Tampere University

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IMMERSIVE EXPERIENCES IN RACING VIDEO GAMES

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ABSTRACT

Joonas Sorkio: Immersive experiences in racing video games
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The purpose of this bachelor's thesis is to investigate immersive gaming experiences in the context of racing games. The emphasis is on how various display and input devices affect the player's immersion, presence, flow and simulator sickness, but some game design perspectives, such as track and audio design, are also examined.

This thesis is written in the form of a literature review. In the first half, the relevant concepts are defined to aid in interpreting the results of the latter half. In the second half, some existing empirical research on display devices, input devices and game design is reviewed in an effort to find an answer to the research question. The highlighted research varies in methods: some utilize controlled laboratory conditions, while some collect data with mass surveys. Immersion, flow, presence and simulator sickness are still measured mostly with subjective questionnaires and interviews.

The main observation of the thesis is that virtual reality head-mounted displays produce more immersive experiences in comparison to traditional monitors. On the other hand, virtual reality is correlated with increased incidence of simulator sickness, which is in itself counterproductive to the immersive experience. It should be noted that simulator sickness can be mitigated over time with repeated virtual reality exposure. In terms of input devices, the results are somewhat inconclusive, which can be explained to an extent by the differences in the research methods. Under laboratory conditions, the steering wheel controllers are experienced to be more natural and presence-inducing than traditional controllers. However, when the players are using the input device that they are most comfortable with, the differences in the quality of the experience are insignificant between the two groups. Race tracks with higher average speed and fewer gear changes are more appealing to the average player than twisty, technical tracks. Audio design is especially critical in racing games: the often exaggerated engine and tyre sounds not only support the immersive experience, but also provide the player with critical feedback of the gameplay.

Keywords: racing game, immersion, flow, simulator sickness, display device, input device

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

TIIVISTELMÄ

Joonas Sorkio: Immersive experiences in racing video games (suom. Immersiiviset kokemukset ajopeleissä)
Kandidaatintutkielma
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Tämän kandidaatintutkielman tavoitteena on tutkia immersiivisiä pelikokemuksia ajopelien kontekstissa. Tutkielmassa painottuu vertailu erilaisten näyttö- ja ohjainlaitteiden vaikutuksesta pelaajan immersioon, läsnäoloon, flow-tilaan ja simulaattoripahoinvointiin, mutta siinä käsitellään myös joitakin pelisuunnittelun tulokulmia, kuten rata- ja äänisuunnittelun vaikutusta.

Tutkielma on toteutettu kirjallisuuskatsauksen muodossa. Työn ensimmäisessä puoliskossa määritellään lähdekirjallisuuden avulla joitakin keskeisimpiä käsitteitä, joiden avulla jälkimmäisen puoliskon tuloksia voidaan tulkita. Työn jälkimmäisessä puoliskossa tarkastellaan aikaisempaa empiiristä tutkimusaineistoa, jonka avulla tutkitaan näyttölaitteiden, ohjainlaitteiden ja pelisuunnittelullisten tekijöiden vaikutusta immersiiviseen kokemukseen ajopeleissä. Tarkasteltavissa tutkimuksissa on käytetty vaihtelevia menetelmiä: osa on järjestetty valvotuissa olosuhteissa, ja osa taas perustuu isoon määrään etänä kerättyä dataa. Immersion, läsnäolon, flow-tilan ja simulaattoripahoinvoinnin mittaamiseen hyödynnetään kuitenkin järjestäen kyselylomakkeita sekä haastatteludataa.

Tutkielman keskeinen havainto on, että ajopelien pelaaminen virtuaalitodellisuudessa koetaan keskimääräisesti immersiivisemmäksi kuin muilla näyttölaitteilla pelattaessa. Toisaalta virtuaalitodellisuus myös aiheuttaa simulaattoripahoinvointia suuremmalla todennäköisyydellä, mikä on itsessään merkittävä este immersiiviselle kokemukselle. Huomattavaa on, että simulaattoripahoinvointi lievenee kun koehenkilöitä altistetaan virtuaalitodellisuudelle toistuvasti. Ohjainlaitteita koskevissa tuloksissa on joitakin eroavaisuuksia, minkä selittänee osin erilaiset koejärjestelyt. Kontrolloiduissa laboratorio-olosuhteissa ratti- ja poljinohjaimet koetaan luonnollisempana tapana ohjata autoa kuin konsoliohjaimet. Kuitenkin kun koehenkilöt käyttävät heille tuttua ohjainlaitetta, pelikokemuksen laadussa ei raportoida selviä eroja eri ohjaintyyppien käyttäjien välillä. Radat joita ajetaan korkeammilla ajoneuvojen keskinopeuksilla ja vähemmillä vaihteiden vaihdolla tuottavat keskiarvoisesti mielekkäämpiä kokemuksia kuin erittäin mutkaiset ja vaikeat (tekniset) radat. Myös äänisuunnittelun vaikutus on ajopeleissä erityisen merkittävä: jopa liioitellut moottori- ja rengasäänet eivät ainoastaan tue immersiota vaan myös antavat pelaajalle tärkeää palautetta ajamisen prosessista.

Avainsanat: ajopelit, immersio, flow, simulaattoripahoinvointi, näyttölaite, ohjainlaite

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Glossary

TERM	DEFINITION
Field of view (FOV)	The extent of the video game environment visible in the display device. It is commonly measured in angle (from the player's in-game location). Physically placing the monitor closer to the player allows for higher in-game FOV while still retaining the appropriate scale of the virtual environment.
Force feedback	Force feedback steering wheel controllers attempt to simulate the mechanical forces felt through the steering wheel of a real race car.
Framerate, Frames-per-second	The rate of which new frames are rendered in-game to the player. It is commonly used in the context of software (games), as opposed to refresh rate, which is related to hardware (display) limitations.
Head-mounted display (HMD)	A display device placed directly on the user's head. The term is most commonly used in conjuction with contemporary virtual reality.
Hotlap	In racing games, hotlaps are laps that are driven as fast as possible to achieve the best possible laptimes. Many racing games have specific hotlap modes that feature optimal track conditions and no fuel consumption.
Input device	In the context of this thesis, the input devices are either force feedback steering wheel controllers, associated pedal controllers or console style hand-held controllers.
Input lag	A blanket term that denotes the time it takes for the game and display device to react and display a new image following a user input. In reality it can be affected by many factors. Reduced input lag is always preferable, but especially beneficial for VR HMD users.

Livery	In racing games and real racing cars alike, the livery includes not only the color of the car, but also any assorted symbols of sponsors, brands, team logos, driver names and numbers.
Refresh rate	The rate of new images being updated in the display device or monitor. Works independently of the framerate in software. Refresh rate is commonly a fixed setting (unless dealing with a variable refresh rate display device).
Sim racing	A sub-genre of racing video games. Sim racing games attempt to more closely simulate real-world driving physics and related conditions (e.g fuel consumption, damage, tyre wear, grip, weather, setups)
Sim rig	A *"sim rig"* or commonly just *rig* consists of a steering wheel rim, wheelbase, pedals (gas, brake, clutch), racing seat, and an accommodating rigid structure. PC, display devices or any additional accessories are often included in the definiton.
Simulator sickness	An sensation of nausea and disorientation (among other symptoms) following the exposure to virtual environments. See section 3.4
Simulator Sickness Questionnaire (SSQ)	A common questionnaire for subjectively measuring the severity of simulator sickness. It is mentioned in more than four sources featured in this thesis.
Virtual reality (VR)	A simulated, virtual experience. Nowadays, the term is mostly used in relation to the virtual reality head-mounted displays.
Wheelbase	A mechanical device that produces the force feedback effect to the player.

1 Introduction

The concept of *immersion* is an integral part of any video game experience. One definition of it could be that it is a certain kind of feeling of being *away* from the real world. Some terms closely related to immersion are *flow*, which describes the optimal experience, and also *presence*, which in turn can be defined as the sense of being *inside* the virtual world. (Bernhaupt, 2015)

In this thesis, the methods of creating these immersive experiences are investigated specifically in the context of racing video games. Racing video games are a promising genre for this kind of study due to several reasons. Firstly, as many players already have some experience of real-life driving physics, even if only as passengers, a good baseline for what driving *should* feel like can be established. This baseline experience can then be compared to the increasingly realistic experiences that modern racing simulators are able to provide. Conducting this kind of study, from this specific angle, would be a difficult task for many other video game genres.

Secondly, racing video games, similarly to other seated cockpit games, are especially suitable for virtual reality head-mounted displays. But it is also intended for them to be just as playable in various other display configurations, such as single-monitor, triple-monitor or projector setups, which again opens numerous possibilities for comparing the immersive experiences between these different conditions. This adaptability also holds true in the context of input devices: to be appealing to a wide audience, a racing game needs to be enjoyable with steering wheel devices and console controllers alike.

Furthermore, areas such as audio and track design also play a major role and should not (and will not) be ignored in a thesis that makes the claim of studying immersive experiences in racing games. **The research question** can then be condensed into the following format: how do all of these (aforementioned) factors affect the immersive experience of the player in racing video games?

In *section 2*, the methods for writing this bachelor's thesis are discussed. *Section 3* describes the important background concepts: immersion, presence, flow, simulator sickness and display devices. Some of the existing empirical research related to the subject matter is analysed in *section 4*. The results are then discussed in detail in *section 5* and a brief summary of the contents can be found in *section 6*.

2 Methods

This bachelor's thesis was written in the form of a literature review. Initially, the prospect of finding suitable studies presented a daunting task, especially when considering that sim racing is a relatively niche genre with a small (although passionate) playerbase. Unfortunately, initial searches dealing specifically in sim racing proved unsuccessful. However, when expanding the subject to include all types of racing games, the number of relevant studies found was surprisingly high. On top of that, many of the studies examined fairly similar scenarios, meaning that they could be analysed against each other for the purposes of this thesis. The *Andor* service of Tampere University was utilized extensively in the search process but four sources (Orozco et al., 2012, Dockwray & Collins, 2015, Carver, 2021, and Finn, 2021) were found through Google search. The relevant databases were *ACM, ScienceDirect, DOAJ, SAGE journals, ProQuest, Safari and Researchgate.* The search terms that yielded relevant sources are displayed in *table 1*.

Table 1. Number of sources found for each search term.

SEARCH TERM(S)	NUMBER OF SOURCES
"racing game" AND immersion	3
"user experience" AND "video games"	1
"racing game" AND input device	1
audio design games	1
audio design racing game	1
display setups in sim racing	2
driving simulation	1
flow video games	1
force feedback research racing games	1
immersion video games	1
simulator sickness	2
Sources found through existing sources	4
Total number of sources	19

The recent study by Galdieri et al. (2021) was among the more fruitful sources, as it included not only comprehensive data on different input devices in the context of racing games but also data on how the users of these input devices experienced tracks with different characteristics. Malone & Brünken (2021) were referenced to the most in this thesis, as their study did not only contain relevant empirical (VR) research, but was also helpful in defining the background concepts. While literature concerning audio design

specifically in racing games was difficult to find, in the end Dockwray & Collins (2015) proved to be an especially useful source for the purposes of the audio design section.

Decades worth of literature concerning the concepts of immersion, presence and flow in video games was available. In the end, the issue here was really about choosing the correct material and which schools of thought should be presented. Immersion itself, as a concept, has garnered quite a few conceptual models and definitions over the years: but considering the limitations of the bachelor's thesis as a format, tough choices had to made to avoid straying too far from the original subject. Many sources were found on psychology journals, such as *Frontiers in Psychology*, which provided a total of three solid sources.

3 Central concepts and phenomena

In this section, some of the most central concepts and phenomena in relation to the subject are described, which should aid the reader in interpreting the analysis during the later sections.

3.1 Introducing the concept of immersion

Both Michailidis et al. (2018) and Brown & Cairns (2004) agree on one thing: that immersion as a concept is somewhat challenging to define. It gets increasingly difficult when attempting to understand this concept in contexts other than video games. While flow is often described as the optimal experience (with no in-between), immersion can be classified as sub-optimal, meaning that it is measured in more of a gradual scale. (Michailidis et al., 2018)

Grounded Theory on immersion splits immersive experiences in video games into three plateaus: *Engagement, Engrossment* and *Total immersion.* A player can be classified to be engaged when he or she displays interest in the game and wants to continue the experience. The second level, engrossment, is achieved when the player becomes more emotionally invested in the game: he or she might be more inclined to suspend their disbelief and also to eliminate any outside distractions (e.g. dimming the lights in the room, increasing the in-game volume). In a state of *total immersion*, the third plateau, the game remains the only thing occupying the player's mind and the player feels completely detached from reality. Achieving total immersion is by no means a certainty and is also understood to be hard to maintain for long periods of time. (Brown & Cairns, 2004)

Sweetser & Wyeth (2005, p. 4) define immersion concisely as "*deep but effortless involvement, reduced concern for self and sense of time*". According to their GameFlow model, immersion does not entail only the player's deepened (emotional and visceral) involvement in the game, but also the lessened awareness of the surrounding real-life environment and the self. A fully immersed player should also experience an altered sense

of time (Sweetser & Wyeth 2005). Immersion, like flow and presence, is commonly measured in research settings subjectively via questionnaires such as the *Immersion Experience Questionnaire* (IEQ) or the *Game Experience Questionnaire* (GEQ).

3.2 Attempting to define presence

The differences between the concepts of immersion and presence are also not abundantly clear. One attempt at some kind of a distinction is by Bernhaupt (2015), who argued that while immersion can be described as the mental state of being *away* from the real world, presence on the other hand denotes the feeling of being *inside* the virtual environment. But on further examination, one could argue that in the absence of any other environments (other than the real and the virtual), the status of being away from the real world would then also imply increased presence in the virtual environment. In other words, following this logic, immersion and presence seemingly measure the same exact experience, that is unless we assume there is an additional state between the real and the virtual worlds that the mind can occupy. If we accept that this third state would be, for example, an individual lost in his or her thoughts (as in not *mentally* engaged in either environment), the aforementioned definition by Bernhaupt (2015) would certainly hold true. Conversely, if we think of presence in the spatial sense, the feeling of being physically located in the virtual environment, and immersion as the feeling of being physically away from the real world, it is much harder to imagine a state that is in-between. That being said, in virtual reality things do get complicated at times, especially when the player is experiencing distracting stimuli from both environments at the same time.

An alternative description is that immersion is more closely related to the fidelity of the *simulation* and (virtual) presence in turn deals with the fidelity of the *experience.* A player that experiences complete presence should feel like he or she is part of the virtual environment, even in the spatial sense. While presence is also usually measured through subjective means, some objective markers such as specific facial expressions, head sway and eye movements have been identified. (Malone & Brünken, 2021)

3.3 Looking for the flow

Flow state can be described as having deep concentration and occupation with an activity. It is regarded to be something that is pleasurable and elicits intensive feelings of enjoyment. (Klasen et al., 2012) It should not, however, be reduced to mere positive feelings: instead one could make the argument that the resulting enjoyment acts as a reward mechanism for finding continuous success within the task at hand.

Despite this brief description, it is reasonable to make the argument, that defining flow is no easier task than defining immersion is. And to add to the confusion, there seems to be a lot of overlap between these concepts: for example, the terms “enjoyment” and “time distortion” can be heard in both contexts. However, flow, while very much

related to the concept of immersion, could be described as more of an "all-or-nothing" state, meaning that the player is either completely engaged in the flow state or not. Attaining flow state then seemingly requires an almost perfect set of conditions coming to fruition. Conversely, some academics argue that even the so-called "lesser" flow experiences, that do not fill all of the criteria, should still fall into the category of flow. (Michailidis et al., 2018)

Both Klasen et al. (2012) and Michailidis et al. (2018) refer to Mihaly Csikszentmihalyi as the early pioneer of flow theory. Csikszentmihalyi divided the flow state into 9 subcategories, five of which (1-5 in *table 2*) can be evaluated externally with objective metrics and the remaining four (6-9 in *table 2*) are mostly internal, subjective states of the player that, in turn, are difficult to quantify.

Table 2. Csikszentmihalyi's 9 factors of flow, as itemized by Klasen et al. (2012). Objective metrics (1-5) displayed in orange and subjective metrics (6-9) in blue.

1. Balance between the ability of the person and the challenges of the task
2. Concentrating and focusing on the activity
3. Direct and unambiguous feedback of action results
4. Clear goals of the activity
5. Control over the activity
6. The activity is autotelic (intrinsically rewarding)
7. Loss of self-consciousness (loss of awareness of oneself as a social actor)
8. Distorted sense of time
9. Merging of action and awareness (the awareness is only focused on the activity)

Is flow then a concept that is interchangeable with immersion and presence? After investigation, it is reasonable to make the assumption that it is not. To summarize, immersion is something that describes the gradual shift of the mind out of the real world and into the virtual environment, it has plateaus and it can be compared (someone can be more immersed). Flow is the complete, optimal experience, something that just clicks. Immersion and presence on the other hand do get used more interchangeably in the literature and often times presence is understood to be a subconcept of immersion.

3.4 Understanding simulator sickness

Simulator sickness is a phenomenon that deserves its own detailed description in this section because it presents an existential obstacle to the immersive experience. In terms of symptoms, it presents many similarities to motion sickness, but the term simulator sickness itself is used specifically in the context of virtual environments. The symptoms of simulator sickness are commonly measured by the *Simulator Sickness Questionnaire*

(SSQ). (Min et al., 2004) These 17 symptoms are displayed in *table 3,* with each SSQ symptom listed as part of one or more symptom groups (*nausea, oculomotor, disorientation*). Because the aim here is to briefly showcase the symptoms that constitute the phenomenon of simulator sickness, the weight and the scoring system of the symptoms are deliberately omitted to avoid confusion.

Table 3. A simplified table of the SSQ symptoms. Modified from the SSQ formulation table (Kennedy et al., 1993 in Min et al. 2004). In this version, the scoring system and the weight of the symptoms are omitted.

SSQ Symptom	**Nausea**	**Oculomotor**	**Disorientation**
General discomfort	X	X	
Fatigue		X	
Headache		X	
Eyestrain		X	
Difficulty focusing		X	X
Increased salivation	X		
Sweating	X		
Nausea	X		X
Difficulty concentrating	X	X	
Fullness of head			X
Blurred vision		X	X
Dizzy (eyes open)			X
Dizzy (eyes closed)			X
Vertigo			X
Stomach awareness	X		
Burping	X		

According to both Dużmańska et al. (2018) and Buker et al. (2012), the number one theory behind the mechanism of simulator sickness is the *sensory conflict theory* by Dr. James Reason. It theorizes that simulator sickness is in fact caused by a conflict of signals handled by the visual, vestibular and non-vestibular systems in the human body. In other words, the different sensory systems reporting contrasting conditions is enough to cause symptoms.

In addition to subjective questionnaires such as the SSQ, simulator sickness can also be detected through several physiological markers: for example, the respiratory rate seems to slow down in affected individuals, which is then contrasted by an increase in heart rate. Other markers include (but are not limited to) increased skin conductivity due to sweating, changes in the blinking rate of the eyes (initial decrease, increase to rates

above normal as the symptoms worsen), and altered electrophysiological activity in the brain as detected by electroencephalography (EEG). (Dużmańska et al., 2018)

Simulator sickness, while a debilitating condition, does not necessarily have to be a permanent, recurring occurrence. In fact, Dużmańska et al. (2018) highlight several studies which suggest that simulator sickness can indeed be greatly mitigated through adaption. In one of the studies, a noticeable decrease was achieved with several virtual reality (VR) sessions in just one day, but for long-term adaptation it would seem that repeated exposure over many days or even weeks can mitigate simulator sickness more effectively. To add, the anecdotal evidence obtained by the author of this thesis during his personal VR experiences certainly supports this data.

3.5 About display devices for racing video games

Four of the studies highlighted in this thesis investigate in some capacity the effects that different display devices, arranged in various ways, have on the gameplay experience. Before comparing the immersive experiences on these different setups in detail, it is be appropriate to provide brief descriptions of the conditions. In the latter parts of this thesis, these display setups are referred to without further explanation.

A *single-monitor setup* is the most common (and often the most affordable) option for racing games: it typically includes an LCD-display of any size, placed close behind the wheelbase, to provide the widest available *field of view (FOV)* to the player. The in-game FOV is then further adjusted to provide a proper scale of the in-game environment, one that closely resembles the real world conditions. However, even some of the more sizable monitors fail to adequately simulate an FOV wide enough: Namely, the vision towards the sides of the vehicle, a critical part of being able to race side-by-side, is completely omitted. Many racing game titles attempt to work around this issue by providing the player with additional assists, such as visual and auditory proximity alerts, or radar applications that display the locations of other vehicles in relation to the player. Nowadays, curved ultrawide monitors are also available and they can mitigate the FOV issue somewhat but as none of the empirical studies examined in this thesis use them, they are not referred to outside of this section. (Finn, 2021)

One solution to the FOV issue is to utilize a ***triple-monitor setup***. This is similar to a single-monitor setup, but an extra monitor is added to each side of the primary monitor and is angled to face the player (Malone & Brünken, 2021). In theory, even more monitors can be added to the setup, albeit with the cost of increased performance demands. The placement and the size of the monitors can vary greatly between different multi-monitor setups, and therefore it is difficult to determine a common baseline. After many years, the triple-monitor setup is still a popular option for the racing game enthusiasts, even with other options (ultrawide monitors, VR) having become available (Carver, 2021).

Eventually, the size of the conventional monitors is limited by technological and practical (cost) considerations and this is where **video projectors** can provide a feasible alternative. Due to their sheer size alone, a significant area of the player's vision can be filled with the contents of the screen, and it is even possible for the canvas to be curved slightly around the player. While the projector-based simulators are not cost-efficient for most racing game enthusiasts, they are utilized extensively by many professional racing teams to prepare their drivers for the real tracks.

With the advent of consumer-grade **virtual reality**, a completely new approach has become a legitimate option. Firstly, the *head-mounted displays* (HMD) provide an unprecedented FOV (90-110 degrees or even more), unmatched by any traditional monitors. The effect is further compounded by the head-tracking technology which enables the player to shift his/her gaze at free will, now being able to observe the virtual environment from every possible angle. Moreover, the separate images rendered for each eye enable stereoscopic vision, creating an illusion of a three-dimensional environment and therefore allowing the player to better judge the distances on the race track. The major drawback of the current generation VR HMDs is that the severity of a phenomenon called *simulator sickness* is greatly increased, although some research suggests that these effects can be adapted to and mitigated through training (Dużmańska et al., 2018). The other major issue with VR is the fact that the combination of higher resolution and wider FOV leads to massively increased performance demands: if these demands are not met by the hardware, the experience can be seriously hindered, either due to poor image quality, unstable frame rate or increased input lag (Carver, 2021).

4 Analysis and results

In this section, we will be investigating several relevant studies that use racing games as a platform. In fact, racing games have garnered some popularity as a solid platform for display, controller and simulator sickness studies, which is a great thing for the purposes of this thesis. The two main points for examination will be the various display and input devices in racing games. We will also be examining audio design and other factors in a limited fashion. The main goal then is to examine these different conditions in terms of immersion, flow and presence.

4.1 Effects of display devices on immersion and simulator sickness

Various display device options for racing games were introduced earlier in section 3.5. Here, the goal is to find an answer to the research question from the point of view of display devices. All of the four studies highlighted in this section compared the performance of VR HMDs to other display devices. Regrettably, none of them featured any direct comparison between the different traditional monitor setups (e.g. single-monitor vs

triple-monitor) but some valuable information can be extrapolated through how well each of them fared against VR.

The study by Pallavicini & Pepe (2019) compared the levels of immersion, flow and related concepts in virtual reality HMD and single-monitor desktop settings. The racing game that served as the platform for the study was *Driveclub* (2014) on Playstation 4. The results obtained through *Game Experience Questionnaire* (GEQ) show that the VR version of the game elicited higher levels of immersion, flow and positive emotions in the players (*table 4*). In terms of competence, tension and challenge the differences between the setups were described to be insignificant.

Table 4. the main findings of Pallavicini & Pepe (2019). Higher score indicates higher measured levels in the relevant metric.

Metric (GEQ)	Virtual reality HMD	Single-monitor setup
Immersion	3.2 (0.81)	2.3 (0.63)
Flow	3.6 (0.88)	2.7 (0.66)
Positive emotions	4.1 (0.78)	3.5 (0.73)
Challenge	2.1 (0.65)	2.1 (0.65)
Tension	1.2 (0.42)	1.1 (0.38)
Competence	2.9 (0.88)	2.6 (0.92)

According to Pallavicini & Pepe (2019) the players were also on average about three seconds faster over two laps of driving in VR. However, with such a small sample size of only two laps driven per setup, definite conclusions should not be made as the performance of the players can vary greatly: a single isolated driving mistake at just one corner can increase the laptime by a second and thus skew the results. That being said, if even a one second difference were to persist over dozens and dozens of laps, it would be a massive edge for VR. Providing the player with conditions that support better individual performance is arguably a contributing factor towards immersion and flow. Unfortunately, other studies investigating the effect of display devices on laptimes are not included in this thesis and any claims of VR making sim racers faster or slower are anecdotal at best.

The main findings of Pallavicini & Pepe (2019) are supported by the study conducted by Walch et al. (2017), although the circumstances were somewhat different. Their study of 20 participants measured the levels immersion, presence and simulator sickness between VR HMD and triple-monitor setups. The racing game used as a platform for the study was *Project Cars (2015)*. The levels of immersion and flow were measured by Immersion Experience Questionnaire (IEQ). Compared to the triple monitor setup, the VR HMD setup resulted in a slightly higher (but almost negligible) overall immersion score (*Figure 1*). However, according to the single question measure of immersion, the participants reported feeling more immersed in VR. Also significantly higher levels of real

world dissociation were measured in the VR scenario. These results initially seem somewhat less pronounced than the results obtained by Pallavicini & Pepe (2019), but one explanation is that due to reasons outlined in section 3.5, the triple-monitor setup is already an improvement to the single-monitor setup, and consequently its differences to the VR are also more subtle.

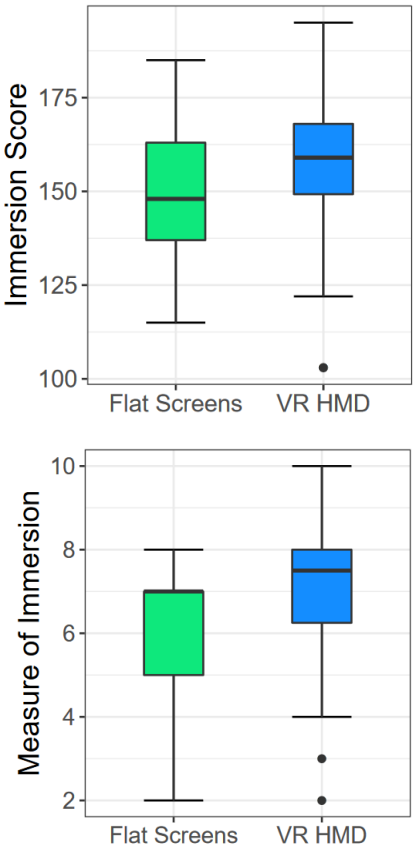

Figure 1. Overall immersion Score and single question measure of Immersion (Walch et al., 2017)

Like Walch et al. (2017), Malone & Brünken (2021) also compared VR and triple-monitors in a driving simulation. Their study showed a positive correlation with VR and increased virtual presence when measured through objective means: head movements of the participants during certain hazardous driving scenarios were used as a metric for objective presence. However, the difference in subjective presence measured by Spatial Presence Questionnaire (MEC-SPQ) was too insignificant to come to any conclusions. Malone & Brünken (2021) themselves speculated that the differences would have likely been more pronounced if the method included direct comparison of the different display devices. This is an astonishingly similar scenario to that of Walch et al., (2017) because in their study the link to increased immersion was also weaker when measured through a general questionnaire but higher with direct questions. Does this mean that the immersion questionnaires need to rethought for future research? Or perhaps this is to be taken as a confirmation that the triple-monitor setup is just that much closer to VR than it is to the more rudimentary single-monitor setup. In either case, the total body of evidence is enough to tip the scale in VR's favour.

What sets the study conducted by Benz et al. (2019) apart from the others, is that their test environment utilized mixed reality: their participants were in fact driving a real vehicle at a real test track, with the corresponding virtual environment projected onto either a projector screen on the windshield of the vehicle, or onto a VR HMD in the alternative scenario. The windshield projector scenario included two sub-scenarios, one with passenger window projections included and vice versa. These special conditions enabled the participants to experience real world physical phenomena such as g forces and vibration, while simultaneously experiencing a virtual environment through visual means. To be clear, Benz et al. (2019) did not utilize a specific metric for measuring immersion but the term presence was used instead. However, the concept of presence was not defined

in great detail at any point in their study and it remains unclear how well it matches the definition outlined by other sources like Bernhaupt (2015) or Malone & Brünken (2021). Nevertheless, the difference in presence between the windshield projector display and the VR HMD scenarios was deemed mostly insignificant.

While there is some room for discussion on display devices and immersion, there seemingly is not any for simulator sickness. Walch et al. (2017), Benz et al. (2019) and Malone & Brünken (2021) all confirmed the following observation: The use of VR HMDs in driving simulations results in increased incidence of simulator sickness in comparison to other display devices. The same argument holds true when comparing VR HMDs to multiple monitors and projectors alike. Interestingly, three out of the 42 VR HMD participants in the Malone & Brünken (2021) study experienced simulator sickness severe enough that they had to be excluded from the results. To reiterate, any direct comparison between various multi-monitor or projector setups is not included but as the incidence of simulator sickness with these devices is fairly low, it would likely not provide any valuable data. Notably, Pallavicini & Pepe (2019) made no mentions of simulator sickness or related terms in their VR/single-monitor study. Did none of their 30 participants truly not experience any simulator sickness? If they did, would it have effected their immersive experience? Having said that, if the link between VR and simulator sickness is already undeniable, perhaps it is also something that does not need to be revisited in every new study.

4.2 Investigating input devices, presence and enjoyment

Modern steering wheel controllers for racing games fill two critical purposes: not only do they translate the players physical input into the game, but they also provide the player with constant feedback of the vehicle's current status through mechanical rotational and vibrational forces. These kinds of effects fall into the category of what is commonly referred to as *force feedback,* which is a concept that relates not only to driving simulations but to controller devices in various disciplines. Force feedback steering wheel controllers attempt simulate the sensations that are felt through the front-axle (and therefore the steering wheel) of a real race car. For example, when a simulated race car travels on straights with higher speeds, it will consequently produce higher longitudinal forces of the tyres, which can then be experienced by the player as heavier steering resistance (torque) and vice versa. (Orozco et al. 2012)

Force feedback wheels also provide critical information of the current grip levels: as the tyres start slipping, the steering resistance is consequently affected (Orozco et al. 2012). To generalize, less grip usually means less resistance, but in practice it depends on many complicated factors: for example, decreased grip in the rear wheels during cornering (oversteer) will produce a completely different force feedback response in comparison

to the loss of grip in the front wheels during corner entry (understeer). Vibration effects can provide some critical information of the road surface (bumps, kerbs) and they are also commonly featured in the console controllers (Orozco et al. 2012). As is the case with audio in racing games (section 4.3), these forces are sometimes slightly exaggerated for the purposes of replacing some of the real world driving feedback (g-force), that would otherwise be omitted in the simulation.

In the study conducted by Schmierbach et al. (2012) steering wheel controllers were compared to traditional controllers through several factors, of which presence has the most relevancy for this thesis. Their experiment included a total 96 participants with limited experience in racing games and was conducted on location in a controlled laboratory environment. The results appeared to be somewhat conclusive, with steering wheel controllers having the edge in terms of perceived natural control, identification, transportation, presence, and challenge–skill balance. Interestingly, Schmierbach et al. (2012) themselves noted that increased presence is not necessarily correlated with increased enjoyment.

A recent study by Galdieri et al. (2021) also included steering wheel and controller comparison. The greatest difference to the Schmierbach et al. (2012) study was that instead of utilizing a laboratory setting, the data was gathered through a mass online survey. Most of the participants were racing game enthusiasts instead of novices like in the other scenario. In addition they were also free to use their own preferred input devices. The results indicated that as long as the participants of different groups had adequate levels of experience with the chosen input device, they experienced similar levels of enjoyment. These findings can be intrepreted as contrasting to those of Schmierbach et al. (2012) but it has to be reiterated that both the metrics and the circumstances differed quite a bit between the two studies.

To summarize, even though there is some evidence of the steering wheel controllers being the better input device in terms of presence and naturalness, the human aspect also cannot be ignored. It seems that the subjective *ability* of the player to control the input device (whichever it might be) has a bigger overall effect on the gameplay experience than just the objective attributes of the input device itself. In other words, the old adage "to each his own" might not be too far removed from reality in this isolated instance. Still, the evidence highlighted in this section is nowhere near enough to arrive at any specific conclusions and there is still plenty of room for further study.

4.3 The role of audio design in racing games

When investigating the methods of building immersive experiences, proper audio design is a massive factor. In fact, Jean-Luc Sinclair (2020) argues that while solid audio design can greatly enhance the player's immersion, poor audio design can ruin the experience altogether. Relatedly, if the player were to receive contradictory feedback through visual and auditory means, the mind will automatically assign the most importance to the visual cues, which is known as the *Colavita visual dominance effect* (Sinclair, 2020). The audio design in racing games requires some special considerations due to the dynamic nature of the soundscape: it is not sufficient for the game to play a simple audio clip following an action, the engine sound for example is composed of many smaller parts and needs to be adjusted constantly in accordance with the player inputs (Dockwray & Collins, 2015).

In the context of racing games, two critical sound cues come to mind. The most prominent one, that is featured in virtually every racing game, is the engine sound. The engine provides instantaneous auditory feedback of the player's throttle application, assists in recognizing the correct window for changing gears and also helps locating the other nearby vehicles in relation to the player. Furthermore, a satisfying engine sound can make the player *feel* as if he or she is driving a powerful vehicle: notably, the developers of *Forza Motorsport 5* mixed lion roars into the engine sounds and people screaming into the tyre sounds to provoke an enhanced emotional response from the player. Many racing games also include exaggerated crowd noises to achieve a similar effect, even though the crowd is not audible to the driver in real life racing situations. (Dockwray & Collins, 2015) Not necessarily the most realistic practice, but something that can be a contributing factor towards building immersive experiences.

Perhaps the most useful sound cue in racing games is the tyre sound, which is featured in impressive detail in many modern racing game titles. Similarly to real-world conditions, as the tyres start losing grip, they will produce audible cues, most commonly howling or squealing sounds of various pitches. With the absence of various other real world cues, such as g-force or chassis movement, tyre noise becomes an even more critical factor for the driving simulators. Exaggerated tyre sounds can help the player to better estimate the current tyre grip level at any given moment. (Dockwray & Collins, 2015) For example, locking up the front tyres during heavy braking would be challenging to perceive just through visual means. In combination with force feedback (section 4.2), the tyre sounds then enable the player to drive the simulated vehicle closer to its perceived maximum potential (*the limit*), which can be conducive towards reaching the flow state during gameplay.

4.4 Miscellaneous factors

In the controller study by Galdieri et al. (2021) (see section 4.2), 22 virtual race tracks were also evaluated by the participants. Each track was evaluated in both hotlap and race conditions with no noticeable difference in scores. There appeared to be some variation in how the users of different input devices enjoyed tracks with specific characteristics: traditional controller users rated the twisty and technical tracks (e.g. Monaco GP track) to be less enjoyable than the steering wheel users. That being said, the race tracks with higher average speed and fewer gear changes were generally found to be more appealing across all groups. The history of the examined tracks' real world counterparts also seemed to be an influence as the tracks with extensive real world racing pedigree (e.g. Monza, Spa-Francorchamps) were consequently more popular in the simulator.

In addition to the controller experiment that is highlighted in section 4.2, Schmierbach et al. (2012) explored the customization of the in-game vehicle liveries (paint job) as a method of producing an extra layer of presence, transportation (flow-like metric) and enjoyment. Surprisingly, while customization provided some increased presence and enjoyment through identification (as an expression of the self), it lead to an overall decrease in enjoyment through other aspects of the game. The reasons for this unexpected result were not clear but it was speculated that attempting to identify with a (customized) vehicle, without a visible driver character, is simply not as effective in producing enjoyment as identifying with a human-like avatar: visual character customization is arguably a successful feature in many other video game genres, such as shooter games. (Schmierbach et al., 2012)

5 Discussion

The most relevant result from the point of view of this thesis is the following: there is sufficient evidence that the use of VR HMDs results in increased immersion, presence and flow in racing video games when it is compared against traditional monitors. Even though the monitor setups were not compared to each other directly in any of the studies, the argument can be made that the gap between VR and single-monitor setups is greater than the gap between VR and triple-monitors, which would then point to the triple-monitor setup being more immersive than the single-monitor setup. The gap between the special in-vehicle projector setup and VR was observed to be inconsequential, but it is good to note that the custom projector setup inside a moving vehicle does not necessarily represent a typical projector setup (if there is such a thing) very accurately.

The analysis in section 4.1 leaves some lingering questions, especially related to the connection of VR and simulator sickness in racing games. When attempting to measure immersive experiences, should simulator sickness be compensated for in the data? Or

alternatively should only the participants that are proven not to experience major symptoms be included in the results (as was the case in the Malone & Brünken (2021) study)? After all, if the participant is unable to properly experience both scenarios, is the resulting data at all meaningful for specifically comparing immersion, flow or presence? It is clear that there is still room for numerous alternative angles in this kind of research. It will also be interesting to revisit this subject in the future when some of the current generation VR HMDs will be utilized as many of the devices in the included studies were already of considerable age. Higher framerates, better head tracking and increased image quality should in theory mitigate the simulator sickness issue even further.

The results for input devices were a bit more inconclusive. While Schmierbach et al. (2012) observed that steering wheel devices were perceived by the participants as being more natural and produced higher presence, their results were partly contrasted by those of Galdieri et al. (2021), who found that users of different input devices experienced similar levels of enjoyment. A fascinating observation by Schmierbach et al. (2012) was also the fact that higher presence did not necessarily correlate with more enjoyment, which could in part explain the perceived differences in results. Relatedly, controller users disliked twisty and low speed tracks more than steering wheel users but overall both groups found high speed tracks more appealing. Visual customization of the race car was also investigated as a method of increasing presence and enjoyment but overall failed to achieve that, according to Schmierbach et al. (2012).

One interesting bit of information learned during the writing process of this thesis is that more realistic is not always more immersive. For example, the developers of racing games seem to be taking some artistic liberties with the audio design. In addition to making the player feel more immersed, exaggerated engine and tyre sounds also have a critical function as gameplay feedback in racing games. Likewise, it can be extrapolated that if the game fails to present an appropriate challenge to the player, it can actually be a hindrance to immersion, presence and flow: a racing simulator with highly realistic physics might be off-putting to some players and in turn immersive to others. However, this argument is pure speculation by the author of this thesis, based on the flow criteria of section 3.3.

Anecdotally, many gamers often rate their childhood gaming experiences more highly, even though objectively these games were less advanced. This would then suggest that the key to immersive experiences might not necessarily lie in the technological aspects but rather it is the human mind that is the most important part of the puzzle. The study by Galdieri et al. (2021), which was highlighted earlier, seems to support this idea, as the players with varying equipment rated their racing experiences to be almost equally

enjoyable. In other words, improvements in hardware or software might not always guarantee improvements in terms of immersion, presence or flow: for example, the case of virtual reality, while an impressive innovation, is absolutely not for everyone.

6 Conclusion

Immersion and presence are concepts that describe the gradual shift of the player's consciousness out of the real world and into the video game environment. Flow can be used to describe the optimal experience: a complete occupation with the activity, something that is also viewed as inherently enjoyable. The studies highlighted in this thesis showed that, in the context of racing video games, VR HMDs are better than traditional monitors in producing all of these three experiences. However, the caveat to VR HMDs is that they induce more simulator sickness. There is some evidence that steering wheel controllers are more conducive towards presence than console controllers are, but if the players have sufficiently adapted to either device, the differences in terms of enjoyment are inconsequential. Importantly, it was also discovered that higher presence does not directly correlate with higher enjoyment. The users of different input devices seem to prefer slightly different race track profiles, with twisty low-speed tracks being even less appealing to the console controller group. Visual vehicle customization in racing video games does not appear to have great significance on the immersive experience. Audio design is a critical part of the racing game experience and the soundscape needs to be adapted to the player inputs in real time. The engine and tyre sounds assist in creating immersive experiences, but above all, they are a crucial source of gameplay feedback.

References

Benz, T. M., Riedl, B. & Chuang, L. L. (2019). Projection Displays Induce Less Simulator Sickness than Head-Mounted Displays in a Real Vehicle Driving Simulator. *AutomotiveUI '19: Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. September 21 - 25, 2019, Utrecht Netherlands. p. 379–387. https://doi.org/10.1145/3342197.3344515

Bernhaupt, R. (2015*). Game User Experience Evaluation.* p.42-43. Springer International Publishing AG.

Brown, E., Cairns, P. (2004). A grounded investigation of game immersion. *CHI EA '04: CHI '04 Extended Abstracts on Human Factors in Computing Systems*. April 24 - 29, 2004, Vienna, Austria. p. 1297–1300. https://doi.org/10.1145/985921.986048

Buker, T.J., Vincenzi, D.A. & Deaton, J.E. (2012) . The Effect of Apparent Latency on Simulator Sickness While Using a See-Through Helmet-Mounted Display: Reducing Apparent Latency With Predictive Compensation. *Human factors, 2012-04, Vol.54 (2),* p.235-249. https://doi.org/10.1177/0018720811428734

Carver, C. (2021) Sim Racing Guide 2021: Screens & More Screens. *Drivetribe.* https://drivetribe.com/p/sim-racing-guide-2021-screens-more-A5nAS_ICRz-xClCCPeT97g

Dockwray, R. & Collins, K.C.(2015). A Symphony of Sound: Surround Sound in Formula One Racing Games. *Living Stereo.* Bloomsbury Academic. p.253-255. http://dx.doi.org/10.5040/9781501309090.ch-011

Dużmańska, N., Strojny, P. & Strojny, A. (2018). Can Simulator Sickness Be Avoided? A Review on Temporal Aspects of Simulator Sickness. *Frontiers in psychology, 2018, Vol.9,* p.2132-2132 . https://doi.org/10.3389/fpsyg.2018.02132

Finn, R. (2021) Gaming Monitors: How to choose the best monitors for sim racing. *Sim racing cockpit.* https://simracingcockpit.com/gaming-monitors-guide/

Galdieri, R., Camardella, C. & Carrozzino, M. A. (2021). What makes a circuit likeable and how different input devices can influence the perception of tracks in racing games. *Computers in Human Behavior Reports Volume 3*, January–July 2021, 100072. https://doi.org/10.1016/j.chbr.2021.100072

Klasen, M., Weber, R., Kircher, T.T.J, Mathiak, K.A. & Mathiak, K. (2012). Neural contributions to flow experience during video game playing. *Social Cognitive and Affective Neuroscience, Volume 7, Issue 4, April 2012*, Pages 485–495. https://doi.org/10.1093/scan/nsr021

Malone, S., Brünken, R. (2021). Hazard Perception, Presence, and Simulation Sickness-A Comparison of Desktop and Head-Mounted Display for Driving Simulation. *Frontiers in psychology*, 2021, Vol.12, p.647723-647723. https://doi.org/10.3389/fpsyg.2021.647723

Michailidis, L., Balaguer-Ballester, E. & He, X. (2018). Flow and Immersion in Video Games: The Aftermath of a Conceptual Challenge. *Frontiers in psychology,* 2018, Vol.9, p.1682-1682. https://doi.org/10.3389/fpsyg.2018.01682

Min, B. C., Chung, S. C., Min, Y. K. & Sakamoto, K. (2004). Psychophysiological evaluation of simulator sickness evoked by a graphic simulator. *Applied Ergonomics. Volume 35, Issue 6,* November 2004, *Pages 549-556.* https://doi.org/10.1016/j.apergo.2004.06.002

Orozco, M., Silva, J., Abdulmotaleb, E.S. & Petriu, E. *(2012).* The Role of Haptics in Games. *Haptics Rendering and Applications*, IntechOpen. *http://dx.doi.org/10.5772/32809*

Pallavicini, F. & Pepe, A. (2019). Comparing Player Experience in Video Games Played in Virtual Reality or on Desktop Displays: Immersion, Flow, and Positive Emotions. *CHI PLAY '19 Extended Abstracts: Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts.* October 22 - 25, 2019. Barcelona, Spain. p. 195–210. https://doi.org/10.1145/3341215.3355736

Schmierbach, M., Limperos, A. M. & Woolley, J.K. (2012). Feeling the Need for (Personalized) Speed: How Natural Controls and Customization Contribute to Enjoyment of a Racing Game Through Enhanced Immersion. *Cyberpsychology, Behavior, and Social Networking.* Jul 2012. p. 364-369. https://doi.org/10.1089/cyber.2012.0025

Sinclair, J. (2020) Chapter 2: The Role of Audio in Interactive and Immersive Environments. *Principles of Game Audio and Sound Design*. Focal Press.

Sweetser, P. & Wyeth, P. (2005). GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment.* Volume 3. Issue 3. July 2005. pp 3. https://doi.org/10.1145/1077246.1077253

Walch, M., Frommel, J., Rogers, K., Schüssel, F., Hock, P., Dobbelstein, D. & Weber, M. (2017). Evaluating VR Driving Simulation from a Player Experience Perspective. *CHI EA '17: Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems.* May 6 - 11, 2017, Denver, CO, USA. p. 2982–2989. https://doi.org/10.1145/3027063.3053202