Hochschule Kempten
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SEMINARARBEIT IM STUDIENGANG GAME ENGINEERING UND VISUAL COMPUTING

MULTIMODALE WAHRNEHMUNGS-EINFLÜSSE ZUR STÄRKUNG DER IMMERSION FÜR VR-ANWENDUNGEN

Kurzbeschreibung

Diese Seminararbeit beschäftigt sich mit Wegen, die die menschliche Wahrnehmung über das Zusammenwirken verschiedener Modalitäten beeinflussen, um die Immersion von Spielern in Virtual-Reality-Anwendungen zu erhöhen.

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INDEX

1 INTRODUCTION

Video games have come a long way, with billions of players worldwide the video games industry has grown into a giant market over the last couple of decades. The complexity of games has changed drastically in this time and a comparison of somewhat modern games, like *Metro Exodus*[1] and *Tom Clancy's Rainbow Six Siege*[2], and some of the earlier video games, like *Pong*[3] or *Doom*[4], would be a night and day difference, not just in terms of technological advances, but also in terms of the overall gameplay experience. Not only can modern games be more visually compelling, with low resolution pixel graphics turning into near photo realism, thanks to better hardware and new as well as more efficient algorithms, but there is also a wide variety of genres with greatly varying gameplay aspects and target audiences. However, like Cairns et al. (Cairns et al., 2008, p. 641) mention, regardless of the age and appearance of games, most successful games have one aspect in common:

> However despite these differences in game design and appearance, successful computer games all have one important element in common: they have an ability to draw people in. Providing an appealing distraction from everyday worries and concerns, computer games allow people to "lose" themselves in the world of the game.

This phenomenon is commonly referred to as *immersion*. It is mostly associated with a positive and enjoyable gaming experience and is therefore often used to describe and advertise games alike. (Cairns et al., 2008, p. 641). Even more so, it is often viewed as a critical requirement for any modern game, regardless of its genre. (Cairns et al., 2008, p. 641). Some even go as far as referring to it as the "holy grail" of video game design. (Goethe, 2019, Xiaoqing & Zhang, 2015).

Among the plethora of games on the market, there is a category that especially stands out regarding immersion, namely virtual reality games. Virtual reality games commonly use, but are not limited to, a head-mounted-display (HMD) to create the illusion of a virtual world to a player and make them feel as if they are being a part of this virtual world. HMDs can create this illusion by encompassing the peripheral vision and offering a wider field of view than traditional monitors do. By doing so, they shut out the surroundings of the user, allowing them to see pretty much nothing but the virtual world. Additionally, HMDs, that are used in virtual reality setups, display the rendered image stereoscopically through the use of two displays instead of just a single one and by rendering the virtual scene from a slightly different point of view on each display.

The level of immersion that these kinds of games can provide is arguably not comparable to the level that traditional games can provide. As both, games experienced via virtual reality technologies and traditional desktop games, make heavy use of the multimodal nature of the human senses to influence the player's perception and move them to immerse themselves, there are many similarities between them. What gives virtual reality games the edge over most other games though, is the degree to which they can encompass the human senses and the level of interactivity that they can offer.

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[1] Website of Metro Exodus - https://www.metrothegame.com

[2] Website of Tom Clancy's Rainbow Six Siege - https://www.ubisoft.com/en-us/game/rainbow-six/siege

[3] Website of the developers of Pong - https://www.atari.com/

[4] Website of the developers of Doom - https://www.idsoftware.com/

FIGURE 1: COMPARISON OF METRO EXODUS (TOP) AND THE 1993 VERSION OF DOOM (BOTTOM). NOT ONLY ARE THE GRAPHICAL AND TECHNICAL SIDE OF METRO EXODUS MORE ADVANCED BUT IT CAN ALSO OFFER A DEEPER LEVEL OF IMMERSION IN MANY ASPECTS.

Although most kinds of games, both desktop and virtual reality, have their focus set on entertainment, there is also a category of games with a more “serious” focus, called serious games. In order to affect the users in the intended and in a meaningful way, most of these use-cases require the users to be at least a little bit involved with the game’s content and experience at least some sense of presence, or in more general terms, have some sort of connection to the virtual content. For example, a serious game that is to be used in the therapeutical context of hoarders not only needs to create a believable and immersive environment, but it also needs to immerse its users enough to cause some form of attachment or connection between the users and the virtual objects. Without this sort of immersion, it will be difficult for the experience to leave any form of lasting impact on the users.

Achieving immersion is generally not always easily done and there is a multitude of factors that can influence the sense of immersion of a player. As the player experiences the virtual environment of a virtual reality game through the stimulation of the different senses they possess, influencing their perception of this virtual environment via them is naturally one of the most appealing and comparatively easier ways of increasing their sense of immersion.

1.1 GOAL AND STRUCTURE

Following the title, the topics of this paper consist of three basic parts, namely multimodal perception, immersion, and the use of the former to increase the latter. As immersion is an important part of game design, the goal of this seminar paper is a summary of some of the different multimodal influences on a person's perception that can lead to an increased sense of immersion in the players of virtual reality applications, in an entertainment as well as a serious game context.

The next chapter of this seminar paper will discuss some basics regarding the human perception and its multimodal nature as well as how this influences virtual reality. The following chapter will discuss some basics regarding the complex phenomenon that is immersion. It starts with a definition of the term immersion, including the different existing views on immersion as well as how it can be viewed in relation to its related concepts of presence and flow. The end of chapter three will mention some of the positive and negative effects that can result from an immersive experience, as well as what implications these effects can have on players and the design of any virtual reality game. Chapter four will bring both perception and immersion together and will mention some of the factors that can make use of the multimodal nature of perception to increase the sense of immersion in players. The second to last chapter will give a sort of conclusion to the topics of this paper, including a somewhat personal opinion on them. The end of this paper will be a more detailed summary of everything that was discussed.

For simplicity's sake, in this paper any form of virtual reality application, be that a game, serious game, or any other kind, will be referred to simply as a virtual reality game most of the time.

2 MULTIMODAL PERCEPTION AND VIRTUAL REALITY

The field of human perception is quite complex, pertaining to both the field of psychology and the field of philosophy, among others. A detailed explanation of it and both its influence and general connection to digital games, and especially virtual reality, would warrant a paper in its own right. Therefore, the following chapters will mostly focus on the for this seminar paper relevant basics of human perception and its connection to virtual reality.

Human beings perceive their surroundings through sensations, which are the result of sensory responses of the different ways we possess to react to external stimuli. (Privitera, 2021, p. 1). Perception, in this context, is the psychological process of making sense of these stimuli. (Privitera, 2021, p. 1). The academic field of perception concerns itself not only with how these senses operate but also with the experiences and behaviors that are a result of the simulation of these senses. (Goldstein, 2010, p. 27).

The senses, that a human can employ to perceive the environment and influence their perception, that most people will immediately recognize, include the senses of vision, hearing, smell, taste, and touch. (Goldstein, 2010, p. 27). Further senses include, but are not limited to, other cutaneous senses, like pain and tickle, as well as the sense of balance (vestibular), proprioception and kinesthesia (the position of limbs as well as the awareness of the body's position and general motion), with each sense producing its own set of sensations. (Goldstein, 2010, p. 27).

2.1 THE MULTIMODALITY OF PERCEPTION

Humans, however, do not perceive their surroundings through a single modality at a time and the different modalities are often also not perceived purely separated from each other. Instead, our brain combines the different available sources of information resulting from the perceptual modalities we possess to analyze the environment[5]. A great example of how the different senses act together and combine different stimuli to provide a single set of information to a person, leading to the creation of a richer mental image of their surroundings, is mentioned by Lachs (Lachs, 2021, p. 1):

> [...] imagine if you witnessed a car collision. You could describe the stimulus generated by this event by considering each of the senses independently; that is, as a set of unimodal stimuli. Your eyes would be stimulated with patterns of light energy bouncing off the cars involved. Your ears would be stimulated with patterns of acoustic energy emanating from the collision. Your nose might even be stimulated by the smell of burning rubber or gasoline. However, all of this information would be relevant to the same thing: your perception of the car collision. Indeed, unless someone was to explicitly ask you to describe your perception in unimodal terms, you would most likely experience the event as a unified bundle of sensations from multiple senses.

This playing together of the different modalities is part of what multimodal perception refers to. How multiple unimodal stimuli are integrated to form a single perceptual experience and how our brain determines which available stimuli are to be considered for a certain experience would also be far beyond the scope of this seminar paper.

Though, one result of this integration of modalities that should be mentioned here is the superadditive effect that it can have on the human perception. Superadditive effect in this context refers to the resulting effect being greater than the effect the stimuli would have had when viewed separately. (Lachs, 2021, Massaro, 2004, Bahrick & Lickliter, 2004). For example, listening to someone in a noisy environment is difficult when your sense of vision and sense of hearing are viewed separately from each other. You can probably not quite hear and understand every single word and seeing the other person's lip movements and expression is in most cases not enough to make out what they are saying either. When both modalities are taken in together though, the resulting effect is superadditive. You hear some of the words the other person says and can piece together the rest of what they say by visually seeing and interpreting the movement of their lips and facial expression. Especially in games with their technological limitations this superadditive effect can be leveraged for storytelling and to contribute to the overall experience of the player.

Multimodality itself can also be defined as "the use of more than one semiotic mode in meaning-making, communication, and representation generally, or in a specific situation" (Chandler & Munday, 2011, p. 287), with semiotics being, broadly speaking, the study of signs and their meanings (Danesi, 2013, p. 590). As such, the "multimodal influences on perception" part of this paper could be seen as the influences that the perceiving and interpreting of any sort of combination of multiple such signs has on human perception. Therefore, going forward, a mix of the two, the perceiving of information through multiple of our sensory modalities, as well as the perceiving of information through the combination of multiple signs resulting from our sensory modalities, will be used, basically meaning that anything that is a result of either of the two or a combination of both will be seen as a multimodal influence on perception.

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[5] The Max Planck Institute for Biological Cybernetics, (9.5.2021), Multimodal Integration, https://www.kyb.tuebingen.mpg.de/149529/multimodal-perception

2.2 THE MULTIMODALITY OF VIRTUAL REALITY

There are many varying and partially quite different definitions of the concept behind virtual reality. The definition that is going to be used in this seminar paper is the one mentioned by Craig and Sherman, as it is "both narrow enough to discard many misleading uses of the term virtual reality and broad enough to include the wide variety of devices used by practitioners of the medium" (Craig & Sherman, 2003, p. 13) and overall, out of all the reviewed papers, seems to be the most fitting for the context of this paper. They define virtual reality as "a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation" (Craig & Sherman, 2003, p. 13).

As their definition already states, a part of virtual reality is the replacement or augmentation of the feedback provided to a single or multiple senses and can therefore also influence the human perception through the feedback it provides. However, the sensory modalities used in combination with virtual reality technologies are rather limited in comparison to the modalities that generally are available to us. As two of the most important sensory modalities that humans possess, the visual and auditory modalities, are often seen as key components of virtual reality, they are being stimulated in pretty much every virtual reality system and are only rarely being left unused. (Beguš et al., 2014, p. 97).

Most commercially available consumer virtual reality setups make use of HMDs to present the virtual environment. The headsets used in combination with these HMDs all either have built in headphones or allow for the usage of separate headphones or speakers. As with more traditional games played on two-dimensional monitors, the visual and auditory sense are therefore accounted for.

Virtual reality setups however pretty much always provide a far greater field of view than standard monitors do (this, of course, also depends on how far away the player is seated from the monitor). On top of that, monitors do not include the player's vision completely, instead there is usually a rather big part of the player's peripheral vision left unattended. Virtual reality headsets, on the other hand, mostly encompass the user's peripheral vision of the surrounding environment (as do CAVE virtual reality and other setups most of the time), facilitating a far greater focus of their sense of vision on the virtual environment rendered on the displays.

Other than the senses of vision and hearing, almost all virtual reality setups also track the player's general position and movements to a certain extent. In most consumer grade virtual reality setups this includes, but is not limited to, tracking of the position and orientation of the player's head (more precisely the position and orientation of the headset) as well as the position and orientation of the player's hands (again, more precisely speaking it would be the controllers held in each hand), and in most cases also provides some very basic haptic feedback through vibrating controllers. This allows for the inclusion of further parts of other senses, such as kinesthesia and the sense of balance.

3 BASICS OF IMMERSION

Most people have probably made use of the term immersion or have at least heard about the concept of immersion somewhere before. It is by far most often used when talking about digital games or describing the experience these games can provide. The

term finds use especially in combination with virtual reality technology and games that use such technology to deliver a virtual environment. Although some researchers mention the notion of immersion, as used in combination with digital games, being somewhat limited to the context of virtual environments (Singer & Witmer, 1998, p. 227), others mention how the notion is similarly used to describe other forms of media, like movies or books. (Goethe, 2019, p. 112).

However, even though immersion as a concept seems to be used in all kinds of media related domains to some extent, most researchers cannot seem to come to an agreement on what immersion precisely consists of and entails. As a result, finding a precise definition of the concept seems to be rather difficult. The literature that was reviewed for this paper provides multiple potential reasons for this.

To start with, as just mentioned, immersion finds usage in a large variety of domains. (Nilsson et al., 2016, p. 109). Most of the time these domains are substantially different to each other, with each formulating and using its own concept and definition of immersion. As a result, each of these domains possibly has its own set of characteristics to include in or exclude from its definition. This is a first potential barrier to finding a common ground regarding a definition of the phenomenon.

Secondly, the term immersion is often used rather vaguely and sometimes without enough context to describe the experience created through it. (Ermi & Mäyrä, 2005, p. 41). That is not all to problematic in most instances, since it is often not necessary to know precisely what form of immersion is being talked about. However, as the term is an umbrella term for the general concept behind immersion, which consists of a whole slew of different subcategories, each being influenced by different factors and having different effects on the person experiencing it, it can be confusing in some cases.

Lastly, on top of the term's sometimes problematically vague usage in general conversations, a similar problem occurs in the term's usage in academic literature. This is partially due to the complex nature that is the notion of immersion and partially due to the varying definitions by authors that have come to be over the last decades, with each taking different aspects into account. (Benavente et al, 2019, p. 234).

3.1 VIEWS OF IMMERSION

Finding a definition that describes the general concept behind immersion proves not to be all too difficult. As Nilsson et al. mention, it should be trivial for most people to explain immersion by drawing parallels to an object or a person being submerged into some sort of fluid. (Nilsson et al., 2016, p. 109). That also explains as to why one of the most accepted definitions according to McMahan (McMahan, 2003, p. 68) seems to be Murray's definition in which she also mentions the origins of the term, the submersion of a person in water (Murray, 1997, p. 98):

> The experience of being transported to an elaborately simulated place is pleasurable in itself, regardless of the fantasy content. We refer to this experience as immersion. 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 [...].

Although Murray's definition is well suited to explain the general concept behind immersion, it is still rather vague about important details. It does however mention the

arguably most important part of immersion: Taking over the users' attention and influencing their perception to create the illusion of a virtual world plausibly existing, with them being drawn in and becoming (heavily) involved with it in some form.

A more in-depth definition and understanding of immersion can only be achieved by looking at the notion of immersion in more detail and splitting it up into its more basic components. In the context of video games, and partially in the context of virtual reality games specifically, there have been a row of suggestions for categorizations of immersion.

A first possible distinction is the interpretation of immersion as a technology, or more specifically, a property of it and its interpretation as a subjective experience. This is exactly where the problems that come with vaguely using the term immersion start. As Nilsson et al. explain, both these interpretations describe two prominently different approaches to immersion (Nilsson et al., 2016, p. 112). They should not and cannot be interchangeably used with each other. They use Murray's definition of immersion as another metaphor to show the differences between these two kinds of immersion: "some believe immersion to be an expression of how deeply one is submerged into a body of fluid, while others believe it to be the subjective experience of being submerged" (Nilsson et al., 2016, p. 110).

Regarding the view of immersion as a property of a system, a detailed definition is the one presented by Slater and Willbur (Slater & Willbur, 1997, pp. 604-605):

> Immersion is a description of a technology, and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant. Inclusive (I) indicates the extent to which physical reality is shut out. Extensive (E) indicates the range of sensory modalities accommodated. Surrounding (S) indicates the extent to which this virtual reality is panoramic rather than limited to a narrow field. Vivid (V) indicates the resolution, fidelity, and variety of energy simulated within a particular modality [...].

This view of immersion sees it purely as a "objective description of what any particular system does provide" (Kooper et al., 1997, p. 3). The level of immersion that a user can experience is therefore "completely determined by the physical properties of the system" (Slater, 2009, p. 3551) and can be reliably assessed. (Slater, 2003, p. 1).

Regarding the view of immersion as a subjective experience, according to Singer and Witmer it can be viewed 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" (Singer & Witmer, 1998, p. 227). When viewed this way the level of immersion varies from person to person and, although they could be playing the same game, they could have completely different immersive experiences. It is to note that Singer and Witmer, in their view of immersion, also separate involvement and immersion, with involvement, in their words, being the result of "focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events" (Singer & Witmer, 1998, p. 227). A player can therefore be extremely involved with some activity or other part of a game but basically not experience any sort of immersion at all.

Alternatively, one possible distinction of immersion is the separation into physical immersion and mental immersion, as mentioned by Craig and Sherman (2003). As the name suggests, physical immersion concerns itself with the physical aspect of immersion that is caused through the aspects of the used hardware/technology that facilitate immersion, or in their words the "synthetic stimulus of the body's senses via the use of technology" (p. 9). In comparison, they describe mental immersion as having "a feeling of being involved in the experience" (p. 9). This includes being in a state of

being deeply engaged, experiencing a suspension of disbelief, and also experiencing involvement (p. 9).

Another one of these suggested categorizations is the gameplay experience model by Ermi and Mäyrä (2005). Their research suggests that "the gameplay experience and immersion into a game are a multidimensional phenomena" (p. 44). They distinguish between three types of immersion:

- **Sensory immersion**: this type of immersion is related to the visuals and audio of a game, with the sensory information from both these aspects being used to shut out the real world and set the focus of the player on the virtual world (pp. 44-45).
- **Challenge-based immersion**: this type of immersion is created through the balanced challenge of the players abilities, either through the usage of the player's motor skill, their mental skill or in most cases a combination of both (p. 45).
- **Imaginative immersion**: as the name suggests, this type is based on the imagination of the player, combining the virtual world, its characters, and their stories to create a sense of immersion (p. 45).

Similar to the categorization into physical and mental immersion, all of these categories can complement each other to allow the player to experience a deeper level of immersion. It is to note though that a game does not require all these categories to create some sort of immersion. Many games manage to create a sense of immersion in the player while mainly focusing on a single category and only barely (if at all) touching the other categories. While some virtual reality games, like *Half Life: Alyx*[6], make use of the full range of sensory, challenge-based and imaginative immersion through their story, world, puzzles, action sequences and characters, other virtual reality games, like Beat Saber[7], rely mostly on challenge-based and sensory immersion factors without really using (or needing) any imaginative immersion factors to cause some feeling of immersion in its players.

A somewhat similar differentiation with slightly different categorizations is the one by Haggis-Burridge. He suggests a categorization into four categories (Haggis-Burridge, 2020, p. 1):

- **Systems immersion**: this type is mostly induced via the gameplay mechanics of the game.
- **Spatial immersion**: spatial immersion depends on how present the player feels in the game's world and is influenced by many factors, including the visuals of the game.
- **Empathic/social immersion**: in Haggis-Burridge's words this type is based on "the player's connection with the personal and social context of the game" (Haggis-Burridge, 2020, p. 7).
- **Narrative/sequential immersion**: this last type is related to the games story and progression.

Adams also differentiates between tactical immersion and strategic immersion. (Adams, 2009, p. 26). According to him, players experience tactical immersion in a fast-paced game, where their brains do not have the time to think much about strategy, the game's story, or anything else, they basically only have time to focus on the hail of

[6] Website of Half Life: Alyx - https://www.half-life.com/en/alyx/

[7] Website of Beat Saber - https://beatsaber.com/

(comparatively small) challenges that are thrown at them. This type of immersion is sometimes also referred to as Tetris trance (Adams, 2009, p. 26), presumably because of the iconic and steadily growing pace of gameplay that Tetris offers. In comparison, strategic immersion is achieved whenever the player is "deeply involved in trying to win a game, like the immersion of the chess master: observing, calculating, and planning" (Adams, 2009, p. 26). Similar to tactical immersion the player does not really think about the game's story, the virtual world itself or the characters that are part of it and instead focuses only on making the best decisions in the current situation. (Adams, 2009, p. 26).

There is also the separation of immersion into perceptual and psychological immersion by McMahan. While the former kind of immersion is influenced by the amount of the player's senses that are shut off from reality and involved with the virtual world, the latter is the reaction of the player being mentally absorbed into the game world. (McMahan, 2003, p. 77).

FIGURE 2: DIAGRAM OF THE DIFFERENT CATEGORIES OF IMMERSION THAT ARE MENTIONED IN THIS PAPER, SORTED BY AUTHOR.

As should be obvious by now, there is slew of different categorizations of immersion, with many not being mentioned here. However, most of these categorizations either end up just using different terms to describe the same basic kind of sense of immersion or boil down to being the same feeling while taking different aspects into account. A full review and analysis of all the existing categorizations of immersion would go far beyond the scope of this seminar paper. Therefore, the categorizations Nilsson et al. mention in their paper will be used to provide a simplified view of immersion while still being granular enough as to not be too vague. Nilsson et al. performed a relatively recent and comprehensive review of many of the existing categorizations of immersion in said paper, including some that are not mentioned here. As a result of their review, they end up distinguishing between four general views of immersion (Nilsson et al., 2016, p. 110):

- **Immersion as a property of a system**: derived from Slater's system immersion, it is based on the degree a system is capable of reproducing the natural perception and action faithfully through the use of technology. (Nilsson et al., 2016, p. 112).
- **Immersion as a perceptual response to a system**: based on and a sort of combination of Singer and Witmer's definition of immersion, McMahan's perceptual immersion, and the concept of sensory immersion by Ermi and Mäyrä. (Nilsson et al., 2016, p. 111). It pertains to different factors, like the degree of isolation of the user from the physical environment and the degree of natural interaction the user can have with different interfaces. (Nilsson et al., 2016, p. 113).
- **Immersion as a response to narratives**: this view consists of three subcategories: temporal, spatial and emotional immersion: These subcategories are based on the story and other events of the game, the virtual world of the game, and the characters inhabiting said world. Narrative immersion overall is mostly a product of the mediated content of the game. (Nilsson et al., 2016, p. 114).
- **Immersion as a response to challenges**: this view is similar to the challenge-based immersion of Ermi and Mäyrä, and, as Nilsson et al. view it, its subcategories tactical and strategic immersion as mentioned by Adams. (Nilsson et al., 2016, p. 117). This category is therefore influenced by challenges that require the use of the player's intellect and their sensorimotor skills as well as a sort of balance of the skills that the player requires to overcome these challenges. (Nilsson et al., 2016, p. 116).

As mentioned earlier, it is to note that the view of immersion as a property of the system and immersion as a perceptual response to a system are somewhat opposing, with the first view regarding immersion as a "property of media form, while the other view stipulates that immersion corresponds to the subjective experience of the media form" (Nilsson et al., 2016, pp. 112-113). With the immersive properties of a system being a sort of requirement for immersion resulting from the perceptual response to be achieved and increased, perhaps it is arguably best to see them as two sides of the same coin.

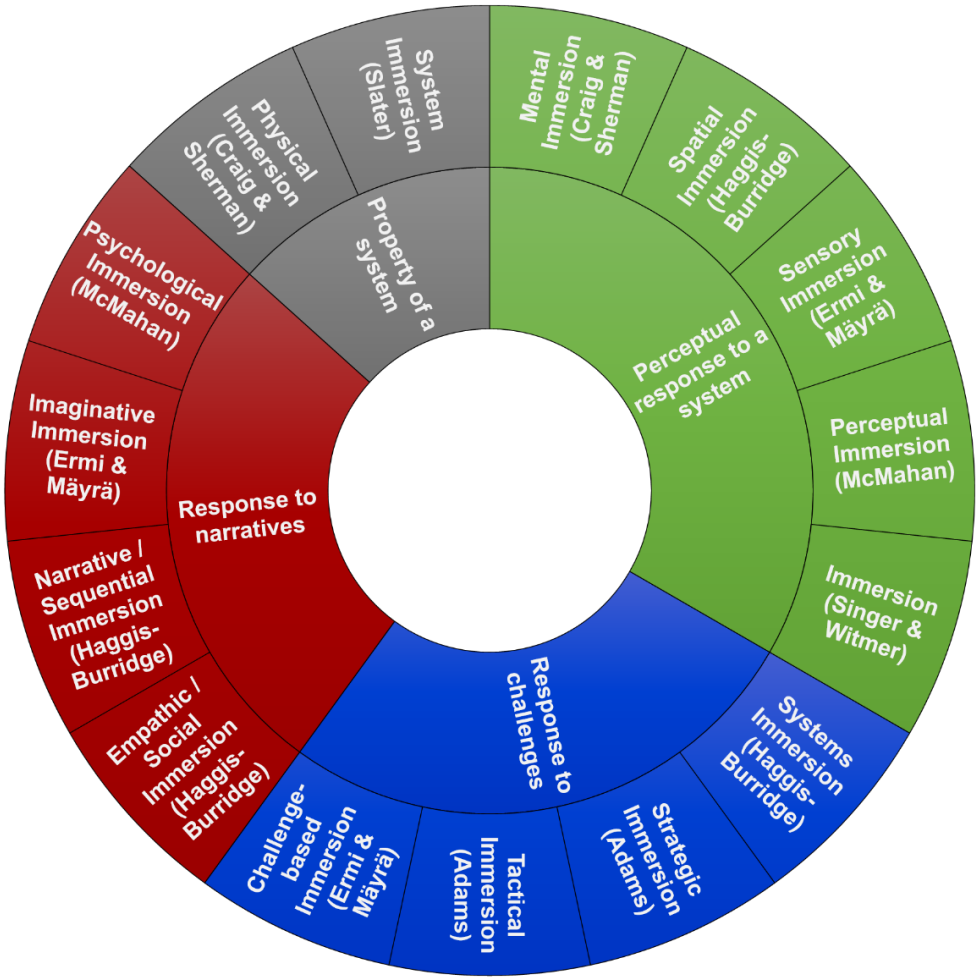

FIGURE 3: DIAGRAM OF MENTIONED CATEGORIES OF IMMERSION AND HOW THEY FIT INTO THE FOUR GENERAL VIEWS OF IMMERSION AS DESCRIBED BY NILSSON ET AL. (2016).

Apart from the separation of immersion based on different influential factors, there is also the idea of separating immersion based on the degree of involvement the players have with a game, put forth by Brown and Cairns (2004). They view immersion as consisting of three levels of involvement (p. 1298): engagement, engrossment, and total immersion. The levels have barriers that need to be lowered to move to the next level (p. 1298). Each level of immersion that is achieved involves the user more and more with the game. (p. 1298).

Engagement is the lowest of the three and its barriers are investment and access (p. 1298). While the former is depended on the preferences of the player and the ease of controls of the game, the latter requires the investment of time as well as effort and attention by the player (p. 1298). It is seen as a prerequisite for the other two levels (p. 1298) and lacks the emotional level of attachment that can be found in them (p. 1299).

The second level, engrossment, is based on the game's construction and its ability to affect the player's emotions. It is described in their paper as being a "Zen-like state where your hands just seem to know what to do, and your mind just carries on with the story" (p. 1299).

The last and most difficult to achieve level is total immersion. “Total immersion is presence” (p. 1299) and the game is the only thing that occupies the player’s mind in this level. The barriers for this level are growth of attachment (empathy) and the development of game construction (atmosphere). (p. 1299).

3.2 RELATION TO PRESENCE

Apart from immersion, another term that is widely used in the gaming industry and especially in combination with virtual reality is *presence*. A relatively short and arguable simple definition of the term presence by Slater et al. is a “sense of ‘being there’ in the virtual environment” (Slater et al., 1994, p. 2). In another paper Slater also defines and describes presence with a bit more detail (Slater, 2018, p. 432):

> […] it is the illusion of being there, notwithstanding that you know for sure that you are not. It is a perceptual but not a cognitive illusion, where the perceptual system, for example, identifies a threat […] and the brain-body system automatically and rapidly reacts […], while the cognitive system relatively slowly catches up and concludes ‘But I know that this isn’t real’. But by then it is too late, the reactions have already occurred.

The concept of presence shares many similarities with the concept of immersion. However, classifying whether presence and immersion are the same or something entirely different, or whether presence is a phenomenon resulting from immersion or not seems to be a heavily debated topic within their respective fields. Some researchers suggest that the concept of presence used in combination with virtual reality seems to correspond to the concept of immersion in the context of traditional video games. (Berthouze et al., 2006, p. 1). Some suggest that both terms are somewhat synonymous and often interchangeably useable as such (McMahan, 2003, Goethe, 2019), while others suggest that, although there might be similarities between both concepts, both are distinct and as such do not describe the same phenomenon. (Cairns et al., 2008, p. 642).

Advocates for the separation of immersion and presence, such as Slater and Gast et al. argue that while immersion is an objective property of a system, presence is a subjective effect on the user. (Slater, 2003, Gast et al., 2018). This seems to stem mostly from the view of immersion as a property of a system, rather than a perceptual response to a system, as mentioned by Nilsson et al. (Nilsson et al., 2016, p. 112). That is also one of the reasons as to why Nilsson et al. exclude the latter one from their taxonomy of existing conceptualizations of immersion, as it increases proportionally with an increase in their notion of system immersion and is overlapping with part of the notion of presence. (Nilsson et al., 2016, p. 117).

Advocates of the other side suggest that presence is a part of immersion. For example, while Goethe and Mahalil et al. state that presence is a form of spatial immersion (Goethe, 2019, Mahalil et al., 2014), Craig and Sherman suggest that it is sort of similar to mental immersion, with “sense of presence” meaning “being mentally immersed” (Craig & Sherman, 2003, p. 9).

Regardless of how one views presence in relation to immersion, there is one part most authors and researchers seem to agree on, that is, that presence is either directly or indirectly a result of some form of immersion (McMahan, 2003, Singer & Witmer, 1998), with immersion sometimes being seen as a requirement to achieve presence (Singer & Witmer, 1998, p. 227).

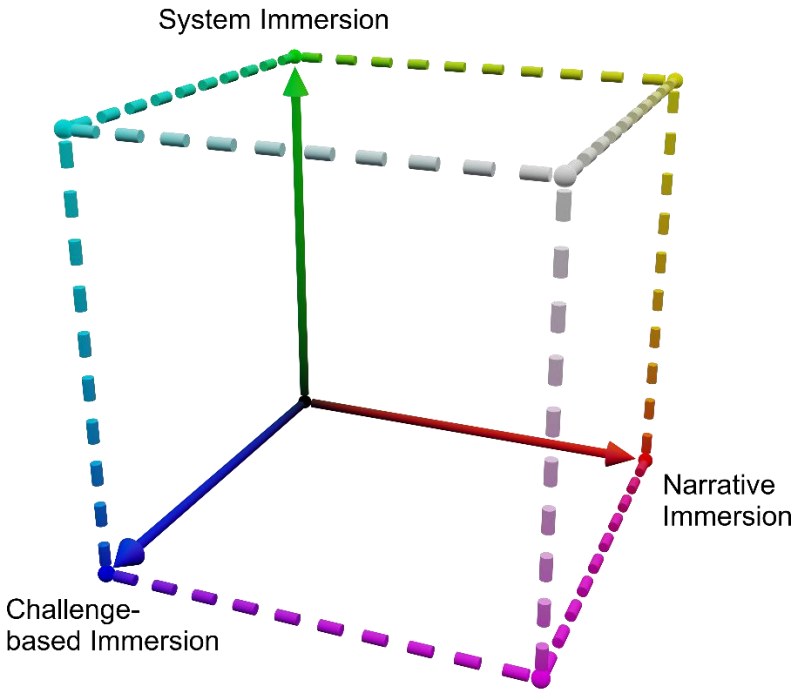

FIGURE 4: ILLUSTRATION OF THE THREE-DIMENSIONAL TAXONOMY OF IMMERSION BASED ON THE ILLUSTRATION OF IT BY NILSSON ET AL. (2016). EACH GENERAL TYPE OF IMMERSION IS REPRESENTED BY ONE AXIS, RANGING FROM ZERO TO ONE. WHILE BLACK EQUALS THE ABSENCE OF ALL THREE KINDS OF IMMERSION, WHITE EQUALS THE HIGHEST POSSIBLE LEVEL OF IMMERSION ACHIEVABLE BY COMBINING ALL THREE KINDS.

3.3 RELATION TO FLOW

Like the terms immersion and presence, another term that is similarly often used in combination with digital games is *flow*. Following Csikszentmihalyi's flow theory to describe the term, it is "a state of concentration so focused that it amounts to absolute absorption in an activity" (Csikszentmihalyi, *1990*, p. 1). As with the relation of immersion and presence, the relation that the concept of flow has to immersion seems to be similarly discussed.

Sometimes both concepts are viewed and defined as being the same. Balaguer-Ballester et al. write that "immersion and flow do not appear as conceptually distinct, and their proposed differences are not compelling enough to set immersion apart as a different mental state" (Balaguer-Ballester et al., 2018, p. 5). However, more often than not immersion and flow are viewed as different but strongly related. As Cairns et al. state, although immersion and flow clearly overlap in certain aspects, they are distinct concepts (Cairns et al., 2008, p. 642):

> [...] immersion is evidently a precursor for flow because that sense of being so involved that nothing else matters is practically a colloquial definition of immersion. However, flow is a particular sort of experience, specifically an optimal and therefore extreme experience. Immersion is not always so extreme.

Likewise, a study by Bowers and Procci suggests that although both concepts are often considered as being similar in literature, they pertain to different constructs and therefore cannot be used interchangeably (Bowers & Procci, 2011, p. 2186).

In this view of flow and immersion, one aspect that is often used to separate the two is the extremity of the player's experience. In their paper Cairns and Sanders state that flow is an "extreme experience where goals, challenge and skill converge. As such flow is an all or nothing experience. By contrast, immersion in games is a much more prosaic experience and graded with low and high levels of immersion possible" (Cairns & Sanders, 2010, p. 160). Although, in their view and the view of others, immersion seems to be often seen as a less extreme experience than flow, there is the concept of levels of immersion put forth by Brown and Cairns, in which the last level, total immersion, is a rather extreme state of immersion. Based on this extremity Balaguer-Ballester et al. compare this level of immersion to Csikszentmihalyi's concept of a deep-flow episode. (Balaguer-Ballester et al., 2018, p. 2).

Overall, it seems like flow can (and probably should) be viewed as corresponding to the "extreme end of immersion where a person is so immersed in the game that they enter a flow state" (Cairns et al., 2013, p. 1071) and therefore being a possible result of being immersed in a game.

3.4 IMMERSION IN VIRTUAL REALITY

Virtual reality technologies are inherently immersive by nature and as such it is not surprising that immersion is often viewed as an integral part of many different definitions of virtual reality, often either being directly included in them or indirectly mentioned. Apart from the earlier mentioned definition by Craig and Sherman, two examples would be the definitions by Gigante, and Burdea and Coiffet. Gigante defines virtual reality as "the illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on three-dimensional [...], stereoscopic, head-tracked displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience" (Gigante, 1993, p. 3). While Gigante includes the immersive aspect directly, Burdea and Coiffet mention it more indirectly though the involvement of the different sensory modalities: "Virtual reality is a high-end user-computer interface that involves real-time simulation and interactions through multiple sensorial channels. These sensorial modalities are visual, auditory, tactile, smell, and taste" (Burdea & Coiffet, 2003, p. 3).

In a sense, most virtual reality technologies can even be viewed as forcing a certain degree of immersion upon the player. Especially setups that use virtual reality headsets are prone to this. A game played on a normal monitor still allows for the player to perceive parts of their surroundings visually, while most HMDs take over the player's visual sense completely by shutting out even their peripheral vision. Combine that with the right pair of headphones and the player completely surrenders two of their arguably most important senses to the virtual environment. To recall Murray's water metaphor again, it really is similar to the submersion in water. Just like a person cannot decide to not be surrounded by water while being submerged, a person experiencing virtual reality can often not decide to just not experience it (without of course leaving the water/taking of the headset).

3.5 EFFECTS OF IMMERSION

As might be concluded from this paper so far, there are quite a lot of different kinds of immersion, consisting of many, sometimes blending, categories. Every single one being influenced by a multitude of sometimes difficult to define factors which have no guarantee of actually causing a sense of immersion in a player. One might wonder, of course, why game developers should even bother to go through all the effort and trouble of purposefully creating an immersive experience to begin with. So, before different factors and ways of increasing immersion can be described, it is important to show some of the possible positive as well as negative effects that can be a result of creating an immersive experience.

Three positive effects that can result from a heightened immersive experience, and could arguably be considered the most important effects for most digital games, are immersion's ability to create a stronger engagement of players with the game (Goethe, 2019, p. 116), create a "deeply and satisfyingly entertaining experience to some" (Adams, 2009, p. 20), and invoke a desire to play the game again (Bangay & Preston, 1998, p. 50).

The first of these three effects is partially a result of the different requirements for immersion to occur to begin with and is quickly explained by looking at some of the views on immersion again. As Goethe states it regarding the narrative aspects of a game, "they also tie up the mental resources" (Goethe, 2019, p. 111), hence players have fewer mental resources to focus on aspects that are not part of the game. A similar effect can be applied to immersion as a result of a challenge, so regardless of whether immersion is being viewed as a response to a narrative or a challenge, it should be clear that increasing either of the two almost requires the player to focus more of their attention on the game as to make sure that they can follow the game's narrative or overcome the challenge they are currently facing.

As for the second effect, it can, at least moderately, be seen as a result of the deepened engagement with the game. Greater engrossment leads to a greater focus of attention on the game, which in turn leads to the game being able to affect the emotions of the player directly and therefore create a greater emotional attachment to the game's story and characters. (Brown & Cairns, 2004, p. 1299). This can result in action sequences being more intense and the death of a character or a wholesome moment being more impactful, and in the end should lead to a more entertaining and enjoyable experience.

A study by Daggubati (2016), that examined the effect of cooperation between players in online games on both the players' immersion and enjoyment, suggests a similar effect of immersion on players (p. 3). Their study used a shooter game in combination with 38 male participants (p. 17), with half of them experiencing the cooperation condition first, followed by the no cooperation condition, and the other half experiencing both conditions in a reversed order (p. 13). The results of their study indicate that immersion has a significant positive effect on game enjoyment, both in individuals and during cooperation with other players (p. 20).

On a more empirical note, the last of the three effects, the desire to play the game again, should be a pretty obvious result of the other two aforementioned effects. Video games are played mostly for the purpose of entertainment after all. Immersion leading to higher engagement, entertainment, and enjoyment of the game is therefore also most likely going to lead players to seek more of the same experience. Apart from entertainment, digital games are also often used by people to escape from problems and unpleasant aspects of their usual everyday life. As Ermi and Mäyrä mention, immersion plays a central role in facilitating this sort of escapism (Ermi & Mäyrä, 2005, p. 40) and will therefore move players to play the game again.

Another effect that could have far reaching implications for traditional digital games, as well as virtual reality games, is mentioned by Cairns and Cheng (2005). While conducting a follow up study to examine the effect of incoherent game behaviour across modalities on the sense of immersion of participants they ended up with somewhat unexpected results. They intended to use "deleterious usability to instil a break in immersion" (p. 3). In the end however "immersion overcame the deleterious usability elements" (p. 4). Some of the participants failed to notice a drastic change in the jumping height of their character (p. 3). This suggests that even comparatively low levels of immersion could be enough to overcome incoherence across different modalities that would normally end up lowering or destroying player immersion (p. 4). It might also be related to the willing suspension of disbelief that is often associated with immersion (Dede. C., 2009, p. 66) and has basically become synonymous with it within the gaming industry. (Adams, 2009, p. 25).

Regardless of what the cause of this turns out to be however, in digital games, where often quite severe shortcuts in calculations and rendering must be taken (due to the requirement for good performance while having extremely limited computing power), this could easily be used to lessen the impact of these shortcuts on the player experience. Players might not even notice a less realistic physics simulation, some artifacts in shading or some inconsistencies in animations if they are immersed enough. Especially in the context of virtual reality and its use of HMDs, with which the virtual world usually requires an even higher degree of computing power to be rendered on each display, while simultaneously needing even higher performance to be comfortable to use, this could prove rather useful for developers.

Further effects, that should be of interest for serious game developers, include immersion's potential to create a sense of presence in the players. In the context of serious games this is extremely important to achieve to some extent in almost any scenario. A game meant for the treatment of some sort of phobia might still be effective to some extent, even without the patient experiencing presence (of course this depends on the specific phobia and its degree in the patient), but a serious game that causes the patient to feel as if they are a part of the virtual environment will obviously have an easier time achieving the desired result. Some studies also show a significant increase in virtual body ownership and agency caused through immersion. (Botsch et al., 2018, p. 1651). This has similar implications for presence in serious games.

Immersion, especially in combination with virtual reality, also shows a strong potential to increase the performance of players in exergames (games meant mostly for exercising). In a study by Kim and Yao (2019) 32 people participated in an experiment to measure the influence of immersion in virtual reality games on their real-life exercising performance (p. 235). Participants were split up into two group with each playing the same biking game on either a normal 2D screen or experiencing it through a virtual reality set up using an HMD (p. 238). They found that higher levels of immersion not only increased the players' feeling of arousal but also that a more immersive experience increased the overall physical exercise performance of the participants (p. 240). As they mention, a heightened level of arousal might lead players to have a "higher level of attention and readiness to the activity" (p. 240) and could "have a positive linkage with the physical exercising outcomes" (p. 240). As they state as well though, their study used self-reported data to measure arousal (p. 240). An increase in actual biological arousal is therefore not guaranteed to occur as well. Regardless, the increased distance traveled by participants in the virtual reality group (p. 240) is a promising indicator of the use of immersion to positively affect exercising performance.

As nice as it would be if immersion only had advantages for players and developers, that is not always the case. Immersion unfortunately also comes with some negative aspects. As Adams points out, players might "find interruptions that break their sense

of immersion jarring and disappointing" (Adams, 2009, p. 25). The implications that this can have on the gameplay experience are pretty straightforward. Problematic decisions in game design that break immersion might leave the player unsatisfied and therefore cause the gameplay experience to be seen in a negative light overall. A good example for this in recent years is the requirement of some games to have a constant connection between the game client and some server to be playable. As long as there are no issues with the connection the game works fine and immersion can be experienced as usual. However, should the connection be interrupted, because of an unstable connection on the client side or issues on the server side, it will leave a bad taste in the player's mouth. Should this occur while the player is immersed it will only amplify this negative experience. Although this is a rather problematic aspect of immersion, it really goes to show how important it is for developers to purposefully create or decrease immersion and, if necessary, interrupt it in a less intrusive way.

Another detrimental effect of immersion is its possible relation to and effect on different forms of addiction. In a study Cairns and Seah expected to find a positive correlation between immersion and addiction/engagement since "immersion leads to extended playing sessions due to loss of time and self awareness and this leads to outcomes associated with behavioural addiction" (Cairns & Seah, 2008, p. 60). They did indeed find a correlation between the two. As they also point out though, correlation does not equal causation and they did not view addiction and engagement as separate factors. (Cairns & Seah, 2008, p. 61). In combination with the earlier mentioned effects of heightened engagement with the game and the strong feeling of gratification immersion can cause, it is not farfetched that it can contribute to some form of game addiction, even if just indirectly.

Immersion also seems to be able to negatively influence other, possibly already existing, forms of addiction. As Heidrich et al. (2020) describe the results of a conducted study in their paper: "Our results show an impairing effect of immersion on simulated real life decision making" (p. 489). The experiment used in their study separated participants randomly into two groups, with one half experiencing the used game via an immersive virtual reality setup and the other via a less immersive desktop one (p. 487). The participants drew significantly more disadvantageous cards in the virtual reality condition compared to the desktop one, indicating the aforementioned imperative effect (p. 488). As "decision making plays a central role in gambling" (p. 483) its impairment can have detrimental effects on the harm-inducing factors of gambling. In an earlier study Heidrich et al. found similar detrimental effects of immersive virtual reality on the urge to gamble, dissociation, and dark flow in combination with a virtual slot machine. (Heidrich et al., 2019, p. 800). The far-reaching ethical implications this could have on the misuse of immersion as a tool to facilitate gambling is concerning, at the very least. These concerns become even more worrisome when the recent trend of including "loot crates", which strongly resemble gambling, is taken into account.

There is a whole slew of other effects that immersion can induce, some negative but most are positive. However, the here mentioned ones should be enough to display the advantages as well as the disadvantages of creating an immersive environment. They should especially show why having knowledge of the different factors that can influence the sense of immersion in players is important and can be utilized to create virtual environments that have, or avoid, a certain effect on players.

4 INCREASING IMMERSION IN VIRTUAL REALITY

Immersion is an extremely complex and very fragile phenomenon that is as hard to achieve as it is easy to break. (Nylund & Landfors, 2015, p. 14). As if that would not be problematic enough, just achieving immersion is often not sufficient, the game also must make sure that this sense of immersion persists for a certain time. (Nylund & Landfors, 2015, p. 14).

Invoking a sense of immersion in players is certainly no trivial task and requires conscious effort of the developers working on the game. (Goethe, 2019, p. 116). With the complex phenomenon that is immersion being heavily "related to [and influenced by] the multi-modal nature of the perceptual senses" (Mestre, 2011, p. 1) developers have to put in a great amount of both physical and mental work to create a game that substitutes "as many real world sensations as possible [...] with the sensations corresponding to the [virtual environment]" (Mestre, 2011, p. 1).

If one were to follow Goethe's suggestion, the game characteristics, which combine the different perceptual modalities to facilitate the achievement of a sense of immersion, can broadly be categorized into two categories (Goethe, 2019, p. 110):

- Characteristics that allow the player to form a rich mental model of the game's world and lore.
- Characteristics that lead to consistency across the different aspects of the game and its world.

As one might notice, both of these do not apply to all of the views and categorizations of immersion mentioned earlier. For example, while narrative immersion is of course influenced by both, neither the game's setting nor any sort of consistency is necessarily important to achieve challenge-based immersion. However, as most, if not all, virtual reality games feature some sort of world and lore, these two categories of characteristics are certainly among the most reliable to invoke some sort of immersion in the players.

Elaborating further on both of his suggested categories, Goethe describes how a rich mental model of the game's setting is strongly related to the information provided by our sensory modalities, with a greater number of senses being involved and working together in the construction of this mental model equaling a deeper immersion as well as a better experience overall. (Goethe, 2019, p. 110). Using his example to illustrate this point: "a bird flying overhead is nice. Hearing it chattering as it does so is better" (Goethe, 2019, p. 110).

Goethe also mentions how "contrivances and abstractions are the enemy of immersion" (Goethe, 2019, p. 110), which is certainly true in many cases as it allows the players to naturally interpret and infer aspects of the game's world and mechanics without needing all too specific knowledge in certain situations.

In addition to richness and coherence across different modalities there are other general factors that a virtual reality game must ensure to create immersion. One such factor that is mentioned equally as often as the already mentioned two, and seems to be as important of a factor, is the number of mental resources being allocated to the game (Nylund, 2015, Goethe, 2019). The game must engage the player's mind through sensory stimulation and keep them busy to retain their attention (Goethe, 2019, p. 108). With an increasing number of mental resources being focused on making progress in the game and understanding the game's world, fewer resources are available to attend to the real world and getting distracted. This is obviously important

to create any kind of immersion that results from the player being faced with some sort of challenge. As can be seen with challenge-based immersion, an appropriate increase in game difficulty can lead to a stronger sense of immersion for the player. This is fairly logical as a more difficult challenge usually requires the player to pay more attention, leading them to focus more of their senses on the game and in the end having less mental capacity for anything but the current challenge in the game.

The barriers that Brown and Cairns define for each of their three levels of immersion can be seen as sort of factors as well. All of the barriers for a certain level need to be overcome to move onto the next level. Virtual reality game developers that want to increase the immersion of their players need to design their games while taking these barriers into account. The specific barriers that Brown and Cairns mention for each of the levels are illustrated in figure 5.

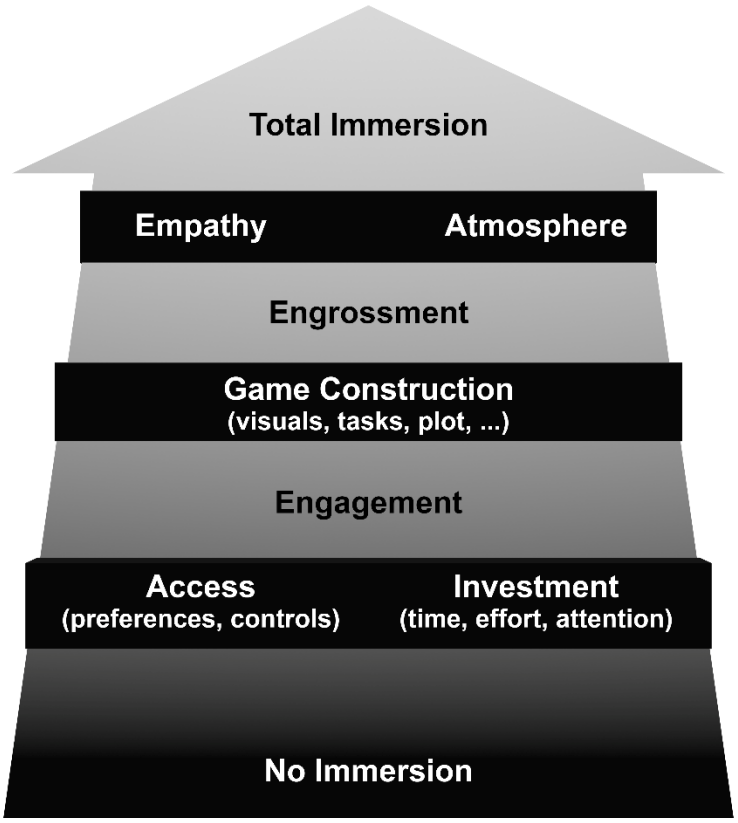

FIGURE 5: ILLUSTRATION OF THE BARRIERS TO IMMERSION AS MENTIONED BY BROWN & CAIRNS (2004), BASED ON THE ILLUSTRATION OF BIANCHI-BERTHOUZE ET AL. (2009).

As it is not just the software that leads to immersion, but also the hardware laying out the foundations for how the players perceive the virtual environment and what sort of interactions will be possible in it to begin with, the hardware used in combination with virtual reality games plays at least an equally important part in achieving immersion. Recalling some aspects of Slater's definition of system immersion at this point, the more inclusive, extensive, surrounding, and vivid a system is, the more immersive it can be. With all four of these being connected to the sensory modalities and how extensively and coherently the modalities are combined by the system, it is pretty intuitive that hardware is one of the key points in increasing the immersiveness of a virtual reality game.

Generally speaking, anything that contributes to the player being able to form a more detailed mental image of the virtual world, creates coherence within the game's setting and the modalities of the player, and leads to a greater involvement of the player with the game, both physically as well as mentally, will lead to a greater sense of immersion in them. As these factors are still pretty vague though, the rest of this chapter will go into a bit more detail about more specific ways of combining the different sensory modalities we possess to increase immersion that can be deducted from most of the just mentioned factors.

One aspect of immersion that should be noted here beforehand though, and might be obvious by now, is that, in most cases, immersion is not purely a result of the design of a game (Adams, 2009, p. 26) and there is no special formula that can guarantee an increase in immersion. (Goethe, 2019, p. 116). Game developers cannot just add some specific things *A* and *B* and guarantee an increase in the sense of immersion in every single one of the players of their game. Of course, *A* and *B* might be likely to increase the player's sense of immersion and, in most cases, probably will, but with the factors that contribute to a sense of immersion being largely dependent on the kind of game being played, the personal preferences and tendencies of the players playing it, and outside factors that could influence the player (Slater & Willbur, 1997, Harth et al., 2018, Haggis-Burridge, 2020), there is no guarantee that they will achieve this in the end. Furthermore, if a player does not want to be immersed (based on their dislike of the genre or game itself, etc.), a game could obviously be as immersive as it possibly can be and still probably not immerse them. As a result, everything that is done in the design of most games to increase immersion will at most end up making it easier for the players to immerse themselves. Naturally, there are some exceptions to this. As mentioned earlier, a virtual reality headset setup that wholly takes over the player's senses of vision and hearing will force a sense of immersion to a certain extent, regardless of the users wishes, as they perceive way fewer of their real-world surroundings.

4.1 MULTIMODAL INTERACTIONS WITH THE VIRTUAL ENVIRONMENT

As the immersiveness of virtual reality starts with the physical immersion of the player into the virtual world (Craig & Sherman, 2003, p. 8), it is perhaps best to discuss the influential factors of the hardware used in facilitating immersion first.

The interactions that the different sensory modalities can have with the virtual environment can vary greatly from system to system. Although most consumer grade virtual reality headsets make use of the same kinds of core components, there are differences in some components that facilitate immersion as well as a row of optional equipment that can lead to a more immersive experience when employed in the right way.

When asked about what increases immersion, a large amount of people would probably mention the graphical representation of the game as well as its soundscape. While in regard to the audio quality, virtual reality games are virtually the same as traditional games, the usage of HMDs in most consumer grade virtual reality systems leads to a great advantage in some aspects of the visual compartment. The stereoscopic perception of the virtual world is obviously one of the main reasons for the level of immersion virtual reality can offer. HMDs unfortunately also have some disadvantages, such as the sometimes noticeable screen-door effect (visible gap between pixels), resulting from the shorter distance to the displays, and increased computational power required as the images have to basically be rendered twice, once for each screen.

During the Steam Dev Days in 2014, Michael Abrash of Valve[8] held a presentation on the future of virtual reality. Part of this presentation were some of the key hardware aspects that can create a sense of presence in virtual reality through influencing the senses. The aspects included a field of view of at least 80 degrees, higher resolutions than 1080p and high refresh rates of around 95 Hz (although less might be sufficient as well), among other aspects[9]. As presence is often seen as a part of immersion and as the mentioned aspects align with Slater and Willbur's definition of hardware aspects that lead to immersion, they should be applicable to immersion as well. Generally speaking, any positive increase in hardware aspects that affect any part of the visual sense can lead to greater immersion as what the player perceives visually can be better match to what they perceive through other senses.

Regarding acoustic fidelity, virtual reality systems often include more or less basic headphones. Headphones with better audio quality or speakers that deliver three-dimensional surround sound will, similarly to an increase in visual quality, lead to better matching between the acoustic sense and other senses.

While both the visual representation as well as the soundscape of a game can of course increase immersion through their own separate modalities, what really creates a sense of immersion in the player and sells the virtual world to their brains, is the combination of these two. Experiencing the world of the game, both visually and auditory, leads to consistency and coherence across the affected modalities. Especially directional sound can be quite effective in achieving this as it makes it easier for the player to detect the direction of a sound and match it to what they see visually in that direction.

One of the arguably biggest advantages, that virtual reality has over the presentation over a normal monitor, is the three-dimensional tracking of certain parts of the player's body that the technology allows. The matching of the tracked body parts to the ones in the virtual world plays a vital role in increasing immersion (Slater & Willbur, 1997, p. 605). The higher the accuracy of this tracking is, the better the matching can be, which in turn increases immersion since the visual feedback that the players receive from the rendered images on the displays matches the proprioceptive feedback that they receive from the positioning of their limbs.

Increasing the accuracy of the tracking of body parts is just one of the ways through which matching can influence different modalities at the same time to increase immersion. The amount of matched body parts and movements also plays an important role. As mentioned earlier, by default most virtual reality setups only track the transformations of the player's head and hands. Often that is already enough to create a strong sense of immersion, as the perspective of the virtual world can be adjusted based on the position and orientation of the player's head and the virtual representation of their hands appears fairly accurately matched to where their hands are in the real world. Increasing the immersion through matching even further requires the use of hardware to track additional body parts and movements. Over the past years there have been several advances made by companies creating this kind of hardware. The use of such hardware to track additional parts of the body fortunately does often not only increase the match between the player's visual and kinesthetic modalities but does also allow for higher consistency and more coherence across other modalities.

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[8] Website of Valve - https://www.valvesoftware.com

[9] Steamworks Development, What VR Could, Should, and Almost Certainly Will Be within Two Years (Steam Dev Days 2014), 11.02.2014, 13:33-20:50, https://www.youtube.com/watch?v=G-2dQoeqVVo

A prime example for this are the controllers of some of the modern virtual reality headsets, like the Valve Index[10]. On top of accurately tracking the hands of the player, the controllers that are included with the Index[11] also allow for each finger to be tracked individually to some extent. Similar to the basic tracking of the player's hands, this allows for more coherence as there is less discrepancy between modalities as well as for a more natural interaction with objects in the virtual world. As the fingers are tracked individually, the index's controllers feature a strap that keeps the controllers attached to the player's hands whenever they let go of it with all their fingers. This not only increases the possible interactions as the player does not have to hold on to the controllers, but it also makes them more intuitive and less awkward to use as they do not have to pay attention on not dropping the controllers by accident. Additionally, the controllers contain multiple force sensors that can sense different levels of grip strength when the player is tightening their grip on the controller's base. The strap in combination with these force sensors allow for even more immersive interactions, like the natural picking up and throwing of items.

Haptic feedback is obviously hard to provide in a virtual environment, since, as the name already states, the objects that are part of it are just that, virtual. For a long time, controllers that can vibrate have been used to provide at least some sort of haptic feedback. This of course does not match the sensations one would perceive when interacting with the real life equivalent of most virtual objects and therefore is naturally still likely to cause some sort of inconsistency across the modalities. The controllers of the Index take this haptic feedback aspect further. As the players do not have to always hold on to the controllers, they receive far less haptic feedback from them (mostly just the strap and the controllers' own weight) and feel less like they are holding something. Whenever they pick up any sort of item, they now tighten their grip around the controller and thereby feel physical resistance from it. Although this is still rather basic in comparison to the haptic feedback we receive from real objects, it leads to more consistency between the senses.

There is further hardware for providing haptic feedback to the player, such as the vest described in a paper by Aracil et al. (Aracil et al., 2016, p. 251) or the suit developed by Teslasuit[12]. Although most of this kind of hardware is certainly not the norm yet, the matching of virtual haptic interactions that you perceive, such as impacts or touch, to real haptic feedback should be a logical step to increase immersion.

Even if every movement and limb position would be tracked, there is still another barrier to immersion that is a result of the interactivity that virtual reality applications provide. Humans are naturally used to moving through space when walking. Virtual reality games relatively often contain worlds that are nearly always larger than the real space that is available to players. As most people do not have access to an industrial hangar sized play space, the spatial movement component proves to be rather problematic to match with the virtual world. Developers have come up with different ways to deal with this in general, but from an immersion perspective it still proves to be problematic. Most games use local movement in combination with either teleportation or controller-based movement for farther distances.

Hardware-wise there is some equipment that solves this problem to a certain extent. Among the most well-known equipment are probably virtual reality treadmills. Most feature an omni-directional pad that the users can move on. More advanced versions,

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[10] Website of the Valve Index - https://www.valvesoftware.com/en/index

[11] Website of the controllers of the Valve Index - https://www.valvesoftware.com/en/index/controllers

[12] Website of Teslasuit - https://teslasuit.io/

like the Omni One by Virtuix[13], feature an apparatus that holds the user in place, so they do not have to pay attention to staying on the treadmill. One could assume that with the more natural interaction that these kinds of treadmills provide (involving only actual movement in the real world to move through the virtual one) would increase immersion as they, again, lead to more coherence between modalities. A study by Janzik et al. however suggests that the only real difference between treadmill-based and controller-based movement is the level of exertion, with the treadmill leading to higher physical exhaustion (Janzik et al., 2021, p. 13).

Indeed, on closer inspection treadmills come with some perceptual problems of their own. For one, they limit the user in the variety of movements that they can make, often limiting them to either standing or crouching while going prone is not an option. Another one is part of the movement itself. While the user might move on the spot, they do not move through actual space. This leads to a different kind of discrepancy between the modalities compared to teleportation or controller-based movement: The user might see themselves move in the virtual world, but they sense themselves just walking on the spot in real life. Arguably the different forms of movement in virtual reality can increase and decrease immersion in their own ways. In the end it will depend on the specifics of the virtual reality game being played to decide which kind will lead to a more immersive experience.

FIGURE 6 & 7: THE LEFT FIGURE SHOWS THE OMNI TREADMILL BY VIRTUIX AND THE RIGHT FIGURE SHOWS A VIRTUAL REALITY VEST, THE TACTSUIT X16 BY BHAPTICS[14]

[13] Website of Virtuix - https://www.virtuix.com/

[14] Website of the TactSuit X16 by bHaptics - https://www.bhaptics.com/tactsuit/tactsuit-x16

4.2 MULTIMODAL INTERACTIONS INSIDE THE VIRTUAL ENVIRONMENT

Similar to how the hardware decides the interactions we can have with the virtual environment, how our modalities are influenced by the interactions within it can also vary greatly on a game-by-game basis. Depending on how the game is designed to immerse its players, they can interact in a more or in a less direct and immersive way with the game.

Let's start with the interfaces the player uses to obtain different kinds of information about the virtual world. The traditional digital games approach of displaying the interface as a purely two-dimensional element on the screen (typically in the edges) does not really work that well in virtual reality. In the case of HMD-based virtual reality systems the UI-elements would be mostly visible in the peripheral vision of the player and even if the player were to move their eyes to look at the UI-elements, in longer play sessions this would obviously not only put unpleasant strain on the eyes but also not exactly lead to an immersive experience. Fortunately, there are more immersive ways to display information to the player.

Many games that feature some form of health mechanic use filters and elements that cover most of the screen instead of a simple health bar to indicate that the player has taken damage or is at a low health level. Most shooters that use these kinds of effects for example use either a red or grey filter to represent the health level of the player, or display blood splatters on the screen to indicate that the player was hit. Using these kinds of effects should of course work in virtual reality as well, but most virtual reality games use an even more immersive way to display relevant information to the player. They either attach the interface elements to the objects in the virtual world or integrate them into the objects themselves, with the later one being naturally more immersive as interfaces are perceived as being a direct part of the virtual environment that way.

FIGURE 8 & 9: ON THE LEFT ARE THE INTEGRATED DISPLAYS ON THE GLOVES IN *HALF LIFE: ALYX* AND ON THE RIGHT THE DISPLAY ON THE SIDE OF THE GUN WHICH SHOWS THE BULLETS THAT ARE LEFT IN THE MAGAZINE.

A good example for this is the way the virtual reality game *Half Life: Alyx* does it. In this game the player possesses special gloves that let them interact with the environment in various ways. The health of the player as well as their current total ammunition for a given weapon is visible in displays directly integrated into the gloves.

The same goes for various other interfaces in the game. The upgrade and health stations show the information on a display on the station itself and as a liquid being drained from a container, respectively. Most minigames utilize the three dimensions and the virtual environment, instead of a simple two-dimensional window. As this sort of display of information is closer to what we are used to experience and involve the player more compared to static elements on the screen, all these sensory cues combine to make the virtual world more believable and immerse the player more.

As immersion is not just a result of the player being influenced by the environment but also by how they can influence it (Singer & Witmer, 1998, p. 227), the level of interactivity that the game allows for, both quantitatively and qualitatively, is a vital part of increasing immersion. The minigames that were mentioned just now illustrate that aspect quite well. They require the player to move and look around the environment and interact with it in various ways, which leads them to perceive themselves as being more of a part of it. Virtual objects should facilitate the actions we naturally expect to be able to have with them. When the player sees a cup in the virtual world, they expect to be able to pick it up and throw it, while they expect to have difficulties moving the way heavier desk the cup was sitting on. Should they not be able to pick up the cup or be able to throw the desk across the room with ease, it will lead to a discrepancy between what they experience and what they are used to and expect. This can easily remind them that they are experiencing a fabricated world and thereby decrease their immersion.

FIGURE 10: AT THE START OF *HALF LIFE: ALYX THERE ARE SOME MARKERS NEXT TO A WINDOW WITH DRAWINGS ON IT*. JUST AS PLAYERS WOULD NATURALLY EXPECT TO BE ABLE TO DRAW ON THE WINDOW WITH THE MARKERS, THE GAME ALLOWS FOR THIS SORT OF INTERACTION.

What contributes to the quality of interactions as well is the ease of control of them. Should the player feel that objects are awkward or annoying to interact with, it will impact their immersion in a negative way. (Singer & Witmer, 1998, p. 227). This is mostly affected by how the interactions are designed but can be affected by other aspects as well. Realism does not always equal more immersion in this context. Having to kneel and reach down to pick up an item that is laying on the floor might be realistic, but it can easily become annoying after a while. As the height of players can vary greatly as well, an object that is located on top of a wardrobe for example can be hard to reach for some. The general design of interactions must therefore also account for external factors to reliably increase immersion.

Other than through the interfaces that the player uses and interactions that they have directly with the world, immersion is also influenced by the general believability of the virtual world. The developers of *The Climb*[15] illustrate this in a blog[16] about the level of presence and immersion in their game quite well (Oculus VR, 28.4.2016). As they went for realistic graphics, and with the player often getting pretty close to objects in the scene, they had to not only have detailed objects, but these objects also had to tell a kind of story of their own. For example, the gloves the player sees themself wear had to look somewhat worn and the screw and spots that they are embedded in had to look weathered. This sort of level of detail greatly contributes to the overall believability of the virtual world as it not only aligns with what the player would likely expect but also makes the world feel more organic and natural.

FIGURE 11: EXAMPLE OF THE LEVEL OF DETAIL THAT IS SEEN IN *THE CLIMB* AND CAN LEAD TO INCREASED IMMERSION. THE SCREW IN THE CENTER SHOWS SIGNS OF WEATHERING AND THE ROCK WALL HAS MARKS LEFT FROM IT BEING SCREWED IN.

Although, realistic graphics and a vivid soundscape can greatly contribute to this, they are not required. (Melo et al., 2018, p. 203). The best graphics and most vivid soundscape also do not matter if they are not synced probably. On top of that, similarly to what we expect from interactions, objects and events in the virtual world should produce the sounds we would expect to come from them as well as when we expect them to come from them. Using Goethe's bird example as a base: Seeing a bird fly overhead might contribute to immersion, not hearing it chattering at all or only after it

[15] Website of The Climb - https://www.theclimbgame.com/

[16] Blog - The Art of Presence and Immersion in The Climb - https://developer.oculus.com/blog/the-art-of-presence-and-immersion-in-the-climb/

is gone, certainly does not. The Objects that are part of the virtual world are not self-contained in this context. They should also react to external sources, such as events in the virtual world or the player. A bird not reacting to a player that is getting too close by flying away would certainly impact the level of immersion. This, in combination with the characters that inhabit the virtual world, leads to the last kind of multimodal interaction that will be mentioned here, the combination of verbal and nonverbal communication that results from the narrative of the game and the characters that are involved in it.

The narrative of a game, overall atmosphere, and the virtual world's believability can be greatly affected by verbal and nonverbal cues that characters in the environment give. Players expect characters to behave in a way that fits the currently happening event in a game, both via what they say verbally and via how they act and react to said events. A character not reacting to an attacking monster by screaming or running away (or any other fitting reaction) is going to look out of place to the player and thereby decrease their immersion. The effect of verbal and nonverbal cues is not limited to just events in the virtual world. Characters that have a certain role are often expected to look and act the part. Sometimes this is also used in storytelling, with both kinds of clues being able to be used to gauge the character of a character.

FIGURE 12: A CHARACTER IN *HALF LIFE: ALYX*. IMMEDIATELY VISIBLE ARE THE NONVERBAL CUES THEY GIVE THROUGH THEIR EXPRESSION, IN THIS CASE SOMETHING AKIN TO CONFUSION. TOGETHER WITH GOOD VOICE ACTING, THIS MAKES THE VIRTUAL CHARACTER MORE BELIEVABLE.

There are a plethora of other ways to increase immersion that are a result of the multimodal interaction of our senses, a good and intriguing story, the shading of objects (correct lighting and shadows to for example get a sense of depth), or the general design of a level to lead to a good game flow, to name a few. The here mentioned ones however should be enough to give a general idea of how the level of immersion is not only affected by how the senses we possess perceive the virtual world on their own, but also by how they work in tandem to make the virtual world more believable and lead to a more immersive experience in general.

5 CONCLUSION

In conclusion, the characteristics of a game that can lead to an increased sense of immersion:

1. allow the player to form a richer mental image of the game's world and lore
2. lead to consistency within the game and its different components
3. allow the game to involve the player and retain their attention to keep them mentally occupied with the game
4. lead to consistency and coherence across the player's sensory modalities

There are also some aspects that were mentioned that I personally do not fully agree with. The first being that "contrivances and abstractions are the enemy of immersion" (Goethe, 2019, p. 110). While abstractions certainly do not contribute to immersion in most cases, as it is often harder for the player to form a proper mental image of something abstract, contrivances, at least in a literal sense, are not necessarily going to pose a problem for immersion. Many fantasy, roleplaying and sci-fi games for example are full of contrivances, yet still are able to immerse the player. The key is that these contrivances have to make sense within the setting and context of the game that is being played.

Something else I do not fully agree with is the taxonomy of immersion put forth by Nilsson et al.. While the axes in their model (narrative immersion, challenge-based immersion, and system immersion) are certainly not wrong, I would argue that it makes more sense to replace the axis of system immersion with their view of immersion as a response to a system, since their concept of system immersion is heavily based on Slater's concept of system immersion and is therefore arguably an objectively measurable property, while both narrative and challenge-based immersion are a mostly subjective experience.

With the large number of factors that can influence the sense of immersion, it can be quite hard to reliably increase the immersion of a player, but this multitude of a factors also makes it easier for the developers to increase immersion in a certain sense as they can choose more freely on what factors they want to focus on. Not making use of the multimodal nature of both virtual reality and immersion would be a waste of immersive potential in pretty much any game. Especially developers, that want to offer the players of their games the best experience that they can create, need to design their games in a way that makes sure that the different available modalities are used to their fullest, with as much consistence and coherence across them as possible. With technology steadily advancing and many developers taking more and more advantage of immersion and the effects that this experience can offer, it is exciting to think about what level of immersion future virtual reality hardware and software will be able to offer. Especially since there is a row of senses that do not really find any use in commercially available virtual reality technologies and are even generally only rarely used in virtual reality, like the senses of taste and smell. These unused modalities would most definitely be able to be integrated with the already used modalities to create a heightened sense of immersion.

Overall, and in the end, creating an immersive experience is definitely an art in itself that requires the combined knowledge of many fields to be reliably achieved and the complex phenomenon that is immersion is certainly a sort of holy grail that all game developers should aim for.

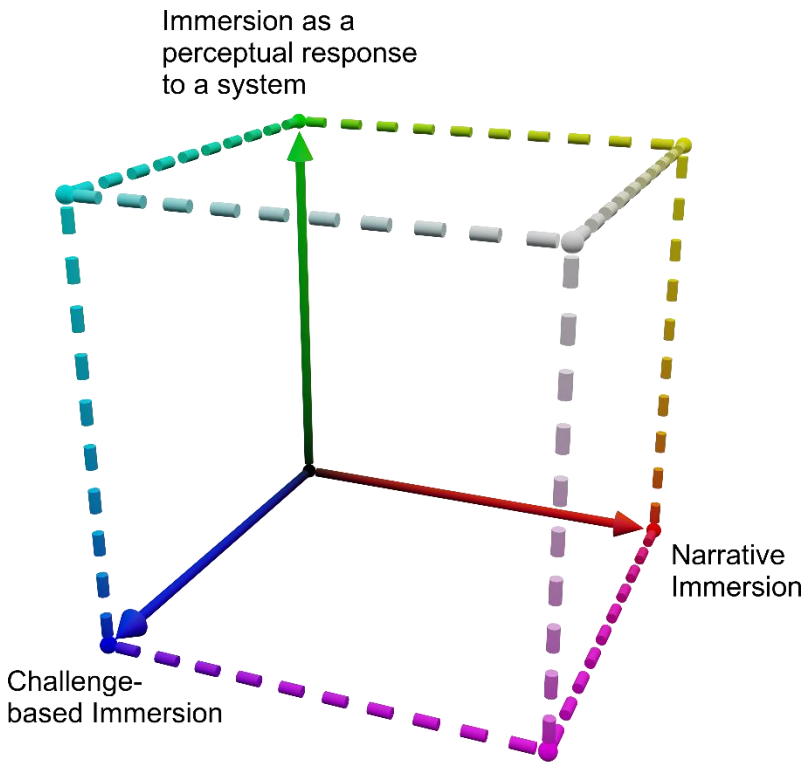

FIGURE 13: ILLUSTRATION OF THE THREE-DIMENSIONAL TAXONOMY OF IMMERSION BASED ON THE ILLUSTRATION OF IT BY NILSSON ET AL. (2016) WITH THE Y-AXIS (GREEN) THAT REPRESENTED SYSTEM IMMERSION IN THEIR ILLUSTRATION BEING REPLACED WITH IMMERSION AS A PERCEPTUAL RESPONSE TO A SYSTEM. THAT WAY A COMPLETELY SUBJECTIVE IMMERSIVE EXPERIENCE IS REPRESENTED BY THE MODEL.

6 SUMMARY

Following a general introduction, this seminar paper started off with a chapter describing the basics of the multimodal nature of the human perception and its relation to virtual reality technologies. Beginning with some of the better-known senses that humans use to perceive their surroundings. This paper mentioned how these senses play together to form a coherent mental image of the surroundings and how this combining of the senses has a superadditive effect on our perception of both the real as well as the virtual world. Following that, a general definition of virtual reality was mentioned as well as how virtual reality technologies are multimodal by nature. This chapter also mentioned how, although still limited, virtual reality technologies can employ more of the human senses to provide feedback to the players.

Chapter three focused on the basics of immersion in relation to games. Starting with the vague and wide usage of the term across different domains as well as potential reasons that lead to this kind of vague usage. This paper mentioned a general definition of immersion and the origin of the term in the submersion in water. The importance of differentiating between the different subcategories that immersion encompasses were discussed and some of the prominent views and categorizations of immersion were mentioned. To simplify the plethora of subcategories and views of immersion that exist, the simplified differentiation into four overall categories, immersion as a property of

the system, as a perceptual response to a system, as a response to narratives, and as a response to challenges, by Nilsson et al. were used.

As the sense of immersion is not an all-or-nothing state, the three basic levels of immersion that Brown and Cairns identified were mentioned. With each of the three levels, ranging from engagement to engrossment, and in the end the most difficult to achieve level total immersion, pertaining to a different kind of experience that tends to be more intense and more engaging with each level.

Following the categorization of immersion, its general relation to the concepts of presence and flow were brought up, starting with the heavily discussed relation to presence. It was mentioned how presence is often seen as one of two things, either being a synonym to immersion or being something entirely different. It was concluded that regardless of the view of their relation, presence seems to be a sort of result of some form of immersion.

Similar to presence, the notion of flow was discussed. It was described how although it is also often seen as being synonymous to immersion, it is more often than not a more extreme experience than immersion, with the possible exception of the level of total immersion that players sometimes achieve. Overall, it got concluded that it can be similarly seen as a possible result of an immersive experience.

Following the description of both these notions, the relation of immersion and virtual reality was brought up. The inherently immersive nature of virtual reality technologies was illustrated by the often direct or indirect inclusion of the term into the very definitions of virtual reality. It was argued that virtual reality forces immersion to a certain degree as the technology often takes over two of the most important perceptual modalities, the visual and auditory one.

Chapter three ended with some of the effects that immersion can have on the player, both good and bad, to illustrate the importance of knowing how to affect the degree of immersion in desired way. These effects included increased engagement with the game, a good experience, and the desire to play again as well as immersion's possible effect of making players overlook certain shortcomings. Some effects that are of interest for serious games were also mentioned, including the possibly resulting sense of presence and heightened performance in exergames. As immersion does not always only come with positive aspects, the potential disappointing feeling that comes with a sudden break of immersion and its more serious potential contribution to addiction were pointed out.

Following the basics of perception and immersion, the usage of the former to increase the latter was discussed. First it was mentioned how immersion required effort by the game's designers to be achieved. Afterwards some factors that can lead to a general increased sense of immersion were brought up, including any characteristic of a game that lets the player form a richer mental image of the game, its world and lore, retains the player's attention, and anything that leads to coherence across their sensory modalities.

The rest of the paper focused on more specific ways of increasing immersion, by influencing different modalities at the same time, that can be deducted by the aforementioned factors. The hardware interactions side consisted of different kinds that allow for the inclusion of modalities and some of their specifications that can combine with other modalities to increase immersion. The interactions within the virtual environment focused on different game design decisions that help to immerse the player, mostly by creating coherence across modalities, involving the user more through interactions, and creating a believable virtual world.

7 LIST OF FIGURES

8 LIST OF REFERENCES

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