpers (voiceover, heads-up display (HUD)). Indeed, the gesture of teleportation was given before each session. We believe this could have brought a bias of memory that could be prevented with a diegetic tutorial. But the problems with testing basic features or WIP (work in progress) are inherent to any playtests, either in the videogame industry or the VR's. To go further, we could use more complex statistical models like structural equation modeling (SEM) in order to address hypotheses that question the relations and the intensity between metrics and variables from questionnaires. In a word, offer a model that blends quantitative and qualitative methods for user studies in VR artwork or games.

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