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The notion of immersion in virtual reality literature and related sources

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Abstract—The paper gives an overview of how virtual reality (VR) literature and related sources describe the notion of immersion, its sub-types and similar terms. There are two main schools giving definitions for immersion in VR, and their definitions are quite different. One school, associated with B. Witmer and M. Singer, regards immersion as a psychological state of the user. The other school, based on the works of M. Slater, sees immersion as an objective characteristic of a VR system. Some authors call the first type of immersion "psychological immersion" and the second type "technological immersion". The authors of the present paper bring up the possibility of using alternative terms: "immersedness" for the immersion concept of the first school, and, for that of the second school, "immersingness" (denoting the actively immersing quality of the system) and "immersing" when referring to the act of immersing the user. The term "immersedness" is unambiguous, contrary to the term "psychological immersion" which could also mean a system characteristic when the system is created with the ability to try to manipulate the user with psychological means.

Keywords—*immersion; immersive; virtual reality; VR; virtual environment; terminology; definition*

I. INTRODUCTION

Virtual reality (VR) researchers, designers, developers, educators, evaluators and consumers often talk about "immersion" and "immersive" VR applications. E.g. in the 10th IEEE International Conference on Cognitive Infocommunications in 2019, there were 16 papers in which such terms occured [1]–[16]. (Papers which contained "immersion", "immerse", "immersed", "immersive", "immersiveness" or "immersivity" were counted in.) But do they always mean the same thing by the term "immersion"? It is worthwhile to look into the concept more closely.

The current Merriam-Webster dictionary [17] defines the verb immerse as

"1: to plunge into something that surrounds or covers especially: to plunge or dip into a fluid

2: engross, absorb
// completely immersed in his work

3: to baptize by immersion"

and notes that the first known use of the verb is from the 15th century.

(The Cambridge Dictionary [18] lists two definitions similar to the first two given above.)

The first meaning listed above relates to a physical experience, the second meaning is a metaphorical use of the first, the third one is derived from the first one and refers to a physical experience (albeit with a spiritual aspect).

In the context of VR, the second, metaphorical meaning listed above is the relevant one.

J. Murray writes in her book [19, p. 99]: *"Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus. We enjoy the movement out of our familiar world, the feeling of alertness that comes from being in this new place, and the delight that comes from learning to move within it. Immersion can entail a mere flooding of the mind with sensation (...) But in a participatory medium, immersion implies learning to swim, to do the things that the new environment makes possible."*

She also states that in the fictional world we do not simply suspend our disbelief but we also create belief actively, and *"we use our intelligence to reinforce rather than to question the reality of the experience."* [19, p. 107]

II. TWO GLIMPSES INTO THE HISTORY OF VR AND IMMERSION

The ability to create a virtual world and getting immersed in it is deeply rooted in human nature and it has preceded computers by at least tens of thousands of years. Prehistoric cave paintings are proofs of this. These paintings can be regarded as media with the purpose of storytelling, realized with pigment on stone [20, p. 5]. D. Mioduser writes about these paintings: *"The representations are a human creation, but their presentation on the walls of the cave evoked a complex relationship between the creator and his creation with regard to the represented reality."* [21, p. 174]

Dated considerably closer to our age, but still long before computers existed, ancient Greek literature can be regarded as another case: The authors of [22] bring up Homer as an example, and claim that Homer intends to immerse his audience mentally, with various means [22, p. 35]. They name three narrative strategies in his works: spatio-temporal immersion, identification, and the covert narrator [22, p. 38]. Among the means of spatio-temporal immersion, they list epithets, similes etc. *"The texts should feed the reader with enough spatial and perceptual clues in order to create a detailed («vivid») mental «picture» of the storyworld."* [22, p. 39] Of identification, they write that Homer provides the readers/listeners *"with a viewpoint within the narrated scene, encouraging them to identify with that viewpoint."* [22, p. 41] The narrator should be as invisible as possible, Homer's works contain only two brief Muse invocations and a few narratorial comments [22, pp. 44–45].

III. IMMERSION AS A TRANSMEDIAL PHENOMENON

Immersion is transmedial, i.e. not connected to a specific medium. The two historical examples mentioned in the previous section concern paintings and literature – two different forms of media.

In his book [23], O. Grau concentrates on visual art and mentions several examples of old and new media of illusion such as wall paintings of Pompeii, entire spaces of illusion like the Chambre du Cerf in the Papal Palace at Avignon (France), baroque ceiling panoramas, battle scene panoramas and their present-day successors: 360º images, and also films and VR. Each era strove to create maximum illusion with the technical means available at the time [23, p. 5].

F. Rose writes in his book that all good fiction is immersive. *"Books, movies, television, virtual worlds — century after century, we port our willing suspension of disbelief to whatever new and more immersive medium appears."* [24, p. 162]

According to the already quoted Murray: *"Once the illusory space is created, it has such psychological presence that it can almost divorce itself from the means of representation."* [19, p. 103]

M-L. Ryan has written extensively about the theories of immersion (mainly in the context of literature). She discusses emotional immersion, spatial immersion (*"a sense of place and a model of space"*), spatio-temporal immersion (*"how to transport the reader onto the scene"*) and temporal immersion, which is *"the reader's desire for the knowledge that awaits her at the end of narrative time."* [25, pp. 121, 130, 140]

Narrative can greatly contribute to immersion in a story. K. Brooks discusses three attributes of narrative: time, context and participation. He notes that these *"map well from oral storytelling to new media and VR applications"* [26, p. 4].

As far as time is concerned, Brooks distinguishes two types of it in the narrative: presentation time and narrative time. Presentation time is *"a real-time experience encompassing the narrative experience"*, describing *"the period of the narrative; that is, the time during which one is in the movie theatre or the*

time during which one is participating in a VR experience. There is a direct and linear relationship to the clock in this aspect of time. It is the version of time that we experience in our lives on a day-by-day and minute-by-minute basis." On the other hand, narrative time exists inside the narrative, it is *"a very flexible and fluid treatment of time (...). Its treatment and scale are completely dependent on the level of detail the storyteller needs to convey at any particular part of the story. (...) When we are drawn into narrative time so completely that we lose track of presentation time, we are immersed."* [26, pp. 4–5] (Cf. in music theatre, especially in opera, it can happen on the stage that a character receives a fatal wound or drinks lethal poison but still has time to sing a complete aria before he/she dies. Actually, the aria, which is usually about the character's feelings and thoughts of farewell, is in narrative time, not presentation time.)

Of context, Brooks says: *"Context is the space in which a story happens: setting of time and place, political and social conditions, individuals present, their goals and agendas, etc."* [26, p. 7] Similarly to the case of time, we can talk about presentation context and narrative context as well. The former relates to the physical environment where the narrative is experienced, the latter is the environment presented by the story [26, p. 7].

The third attribute is participation, it is desirable to enable people to participate physically and mentally as well [26, p. 10].

Brooks also emphasizes the importance of bringing all three attributes together [26, p. 13].

J. Loomis et al. state that throughout human history, artifacts, intended for the representation and recreation of external reality, have progressed from the literature, graphic arts and sculpture of earlier times to photos, films and audio recordings of the modern age. In recent times, computer technologies such as 3D graphics have been creating increasingly realistic artifacts, blurring the distinction between reality and representation [27, p. 557].

Ryan makes this bold statement: "*VR is not so much a medium in itself, as a technology for the synthesis of all media toward a total experience."* [28, p. 112]

IV. IMMERSION IN VR LITERATURE

In VR literature, there are two main schools defining the notion of immersion, and their definitions are quite different.

The first school is most often associated with the names of B. Witmer and M. Singer and regards immersion as a psychological state of the user. The second school is based on the works of M. Slater who sees immersion as an objective characteristic of a VR system.

The first school is in tune with the sources quoted in the previous sections and bases the definition of immersion on the well-known paper [29]. In this paper, the authors define three interrelated terms: presence, involvement and immersion.

They define **presence** as "*the subjective experience of being in one place or environment, even when one is physically*

situated in another". They emphasize that individuals can experience aspects of the virtual environment and events in their real environment at the same time [29, p. 225].

They give the following definition for **involvement**: *"Involvement is a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events."* Becoming more involved increases the users' sense of presence [29, p. 227].

Finally, the authors define **immersion** as *"a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences. A VE[1] that produces a greater sense of immersion will produce higher levels of presence. Factors that affect immersion include isolation from the physical environment, perception of self-inclusion in the VE, natural modes of interaction and control, and perception of self-movement."* They name the helmet-mounted display (HMD) – nowadays rather called head-mounted display – as a typical device providing the above mentioned isolation. They also underline the importance of interaction: *"When users interact naturally with a VE, able to both affect and be affected by the VE stimuli, they become more immersed in that environment. Perceiving oneself as moving inside a simulated environment or directly interacting with other entities in that environment will also increase one's sense of being immersed. Immersing people in a simulated environment is what VEs are designed to do, and that is why VEs have the potential to produce presence. (...) In our view, immersion, like involvement and presence, is something the individual experiences."* [29, p. 227]

S. Agrawal et al. essentially adopt the views of the first school. They propose the following definition: *"Immersion is a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes (with or without sensory stimulation) cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world."* [30, p. 5] They add: *"The three recognized reasons which can lead (independently or along with other reasons) to psychological immersion are the subjective sense of being surrounded or experiencing multisensory stimulation, absorption in the narrative or the depiction of the narrative, and absorption when facing strategic or tactical challenges."* [30, p. 5]

The authors also mention the term *transportation*, which, according to them, *"can be viewed as immersion which is fundamentally focused on the narrative"* [30, p. 6]. Another term they bring up is *envelopment*, which is often used in the context of spatial audio. According to them, the difference between envelopment and immersion is that envelopment is perceptual while immersion is cognitive [30, p. 7].

Also in the vein of Witmer and Singer, E. Adams and A. Rollings state: *"Immersion is the feeling of being submerged in a form of entertainment, or rather, being unaware that you are experiencing an artificial world."* [31, p. 25] They identify three sub-types of immersion in the context of game playing:

tactical, strategic and narrative immersion. Tactical immersion is also known as the "Tetris trance". The game goes at such a speed that the player cannot think of anything else, he/she just wants to survive. The game typically offers small challenges to the player, one after the other. These challenges are quite alike. When the player is in strategic immersion, then he/she plans ahead in order to win the game, focusing on optimization (but not on the story or the characters). The rules of the game should be clear to him/her, in order to facilitate planning. There should not be too many unpredictable elements in the game. When in narrative immersion, the player feels being inside the story of the game. Good books or films can evoke the same feeling, but in VR games the player can also participate actively in the plot [31, p. 26].

E. Brown and P. Cairns have interviewed gamers about their gaming experiences and identified three levels of immersion: engagement, engrossment and total immersion [32].

L. Ermi and F. Mäyrä [33] also follow Witmer's and Singer's line. They have set up the SCI Gameplay Experience Model, based on their experimental research of game playing. They distinguish three dimensions of a gameplay experience: sensory immersion (S) related to the audiovisual execution of the game; challenge-based immersion (C) where challenges in the game can be related to motor skills and/or mental skills; and imaginative immersion (I) which is is the area in which the game offers the player a chance to use his/her imagination, empathize with the characters etc.

D. Arsenault [34] has suggested calling the imaginative immersion term of Ermi and Mäyrä fictional immersion instead, saying that we can be immersed in a story without exercising our imagination. He also suggests to use the term systemic immersion instead of challenge-based immersion, because the game player adopts the game's system i.e. the game's rules, and forgets about the rules of the real world, and also because we can be immersed in a system without necessarily being challenged by it.

Some literature mentioning immersion discuss the notions of user experience (UX) and flow as well:

According to D. Janssen et al.: *"The users' mental experiences in a VR environment are generally summarized by the term 'user experience' (UX), which can further be subdivided into certain theoretical constructs like immersion, presence and flow (...) Flow is defined as a reflection-free merging in smooth ongoing activities that have been under control despite high strain (...)."* They also say that in a state of flow the person's requirements and competences are balanced [35, p. 21].

The authors of [36] regard flow as a sort of psychological absorption and underline that flow is always enjoyable [36, p. 19].

C. Jennett et al. opine that immersion is a precursor for flow [37, p. 6].

D. Weibel and B. Wissmath have empirically examined the relationship between (spatial) presence and flow in the context of various computer games. They regard both flow and

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[1]   Virtual Environment

presence as immersive experiences. They have found that *"presence and flow are distinct constructs, which do hardly share common variance"* and come to the conclusion that while presence refers to the feeling of being there in the mediated world, flow refers to being involved in the gaming action. Their analyses have shown that flow and presence are influenced by motivation and immersive tendency [38, p. 1].

Flow is also discussed by Agrawal et al., who remark that the literature on the experience of flow is inconsistent [30, p. 6].

Another related concept, *cognitive absorption* is also worthy of mention. R. Agarwal and E. Karahana [39] have defined it as a state of deep involvement with software. According to them, it is exhibited through the following five dimensions: temporal dissociation (the inability to register the passage of time while engaged in interaction), focused immersion (the experience of total engagement where other attentional demands are, in essence, ignored), heightened enjoyment (capturing the pleasurable aspects of the interaction), control (representing the user's perception of being in charge of the interaction) and curiosity. (A review of cognitive absorption literature can be found in [40].)

According to the definition variations of the first school quoted and discussed above, immersion is a psychological state of the user. The second school, M. Slater and his co-authors and followers (e.g. [41], [42]) define immersion quite differently. They are of the view that immersion is an objective characteristic of a VR system (but they define presence similarly to the first school). They call immersion *"a quantifiable description of a technology. It includes the extent to which the computer displays are extensive, surrounding, inclusive, vivid and matching."* They state that the more senses it serves, the more extensive a display is. The surrounding quality means realistic spatial distribution of sensory signals (including visual stereopsis and spatial audio). Inclusiveness means shutting out sensory data coming from physical reality. Vividness depends on the characteristics of the displays, including richness, information content, resolution. They also describe what they mean by the term "matching": *"(...) immersion requires that there is **match** between the participant's proprioceptive feedback about body movements, and the information generated on the displays."* Turning one's head should cause a congruous change in the visual display and – where applicable – in the auditory display as well. Body tracking (at least head tracking) is mandatory for matching [43, pp. 164–165].

They state that immersion also requires a virtual representation of the participant in the VE. This representation is called the virtual body. Interaction, which is the ability to modify the virtual world, is a dimension of immersion [43, p. 165].

They outline the difference between (their definition of) immersion and presence. According to them, immersion is *"an objective description of what any particular system does provide. Presence is a state of consciousness, the (psychological) sense of being in the virtual environment, and corresponding modes of behaviour. (...) Behaviours in the VE should be consistent with behaviours that would have occurred in everyday reality in similar circumstances."* [43, p. 165] In another paper, Slater says: *"Presence is a human reaction to immersion."* [45, p. 2]

Slater states in a third paper that he defined the term immersion *"to mean the extent to which the actual system delivers a surrounding environment, one which shuts out sensations from the 'real world', which accommodates many sensory modalities, has rich representational capability, and so on (...)."* He distinguishes his meaning of the word from the other definition by calling it *"system immersion"* vs. *"immersive response"*. [44, pp. 1–2]

The definition by Biocca and Delaney is also in Slater's vein: *"Immersive is a term that refers to the degree to which a virtual environment submerges the perceptual system of the user in computer-generated stimuli."* [41, p. 57] M. Lombard and T. Ditton call the immersion defined by Biocca and Delaney *"perceptual immersion"* [46].

To distinguish the definitions by the two schools from each other, some authors use the terms *"psychological immersion"* and *"technological immersion"* (e.g. [36], [47]). Other authors adopt the term "psychological immersion", but prefer the expressions *"perceptual immersion"* or *"sensory immersion"* to "technological immersion" [30].

Sherman and Craig call the two types of immersion *"mental immersion"* and *"physical immersion"* [20, p. 10].

Agrawal et al. criticize Slater's definition by saying that it *"implies that increasing the number of channels and loudspeakers augments immersiveness, irrespective of the content, context, and individual preferences."* [30, p. 4] They state that immersion as defined by Slater is a facilitator for "psychological immersion". They accept the views of Witmer and Singer on immersion, but they also introduce the concept of *"immersive potential"* which is the system's or content's potential to elicit immersion [30, p. 5]. This is close to Slater's concept of immersion.

R. Skarbez et al. try to bridge the gap between the two schools: *"Slater's immersion is what makes it possible to experience Witmer and Singer's immersion"*. [48, p. 96:3]

Actually, the two schools see the term immersion from two different perspectives. The first school takes the **user's view: the user immerses himself/herself in the VE and/or lets the VE immerse him/her**. The second school takes the **creator's view: the system, created by the designers and developers, immerses the user**.

It would be advantageous to distinguish these two concepts of immersion with distinct, self-explanatory terms. The authors of the present paper propose to use the term pair **"immersedness" – "immersingness"**. "Immersedness" can be used for the immersion concept of the first school, denoting a psychological state. The second type of immersion could be called "immersing" for the act of immersing the user, and "immersingness" referring to the actively immersing quality of the VE. As an alternative to the latter, **"immersiveness"** could also be used. The term "immersingness" underlines the directionality of this type of immersion a bit more than

"immersiveness" does: it is the system which immerses the user, it is the system that has the actively immersing quality.

The term *immersedness*, for the immersion concept of the first school, is totally unambiguous, while "psychological immersion" or "mental immersion" can sometimes be taken as a characteristic of the system, i.e. *immersingness*, when the system tries to influence the user in a psychological way. An example of such manipulation could be to shape the virtual world in a way which matches the previously obtained characteristics, preferences of the user.

The word "immersedness" actually sporadically appears in scholarly writings. It is used in mathematics, e.g. [49] but the mathematical term has nothing to do with psychology or VR. More close is the use in writings about poetry e.g. [50], and one publication in the field of visual arts has been found: [51] gives an overview of the development of technologically mediated experiences of nature, and in the context of panoramas (large 360 degree paintings ideally covering the viewer's entire field of view, cf. [23]) mentions the various visual effects applied *"to heighten the feeling of realism and immersedness"* [51, p. 5]. There is also one paper which uses the word in the context of bodily movements as gestures, and it states: *"How strong the bond towards this natural medium – the bodily self – is can be the degree of natural immersedness inside our bodies."* [52, p. 101] In all non-mathematical uses, the term clearly refers to a psychological state.

The word "immersingness" occurs only in a posting by an online graphics artist (*https://www.deviantart.com/itswalky/art/ Some-SP-background-sets-199472245)*. The word is used rather colloquially but it seems to refer to the immersive ability of a virtual space.

V. SOME STATISTICS OF THE TWO USES OF THE TERM

It could be enlightening to check in VR-related scientific papers in which the concept of immersion comes up, whether the use of the term relates to the immersion concept of the first or the second school. It is relatively easy to classify these occurrences, if not from the term itself then from the context. E.g. "immersive experience" belongs to the first school, "immersive system" to the second school, while, when the word "immersion" is used, the broader context should be examined.

In the conference papers [1]–[16] mentioned in the Introduction, the relevant terms belong to the first school in 4 papers, to the second school in 9 papers, while in 3 papers some occurrences belong to the first school and others to the second school.

The relevant 18 papers [53]–[70] in the journal Acta Polytechnica Hungarica (*http://acta.uni-obuda.hu/*) have also been similarly examined, and the results are: 7, 6, 5, respectively.

Thus, it can be stated that both concepts are present in these publications, the concept of the second school is somewhat more used than that of the first, and mixed use is common. The latter is not a "crime", as the viewpoints of the user and the designer can both be present in the same paper.

VI. CONCLUSION

On the basis of the literature, the two widespread and quite different definitions of immersion have been reviewed, various related definitions have been discussed. A proposal has been made for using a pair of unambiguous terms to distinguish between the two immersion concepts.

VR-related papers of a conference and of a journal have been examined for the occurrence of the two immersion concepts. A total of 34 such papers have been found. One concept is somewhat more used than the other, mixed use (within the same paper) is common.

The present paper has mostly concentrated on VR literature, but, as Ryan puts it: *"Far from being restricted to VR, the features of immersion and interactivity can be regarded as the cornerstones of a general theory of representation and communication."* [28, p. 3]

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