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MAPPING HUMAN FACTORS IN VIRTUAL REALITY: VRUX

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Industry 5.0 addresses the technocentric limitations of Industry 4.0 and opts for a more human-centred industry. This affects the different technologies that are already being implemented in manufacturing such as exoskeletons, wearables, cobots and even augmented and virtual reality. The latter enables the possibility of simulating hyper-realistic environments that may occur in industrial processes and using them for simulation, training or even performing tasks remotely. Based on the existing literature, this paper analyses the human factors related to user experience in immersive environments, and the relationships among VR quality components like presence, immersion or interactivity. As a result, the VRUX Map is created. An ontology that is intended to be a starting point for research and get to understand how the UX is enhanced by the extra quality components VR offers compared to previous technologies regarding industrial VR experiences.

Keywords: virtual reality; industry; human factors; user experience

MAPEO DE LOS FACTORES HUMANOS RELACIONADOS CON LA REALIDAD VIRTUAL: VRUX

La Industria 5.0 aborda las limitaciones tecnocéntricas de la Industria 4.0 y opta por una industria más centrada en las personas. Esto afecta a las distintas tecnologías que ya se están implantando en la industria, como los exoesqueletos, los wearables, los cobots e incluso la realidad aumentada y virtual. Esta última permite la posibilidad de simular entornos hiperrealistas que pueden darse en los procesos industriales y utilizarlos para la simulación, la formación o incluso la realización de tareas a distancia. A partir de la literatura existente, este trabajo analiza los factores humanos relacionados con la experiencia del usuario en entornos inmersivos, y las relaciones entre componentes de calidad de la RV como la presencia, la inmersión o la interactividad. Como resultado, se crea el Mapa VRUX. Una ontología que pretende ser un punto de partida para la investigación y llegar a comprender cómo mejora la UX gracias a los componentes de calidad adicionales que ofrece la RV en comparación con tecnologías anteriores en lo que respecta a experiencias industriales de RV.

Palabras clave: realidad virtual; industria; factores humanos; experiencia de usuario

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1. Introduction

The technological evolution of the last decades has enabled the application of new technologies for media consumption, manufacturing from images, digital documents or videos to video games, interactive experiences or even digital twins through virtual reality. Virtual Reality (VR) is rapidly evolving, but, like other interactive technologies, the promising applications of VR, its effectiveness specially in manufacturing industry and its success, depend to a large extent on the quality of the user experience. Even so, we must bear in mind that the VR field is still at an early stage. The variety of new devices and platforms currently used for VR services, the undeniable technological challenges, the different research approaches and concepts, together with a market hype that may or may not be justifiable, are obstacles to overcome. There are guidelines that can serve as a point of reference, but due to this variety of information and sources, it is sometimes difficult to identify valid patterns that can be beneficial for designers of VR experiences (Vi et al., 2019)

However, there are different studies that analyse how these UX factors impact each other based on quantitative and qualitative experimentation. For example, Mütterlein,(2018) defined and tested a hypothetical map showing how immersion directly influences user satisfaction, which at the same time is affected by both telepresence and interactivity. It also tests the effect of interactivity on telepresence and immersion. Then, focusing on educational contexts, considering that "learning" was the ultimate goal, Makransky & Petersen, (2021) developed a similar map, showing which factors and how their relationships generate a satisfactory experience. In that map, other factors such as agency, interactivity and presence also appear.

Based on such literature, this paper presents an ontology that maps the interrelationships between the quality components of VR and the points where UX can have the most impact.

1.1. Objective

This paper aims to present a first approach to identifying the human factors related to the user experience in immersive environments and the relationships between the quality components of VR. In the same way, the paper aims to establish the basis for the creation of the VRUX Map.

The creation of this ontology intends to be a starting point for future research and to understand how the user experience improves by the additional quality components offered by VR compared to previous technologies in the field of industrial experiences in VR. Ultimately, it details the basis for further development of a new framework for analysing VR experiences based on the user experience components.

2. State of the art

Based on the two key fields to achieve the objective of this communication, a literature review has been carried out using the snowballing methodology (Wohlin, 2014). The findings of the review are shown below.

2.1. VR Quality components

In this section, a review of the literature has been carried out to identify the most relevant characteristics of VR that add value to the user compared to these other technologies.

There are 3 components that are considered main quality components of VR: presence, immersion and interactivity (Mütterlein, 2018), being the first two that add different value versus other media platforms(Jung & Lindeman, 2021) .Also, these key components enhance the user experience in media consumption and more interactive ecosystems such as videogames, education and manufacturing.

Based on research to understand their meaning and role in VR platforms, a deeper knowledge of these three components is given. It must be said that these are not independent quality components but interrelated elements that offer satisfactory user experiences (Mütterlein, 2018). In addition, it is noticeable that there were many discrepancies when agreeing on general definitions, even though they all have similar cores. Some researchers rely on a purely objective perspective when defining the concepts of immersion and interactivity, whereas others define them as subjective characteristics, as shown in the next points. After the above-mentioned research, at the end of the section Table 1 is shown with the identified quality components and their definitions.

2.1.1. Presence:

Presence has been defined in many ways, mostly based on psychological perception. Starting in 1980, when MIT professor and artificial intelligence pioneer Marvin Minsky described it as "the phenomenon where a human operator develops a sense of being physically present at a remote location through interaction with the system's human interface" (Coelho et al., 2006; North & North, 2016).

The memory process can be highlighted among the many characteristics that affect this phenomenon since it plays an important role in activating the sense of familiarity. Therefore, it makes the user feel that he or she recognises the space in which it is present (Cerda et al., 2021) and which can be achieved by producing sensory-rich or vivid environments (Steuer, 1992) In addition to the visual perception of the space, other senses also play a big role in creating the sense of presence, such as haptic or auditory feedback (Kim et al., 2017), which are the basic means of interaction.

The first quality component, presence, is the consequence of many technically generated factors, such as vividness, realism, and interactivity. Nevertheless, the concept is more related to the human experience, where the subject feels like being in another place, either real or virtual, and reacts consequently (Steuer, 1992).

2.1.2. Immersion

In addition to the feeling of presence, this is considered another key value of VR experiences, which has been defined both as an objective and subjective element (Wohlgenannt et al., 2020). Considering this term dependent on technical factors distinguishes it from the concept of presence, as definitions of immersion based on subjective perception mainly state that it is the feeling of being caught up in the virtual world, like the previous component.

Considering immersion as an objective property of a system, it is said that the technical factors influencing a high level of immersion are the Field of View (FOV), the Field of Regard (FOR), the size of the display, resolution of the display, stereoscopy, head-based rendering, lightning, choiframerate, refresh rate, the number of senses it simulates, the realism of the displayed images, latency, etc.(Bowman & McMahan, 2007; Choi et al., 2019; Sanchez-Vives & Slater, 2005). On the other hand, when looking at this characteristic from a subjective standpoint (Mütterlein, 2018; Witmer & Singer, 1998) , which makes more sense when analysing the user experience, Mütterlein describes it as a flow-based concept, which is generally affected by dimensions such as temporal dissociation or merging of action and awareness.

Two different components have been identified based on the different perspectives from which immersion has been defined. The first one, immersion, highlights the technical characteristics of VR platforms. The other one, focuses on the psychological characteristic of the flow state as a way of perceiving and reacting to the experience.

2.1.3. Interactivity

This component is common with previous digital systems. The ability to impact the system has almost always been a key value of media consumption platforms and digital systems such as games, web, or mobile apps. As an immersive medium, VR environments become more valuable as users can interact and live the experiences as if they were real. That is why the capacity to make changes in space and get realistic reactions from the environment makes this technology so immersive and innovative. This term has mainly been defined as a technical component, referring to the extent to which the user can make changes in the environment. In this case, the response time of the virtual world is key since the immediacy of responses affects the quality of the feedback from the environment. Also, the number of possible results or reactions from users' actions is crucial for interactivity. Finally, when it comes to technical aspects, the ability of the computer system to produce results as good as the real world responding to user actions, thus, vividness, also increases interactivity (Petersen et al., 2022). Following the same approach as immersion and considering that this project focuses on user experience in VR, a subjective perspective regarding interactivity is also considered. In this case, the human factor of consciousness plays a big role in offering good experiences. Therefore having the sense that the user can act on the stimulus (or fail to do so) that is received by the environment also affects the experience. This stimulus is called agency (Sanchez-Vives & Slater, 2005).

The fact that a VR environment is designed with plenty of interactive elements adds no value to the experience if users are not conscious of their capacity to impact them. That is why, as it is made with the term Immersion, the concept of interactivity is also divided into two: interactivity and agency.

As can be seen, for the same terms, different authors describe them slightly with different nuances. That is why, in addition to identifying the five quality components, Table 1 also shows the definitions that will be used as a reference for the continuation of the discussion.

Table 1:Quality components and definitions

Quality component	Definition
Presence	“The subjective experience of being and experiencing one place or environment, even when one is physically situated in another” (Sanchez-Vives & Slater, 2005)
Immersion	“The objective level of sensory fidelity provided by a VR system.” (Bowman & McMahan, 2007)
Flow State	“The state where users are fully immersed in activities that capture their interests to the exclusion of most other realities outside of themselves.” (Hassan et al., 2020)
Interactivity	“The extent to which users can participate in modifying the form and content of a mediated environment in real-time.” (Steuer, 1992)
Agency	“The feeling of generating and controlling actions a user has over their current environment or situation.” (Makransky & Petersen, 2021)

In conclusion, five quality components have been identified that have sufficient relevance to be analysed individually, bearing in mind that they are not independent of each other, as mentioned above, but are interrelated. In other words, a change in one of these components could also affect the rest. This comprehensive understanding of the components is essential to further advancing VR technology and optimising virtual experiences. Maintaining a clear understanding of these key components, as well as their interrelationships, to provide more engaging and satisfying user experiences in the future. By doing so, the full potential of VR as a transformative medium can be realised, ultimately enriching various aspects of human life and interaction.

2.2 User Experience

Once the literature about VR is analysed and summarised, UX theories are also checked to understand its current context and the key considerations for designing nowadays.

The most extended definition of UX is based on perceptions and responses (International Organization for Standarization [9241-210:2019], 2019) which means that, in the end, it is subjective.

Apart from the definition of the UX, components affecting the overall experience of products, services and processes have been analysed and improved for centuries, from space design to physical ergonomics or digital usability. This evolution, specifically in the last decades of the digital area, led to the definition of different theories about user experience. The UX Honeycomb (Morville, 2005) defines and connects the main characteristics of a good user experience. (Dillon, 2018.) This Honeycomb model is one of the most known UX models, and it has been used many times as an educational tool since it was created in 2004. Nevertheless, one key problem keeps this model incomplete, as Katerina Karagianni assures in one of her articles. There needs to be more connection between the components, which made the theory lose clarity. That is why she updated the visualisation of the UX Honeycomb, which is used as a reference for this article. In it, almost every concept mentioned until this point is grouped in a simple and understandable image (Karagianni, 2018) The seven key qualities are highlighted, which are:

- **Desirable:** The quality of making the brand and experience attractive to the user.
- **Credible:** The quality of being trusted by the user on what the design transmits.
- **Accessible:** The quality of being easy to use for people with a wide range of abilities.
- **Findable:** The quality of being easy for navigation and object location for users to find what they need.
- **Usable:** The quality of being easy to use and understand to achieve specific goals with effectiveness, efficiency, and satisfaction in a specified context.
- **Useful:** The extent to which the system serves a purpose for the target user.
- **Valuable:** The quality of being able to help users and business get their goals while improving user satisfaction.

3. VRUX Map

Regarding VR, a summary of all gathered information is offered in the VR Map. There is also an explanation of all the five main quality components and their relationships. In addition, the specific elements that create or enhance those components are analysed and explained, aiming to simplify the VR value framework in one image.

Figure 1 shows the map proposed, aiming to show the connections among the main quality components of VR in a way that makes the reader understand how these valuable characteristics are generated and interrelated. Furthermore, the UX impact points are pinpointed.

Firstly, these components are divided into technological and human factors since the main value these technologies offer is the ability to make users be in new worlds, focusing on their feelings and consciousness. Technological development of VR platforms has many elements to focus on, among which we can find the Field Of View (FOV), latency, resolution, display size, etc. Many types of hardware and software can be used to develop these environments and create high-quality scenarios and experiences. It is known that there are multiple cases in which characteristics vary, but technological development needs to get some realism, vividness, and feedback as its basis.

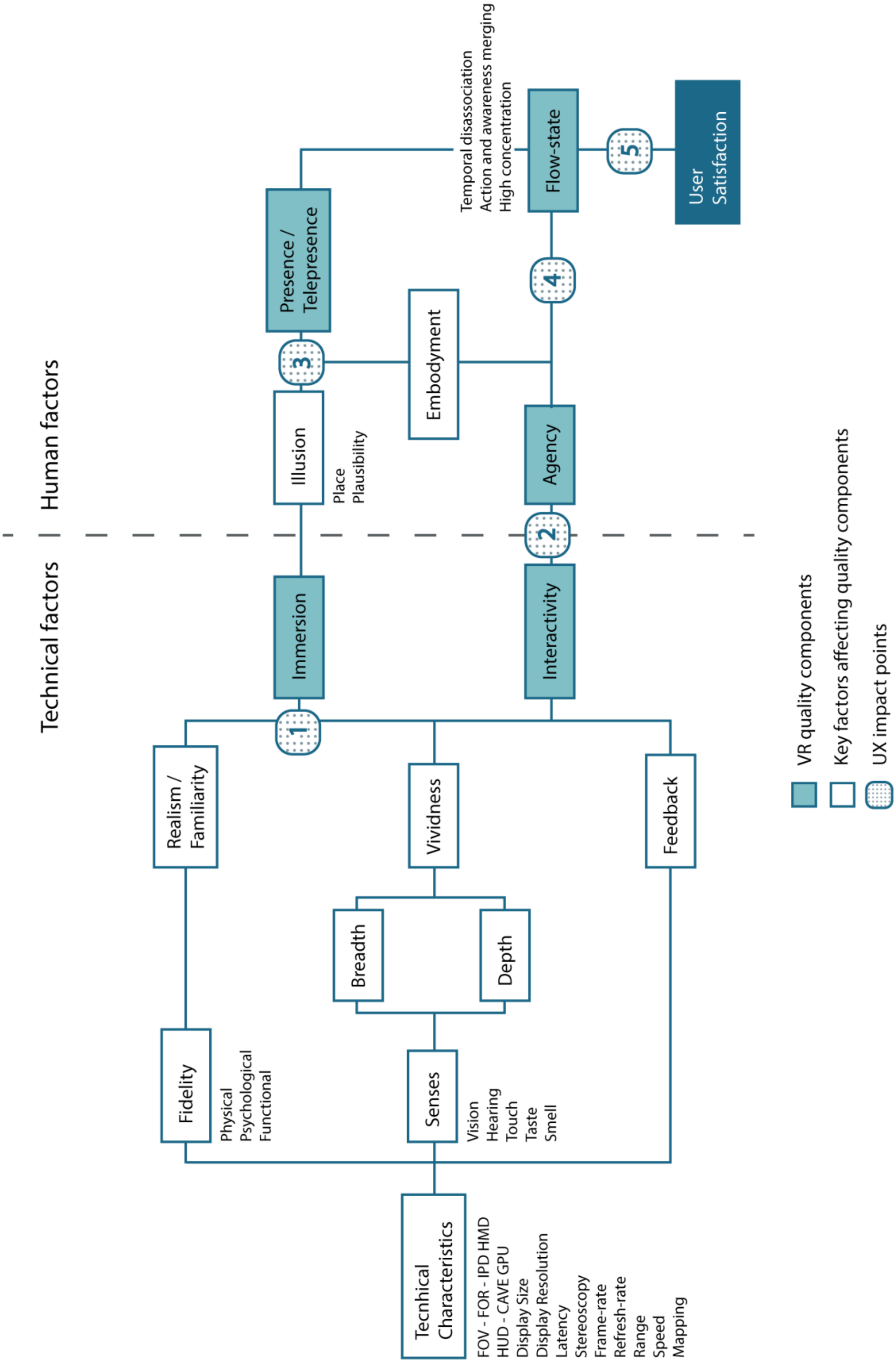

Figure 1: VRUX Map

Realism, also called familiarity, refers to the extent to which the virtual environment emulates the real world (Jung & Lindeman, 2021). Generating familiar environments by making high-quality sensory experiences will increase users' immersion and enhance the sense of presence.

Vividness also affects immersion since it is described as the representational richness of a mediated environment as defined by its formal features, that is, how an environment presents information to the senses (Steuer, 1992) It also affects interactivity by alluding to those senses that make the experience like one in the real world, which, added to great feedback, leads to a high-quality interactive platform.

Approaching the human aspect of VR experiences, research shows that a couple of phenomena need to occur for the user to feel presence and agency: illusion and body ownership (when wanting to represent the user in the virtual world). The first element is divided into two specific components related to users' belief of what is happening, place illusion (PI) and plausibility illusion (Psi). PI is defined as the strong illusion of being in a place despite the sure knowledge that you are not there, which is often called presence, and it is constrained by the sensorimotor inputs and actions afforded by the VR system. Psi has been described as the illusion that the scenario being depicted is occurring, and it is determined by the extent to which the system generates events that directly relate to the participant. (Slater, 2009) The combination of both types of illusion offers a deeper understanding of presence. In addition, when the human body or parts of it are represented in the virtual world very realistically, and users feel that it is their own body by how they move around and interact with elements, body ownership is generated, which also enhances presence.

Finally, as the concept of flow state has been considered a key quality component of VR experiences, this map describes it as a combination of presence and agency. Feeling that the user is in a place and that the things that are happening there are occurring, as well as his or her controllability of the environment, pushes consciousness to focus on what is going on in that very moment, enhancing action and awareness, merging concentration, and temporal dissociation.

4. Discussion of the VRUX Map

The proposed VRUX Map, not only focuses on the quality components and their connections, but also pinpoints where and how a good user experience can be better achieved. This is marked in the in Figure 1, and they represent the 5 statements presented below:

1. High levels of vividness and realism increase desirability and credibility, as familiar and high-quality sensorial environments are more appealing and trusted by users: Deep sensorial experiences in VR, primarily through sight and hearing, create immersive environments that elicit instinctive, visceral reactions. High desirability stems from attractive design and high-quality technical development, boosting trust and attractiveness. Although human factors influence desirability and credibility, technical development forms the foundation for these elements. Consistent, appealing, high-quality environments enhance familiarity and vividness, increasing user engagement.
2. Well-developed interactivity improves accessibility, findability, and credibility because it offers clear, understandable, and easy ways of experiencing the environment for people with a wide range of abilities, which increases trust in the design: Driven by the gaming industry, VR technology emphasises interactivity. Effective interactivity fosters user trust, reduces confusion, and accommodates diverse abilities. Designing accessible environments and offering varied interaction methods contribute to user control and understanding. Proper system structure and UI elements are essential for fostering interactivity and agency.
3. The combination of high immersion and agency increases the sense of the user's presence since a high level of sensory fidelity and awareness of the ability to interact with the environment makes the user feel inside it, which enhances both desirability and credibility. Technical aspects enhance attractiveness and trust in VR but ultimately rely on human perception. Presence, the main value offered by VR, influences these

emotions. Combining immersion and agency creates a presence involving various design disciplines. Aesthetics and interactivity both play crucial roles in generating presence, the core quality component of VR systems.

4. A good agency is the main quality that improves usability among VR Quality Components. It is key for users to acknowledge their ability to interact with the environment to get tasks done easily: Usability hinges on users easily interacting with elements in their environment. Clarifying users' roles and abilities, such as moving, touching, and controlling within the immersive world, is essential. Clearly define user goals and means of achieving them, optimising system structure and interfaces for seamless interaction. Effective communication of interaction possibilities fosters swift goal attainment.
5. Usefulness comes from achieving what is needed, and value is generated by getting what is needed through a satisfactory experience: Usefulness and value in UX arise from meeting users' needs with satisfying experiences. Users continually engage with products/services fulfilling necessities like entertainment, learning, or communication. Understanding and addressing user goals through research and enjoyable interactions 7sabil good systems offering value.

In practical terms, the VRUX Map would offer a comprehensive guide to creating high-quality VR experiences. By focusing on the components that contribute to user experience, the map highlights the key elements that can improve desirability, credibility, accessibility, and usability. At the heart of these components are human perceptions, feelings, and reactions, which ultimately determine the success of a VR platform. While technical development is undoubtedly important, it is the combination of technical proficiency and human-centric design that creates truly immersive and engaging experiences.

5. Conclusions and future work

The five statements presented in the VRUX Map demonstrate the interplay between technical and human factors. High levels of vividness and realism increase desirability and credibility, as familiar and high-quality sensorial environments are more appealing and trusted by users. Well-developed interactivity improves accessibility, findability, and credibility by offering clear and easy ways of experiencing the environment. The combination of high immersion and agency increases the sense of the user's presence, which enhances both desirability and credibility. A good agency is the main quality that improves usability among VR Quality Components, making it key for users to acknowledge their ability to interact with the environment to get tasks done easily. Finally, usefulness and value are generated by meeting users' needs with satisfying experiences.

Overall, the VRUX map highlights the importance of considering users' goals, abilities and perceptions when designing VR platforms. By creating immersive and interactive environments that offer clear goals and means to achieve them, designers can create VR experiences that are both technically proficient and human-centred. Ultimately, it is the combination of technical and human factors that creates VR experiences that are engaging, useful and valuable to users. However, it should be noted that this is a proposal that needs to be validated, and therefore various actions have been identified to further develop and validate this ontology. It would also be interesting to develop similar use cases with small variations regarding the individual factors mentioned above, to see if changes made in one of the aspects also affect other directly related quality components, in the same way as (Mütterlein, 2018).

Last, but not least, it would be interesting to deepen into the tools for assessment. Now these quality components and factors are identified, it would be interesting to carry out a literature review of what tools, both qualitative and quantitative, exist to measure or evaluate each of the quality components to be able to evaluate the VRUX Map more effectively. It is also true that it is not known whether these tools evaluate the quality components individually or whether they take into account the interrelation proposed above with the ontology.

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