VIRTUAL REALITY DESIGN:
HOW UPCOMING HEAD-MOUNTED DISPLAYS
CHANGE DESIGN PARADIGMS OF VIRTUAL REALITY
WORLDS

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“The matrix has its roots in primitive arcade games. […] Cyberspace. A consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts. […] A graphic representation of data abstracted from banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights, receding.”

— William Gibson, Neuromancer (1984)

1. Introduction

When William Gibson describes the matrix in his canonical cyber-punk novel Neuromancer, it is a computer-generated parallel universe populated and designed by people all over the world. While it would be an exaggeration to say this is about to become a reality, with current-generation virtual reality systems an important step toward immersive digital worlds has already taken place.

This article focuses on current developments in virtual reality (VR) with head-mounted displays (HMDs) and their unique digital experiences. After decades of experimentation with VR beginning in the late 1980s, hardware, software, and consumer mindsets are finally ready for the immersive VR experiences its early visionaries dreamed of. As far back as 1962, Morton Heilig developed the first true VR experience with Sensorama, where users could ride a “motorcycle” coupled with a three-dimensional picture; it even
included wind, various smells, and engine vibrations. Many followed in Heilig’s footsteps, perhaps most famously Ivan Sutherland with his 1968 VR system *The Sword of Damocles.* ¹ These developments did not simply constitute the next step in display technology or gamer hardware, but rather a major break in conceptualizations of space, speed, sight, immersion, and even body. By 1993 VR was defined as:

The illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on three-dimensional (3D), stereoscopic, head-tracked displays, hand/body tracking, and binaural sound. VR is an immersive, multi-sensory experience.²

Though this definition still holds today, hardware has developed extensively and the quality of the illusion has changed dramatically.³ Indeed, it is because of these changes that it is necessary to understand why current applications work the way they do. Present-generation devices are effecting paradigmatic changes on “virtual reality”⁴ in its current form as virtual reality head-mounted displays (VR-HMDs). Since the first Oculus Rift prototype was announced in 2012, VR has referred to the available hardware (with its possible extensions) rather than theoretical ideas, impelling us to focus on practical applications and developments.

Though modern technological approaches to VR originated in gaming, its applicability extends beyond those platforms.⁵ Every unique VR experience requires the use of general design principles, which can differ from conventional game principles. But to this day there is little knowledge of which designs work best with current VR-HMDs: what can be reapplied from existing

³ Although many current technological approaches had already been described by 1993, the technical capabilities were very limited: “[m]uch of the equipment available to VR researchers today suffers from inadequacies that need to be addressed before VR will become a prominent technology.” Earnshaw, *Virtual Reality Systems*, 25.
⁴ While there are several types of HMDs—such as heads-up or see-through displays—providing different spatial conceptualizations, VR-HMDs explicitly refer to opaque displays that exclude the physical world and cover the entire field of view. As there are other forms of VR that use different display technology, this article will address HMD-based VR.
Many principles and techniques in conventional computer game design allow for creating immersive, interesting, and fun games that are often implicitly used by developers, and even implemented into the game engines themselves. And as they are normally developed for a specific hardware platform, moving games across different platforms is especially difficult. Indeed, its difficulty is not simply a technical challenge; hardware implies particular user groups, habits, experiences, expectations, knowledge, and the circumstances of its usage: “As all representations are eventually filtered through human perception, the application designer must consider human characteristics ranging from the physiological to the psychological to the emotional.” Next-generation VR-HMDs entering the market in 2016 are affecting paradigmatic shifts in content, especially for VR. As many analysts have predicted, these experiences will be widely present in developed countries within the next few years and can potentially generate a huge market with a broad spectrum of applications. If we take the above seriously, there is a need to combine practical knowledge with theoretical analysis, since this technology will affect not only gamers, but media users of all kinds.

VR-HMDs change not only the display, but also the main controller, now operated with the head instead of the hand. With this comes a shift in both the sense of presence in virtual environments and in game design itself: “If you want to create a virtual reality game, the focus should be to create that sense of presence and then never take it away from the player.” To this end, the pace

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10 The most important new generation VR-HMDs are the Oculus Rift, the HTC Vive, and the Playstation VR. They are expected to be the first to enter the market, and the companies behind them (Oculus VR, Valve, and Sony) are deeply committed to VR content production.
of first-person games has increased considerably, so that today quick movement is induced by game world design. But the speed of these movements is unsuitable for VR because of the potential for the loss of orientation in the user; the variance between bodily movement and being stationary, for the most part, including the change in perspective, is too great. Moreover, it is highly problematic to take the camera view out of the user’s control and bring it to a perspective the user did not steer with their head movement. Users tend to spend more time examining objects, exploring them from different angles, and searching for details compared to conventional screen-based games. Where the difference is neither experienced nor compensated by new hardware tools, the deviation of visual (or acoustic) perception from equilibrium, acceleration, and rotation makes a different design necessary.

But it is not only design that is affected by these developments. We must now also practically contend with the difference between reality and simulation, and in what way(s) they can both be incorporated. Where are they inextricably merged? When the very concept of reality changes, the game changes accordingly. While many psychologists and gamification experts agree that considerable parts of external reality can be described as a well- (or poorly-) designed game that can be optimized, VR experts predict that VR will not be mainly about gaming. As the borders of what we know to be reality are starting to change, we need to reconceptualize boundaries and affiliations.

In what follows, I provide an overview of the peculiarities of VR as they are related to current forms of VR-HMD technologies, including their potential effects and broader implications. I begin in Section 2 with a discussion of immersion viewed through the combination of VR-HMD technology and its corresponding VR worlds. Section 3 describes principles of world design in VR, followed in Section 4 by an analysis of the application Sightline. Section 5 addresses user perception, orientation, and the virtual body. Jumping off from this discussion, Section 6 employs and re-examines user experience in the recent VR-enabled game Alien: Isolation. Offering a summation of known game world design principles, Section 7 offers recommendations for future development. Finally, the scope of both “reality” and “virtuality” (as physicality and simulation, respectively) are challenged in order to question how they might be differentiated at all.

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13 Gamification is understood here as the usage of game-design and game elements in non-game contexts.

2. Creating Immersion

Over the last four years, HMD-based VR has moved from a niche interest to a rapidly growing global movement in search of higher levels of immersion. And although immersion may be examined from multiple perspectives—spatial, ludic, narrative, or social immersion—the current global development in VR-HMD is focusing on technologically-generated spatial immersion:

Devices for immersion have existed from time immemorial. Theaters and religious rituals have historically used different types of immersion experiences, from baptism by water to theater-in-the-round. The decisive factor in VR technology is the computer that handles the data. The computer consumes vast amounts of information to track the positions of the eyes and hands and then converts those positions into the changing geometry of a table or chair as it shifts in thousands of different perceptual angles captured by the human perceiver moving through virtual environment.15

Aside from early science fiction prototypes, a movement exploring the use of computer technology for immersion took root in the early 1980s.16 Their dream was termed “virtual reality,” and was described concretely, for the first time, by Damie Broderick in his novel The Judas Mandala.17

What followed over the next 30 years was a period of continuous development for VR systems and HMDs. Many systems developed were related to the digital game industry, as it had traditionally shown a high degree of openness to and interest in new developments in computer graphics. In 1991 Sega had already released the Sega VR, an early VR-HMD that included head tracking. Four years later, in 1995, Nintendo similarly experimented with the release of the Virtual Boy. Both were commercial failures. While enough to spark interest, neither device could support continuous, long-term gaming.18

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But despite the lack of commercial success, an important milestone in VR development was reached. While many other systems would be developed, few made it beyond the prototype stage, as the technical requirements for immersive systems were not yet commercially available.

All of this changed when Lucky Palmer introduced the early prototype for the Oculus Rift in 2010. With development in mobile technology came small, affordable, and precise sensors and high-resolution graphic panels fast and capable enough for VR. The Oculus prototype underwent six years of work until, in 2016, the release of the first commercial model was ready—standing as, possibly, the most important milestone for VR-HMD technology to date. In its current state, Todd Richmond, director of advanced prototypes at the University of Southern California Institute for Creative Technologies, says of VR:

There is no doubt that these immersive technologies will be the most important innovation of the next gaming generation, and will also impact every other aspect of our lives. The gaming industry will be an early adopter and help figure out how the technology is viable. By 2017, AR/VR/blended reality technologies will be easily and affordably brought into consumer homes thanks largely to video games.  

With the introduction of commercial technology, and coupled with the increasing affordability of hardware and software, ranging from U.S. $400 to $1000 for the current generation, VR-HMDs may become a common medium for larger segments of the population. The most prominent technology available today, however, is still the Oculus Rift, which resembles diving goggles fastened around the head to filter out all external light. Weighing roughly 400 grams and consisting of a 5.6-inch OLED double display with a resolution of 2160×1200 pixels and magnifying lenses for both eyes, the Oculus display provides each eye with a slightly shifted image enabling stereoscopic vision.

The interesting point about the Oculus Rift’s glasses, and indeed similar VR-HMDs, is not the three-dimensional image already well known in 3D cinema. Rather, it is that the glasses offer users a radically new experience of a virtual space with a three-dimensional image lacking either frames or limitations in perspective. No matter how large a cinema screen may be, by

turning your head you will see the rest of the cinema behind you. But with VR glasses this changes: any way the users turn they perceive the simulated world—a virtual sky arching above them, a virtual floor stretching beneath them. The observer, in this sense, constitutes a part of the virtual world. Present-day VR-HMD glasses respond to the direction of users’ gaze and have become so sophisticated as to reduce dizziness and motion sickness (if the displayed content follows the rules of VR-HMDs—see section 7). Moreover, head movements accurately match the visual impression of virtual space while delays in the picture are rendered nearly imperceptible.

The potential uses for such a technology are broad, spanning from entertainment to research. For example, the glasses might be used to more accurately gauge spatial parameters such as size and distance. Architects might walk through a virtually rendered model of a building prior to construction; historians and archaeologists might explore reconstructions of ancient sites while engineers study the spatial organization of industrial facilities. Virtual glasses might be employed as therapeutic aids to help treat phobias by gradually approaching the object of their fear in the virtual world. Surgeons could conceivably train for complicated operations in virtual simulations of successful operations from a first-person perspective. The range of potential applications appears limitless, reaching into robotics, scientific visualization, design, education, collaboration, space exploration, entertainment, and social networks, all of which are today only beginning to discover the opportunities that virtual reality affords.

With VR people consider it possible to create a self-designed, perceivable reality, and, moreover, a reality that can be constructed on the basis of VR movement:

Take away reality, and all that is left is relativism, a belief that truth can be established simply by asserting it, that the self is all that exists—no, that myself is all that exists. The computing industry was built on the liberal belief in the individual as the only legitimate political entity, and virtual reality has, in some hands, been promoted as the ultimate embodiment of that principle. What better way of expressing your individualism than by creating your own individual reality? Empowered by the personal computer, liberated by virtual reality, the individual becomes the God of his or her own universe.26

The potential to create worlds that are not only highly immersive but that also reflect an individual perspective was a key driver of VR content development since the first Oculus Rift in 2012. However, just as the “physical” world has its constraints, so too do virtual worlds have rules: the more immersive a virtual world is designed to feel, the more it must comply with the particularities of virtual reality.

3. Developing Worlds: Looking at Virtual Reality

In this section I examine the unique features of VR-HMD-based experiences compared to other media forms that concern three dimensionality, framelessness, focus, and visuality. I also consider what approaches have been taken by developers to handle particular differences in the experiences.

A technical threshold has always challenged digital game and simulation design: how realistic can an experience be designed to be? More realistic experiences became possible through hardware (improved graphics cards that permit higher and more specialized calculation power, graphics accelerators, and new displays) and software alike (sophisticated game engines, interfaces, and frameworks that provide new visual effects and physical simulation). These developments have been deeply integrated: new games and simulations demanded specialized, faster hardware, and so the development of hardware made new kinds of experiences possible. In this way, games are designed with a certain hardware setup in mind, which enables the intended

game experience. This has always been easier on consoles, such as the PlayStation or Xbox, than on PC gaming platforms because PC hardware setups are intended for a variety of uses, while consoles are sold in a singular version that is precisely known.27

Visual game design constantly pushes the boundaries of what is possible; it tries to impress gamers with higher resolutions, higher frame rates, more detail, more effects, sophisticated animation, larger game worlds, and new forms of interaction. The goal for developers, game designers, and publishers has been to generate a greater impact on the player: consistent and intense experiences, a higher degree of immersion and emotional involvement. The gamer’s experience provides the obvious economic impetus for content developers: players will spend more time in games and more players will purchase them.

When the first version of the Oculus Rift Development Kit 1 (DK1) was released in 2012, virtual reality became a reality for developers. The DK1 did not offer a high resolution, nor did it offer a convenient user experience.28 But it was available for purchase for a price those interested in VR could actually afford: at U.S. $300 it could be ordered online and shipped nearly anywhere worldwide. This low price was the starting point for a broader VR community consisting of game developers, VR enthusiasts, and those quick to adopt new technologies. Use and development were closely tied to the explorations of hitherto undiscovered possibilities. Few knew at the time what could be done in VR. It was this community that explored the first rules and patterns of how to develop VR-specific applications. News sites, blogs, and forums, such as vnerds.de, roadtovr.com, and Reddit’s “virtualreality” subreddit offered platforms for discussion and the sharing of experiences and source code. The Oculus Share space (share.oculus.com), on the other hand, became the basis for sharing prototypes of VR applications of various kinds.

Due to the lack of knowledge on how to develop good VR experiences, especially in those early days, the testing of other prototypes was the only way for developers to find solutions for their own VR projects. That way, Oculus Share became a learning and knowledge hub. Its value was not only in the improvement of prototypes, but moreover the development of small test

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projects: those that did not work, those that tried but failed using a certain approach, the unpolished demos, and those with a mismatched balancing of speed, space, and size.\footnote{A good example of this is Mirror’s Edge in the VR version, which includes a lot of jumping and creates motion sickness almost immediately. See “MIRROR’S EDGE with the OCULUS RIFT | I’M SCARED OF HEIGHTS!!,” October 25, 2013, accessed June 1, 2016, https://www.youtube.com/watch?v=pVdZh03ju6U&feature=youtu.be. Another example is Air Accident Experience, which simulates an air crash and fails to combine weather conditions with VR interactions. See “Air Accident Experience on Oculus Rift DK2,” March 26, 2015, accessed June 1, 2016, https://www.youtube.com/watch?v=dMy6XQwAiHg.}

Lucky Palmer, for example, states:

The actual truth is that we don’t know how things are going to play out. We know there are going to be a lot of successes, but the likelihood is that there are also going to be a lot of failures, it’s really the same of anyone else in the games industry.


Knowledge about VR was achieved not only by seeing how it looked but also by testing how comfortable it felt. Even with the best available hardware, low latency, and high frame rates, it was game and interaction design that made the difference in deep immersion and motion sickness.

3.1 Straight Forward

Several user observations show that users tend to follow a certain learning curve when they embark on their first VR experience.\footnote{This is my own personal observation based on watching over 100 users experience VR-HMDs for the first time.} They normally sit straight on the chair and watch straight in front of them without moving their head too much. Previous experience with other forms of media explains this behaviour. People are used to watching what is in front of them: computer screens, TVs, and 3-D cinema screens do not move in front of the eye and have a clearly perceivable frame. This frame marks and limits the space of visual virtuality. Outside the frame, physical reality is still the visible. Thus, virtuality is displayed inside so-called reality; that is where it is situated. No matter how big the screen is, no matter if the picture is 2-D or 3-D, if a user looks down, there will still be the seat with his or her body on it. The user sits in front of the virtual world, looking in through a window: the screen. The experience is happening in front of, not around, them. So, in many cases, users need a few
moments to realize that they can actually look around without seeing any frame. This results in a clearly articulated note of surprise for many of them:

[N]ot just our bodies are transported, but also our history and our social and cultural context. In terms of VR, there is clear evidence that people bring their everyday, real-world understandings and social experiences to new virtual encounters.32

To the extent that inexperienced users of VR-HMDs act according to their mainly passive previous experiences with media, many content developers are trying to simply transfer traditional media to VR without reflecting its unique features. Even though VR-HMDs have been available since the 1980s, that technology cannot be transferred, for the most part, to current generation hardware. With current-generation HMDs, certain problems are becoming visible for the first time, as the technological limits of earlier prototypes had obscured issues that now reveal themselves to be important.33 Moreover, most content developers have far more experience with traditional media than with VR-HMD and try to transfer it directly:

Virtual reality is inherently an interactive medium; therefore, the simple transference of content from sequential media makes little sense. For instance, reading a Herman Melville novel does not become more interesting, engaging, or useful if it is done while wearing a head-mounted display. Watching an Orson Welles film is not enhanced by making the viewer turn their head to follow the action of the film. On the other hand, if the original content is modified for the new medium by adding interactivity, the filmmaker’s role of setting the tone and pacing via camera angles, editing, and other techniques is diminished.34

Content developed for VR creates possibilities for completely new forms of narration, wherein the user’s perspective is not fixed and guided but rather becomes meaningful for the story being told, or the world being shown:35

34 Sherman and Craig, Understanding Virtual Reality, 419.
In VR, the viewer is not passive like he or she used to be. With this new technology, the viewer can go through the story with movement, being active and making decisions. The language associated with VR is still being developed and this concept has been recently referred to as “presence.” This leads to a fundamental difference between 360 and VR, as virtual reality is interactive. VR is about having an experience.\(^{36}\)

As there is no frame anymore, perspective becomes the most crucial form of interaction in VR-HMD-based content. Content developers must take this idea as their point of departure, making multiple viewpoints possible, indirectly guiding the user’s perspective through motion or sound, even allowing for different storylines depending on where the user’s focus lies.\(^{37}\)

### 3.2 Focus on Frameless Environments

Superseding the flexibility in choosing one’s own perspective, it is three-dimensionality that is typically perceived as the initial stunning effect, although it might already be known from 3-D cinema or 3-D television sets. But, in a three-dimensional environment, three-dimensional perception is quite different. In 3-D cinema, action is perceived from a safe distance, and objects that appear close to the audience are basically used as a special effect.\(^{38}\) This usage results from the fact that viewing a 3-D picture creates different focal points. To see the picture clearly, in other words, the eyes must focus on the display screen, although the actual focal point of the three-dimensional picture could be before or behind it. This is why the basic rule of 3-D filmmaking is to adjust the most important details to display screen distance.\(^{39}\)

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\(^{36}\) “Storytelling in VR,” Kilograph, February 10, 2016, accessed June 1, 2016, [http://kilograph.net/storytelling-in-vr/](http://kilograph.net/storytelling-in-vr/). The number “360” here refers to a 360-degree video that can also be watched on a VR-HMD, allowing for free head movement. Though still a video, the content presented is fixed to the 360-degree camera. Positional tracking or interactive content is, therefore, not possible.


Moreover, many 3-D movies still use depth-of-field blur to have the audience focus on certain visual elements. As this is a technique from 2-D filmmaking, it does not enable the audience to choose their own point of focus. It results in a distortion, since the eye is trying to centre its attention on a certain point, but cannot bring it into focus.

By contrast, in VR-HMD-based experiences the world is dynamically rendered and everything is normally displayed and equally sharp so the eye can focus on it as it may—notwithstanding some minor restrictions from game engine optimization, post processing effects, and display quality. Switching focus between different virtual objects at different distances can still be problematic and cause “visual discomfort and fatigue, eyestrain, diplopic vision, headaches, nausea, [and] compromised image quality.” These effects result from the fact that the distance of the displayed object to the eye is still constant, as the display itself does not move. Current research is trying to circumvent this effect, known as the *vergence-accommodation conflict*, with the use of light field technology that allows for natural depth focusing.

Current-generation VR displays support many depth cues of human vision: motion parallax, binocular disparity, binocular occlusions, and vergence. However, focus cues are usually not supported by stereoscopic displays, including head mounted displays (HMDs). Focus cues and vergence are artificially decoupled, forcing observers to maintain a fixed focal distance (on the display screen or its virtual image) while varying the vergence angle of their eyes.

So long as light field-based VR headsets are still in the prototype stage, developers of VR worlds must address this problem by minimizing the focus difference of objects the user is encouraged to focus on, as correct or nearly-correct focus cues significantly improve stereoscopic correspondence. The most fitting viewing distance in current VR-HMDs is 0.75 to 3.5 metres, which

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41 Ibid., 1.

means that game worlds should provide those objects the user interacts with mostly at this range.\footnote{Oculus Best Practices, Version 310-30000-02," Oculus VR, 2016, accessed June 1, 2016, http://static.oculus.com/documentation/pdfs/intro-vr/latest/bp.pdf. See page 8.}

As a consequence, the full spectrum of a 3-D environment cannot be used as it is. The virtual world has to be designed in such a way that viewing distances and focal points are suitable with the available hardware. So, it is possible to show a far-off panorama, objects, and effects as well as objects or characters that get very close, but this should not be the major part of the experience. A typical game interaction should be in focus at a comfortable viewing distance. For game world designs, this means that everything outside this preferred distance should be used only as a 3-D effect to build a compelling scene, though it will play a minor role in the mechanics of the interaction. No matter how far users can see in VR-HMD worlds, the virtual environment they can actively interact with is limited to roughly the size of a living room. In a way, a visual limitation, similar to the frame in conventional displays screens, is once again present—not as an external impediment, but as an internal one that, nonetheless, limits the possibilities of what can be displayed.

3.3 Virtuality and Visuality

Each object, scene, or character displayed in a VR-HMD can be considered “virtual” in the common sense of the word. However, there is a difference between what is virtual and what is perceived as virtual. Immersion is much more about perceptual awareness than about the nature of these digital objects. Reception to the virtual is more about whether users can compare physical and virtual objects in their field of vision:

As a start, VR requires new ways of thinking about space, dimension, immersion, interaction, and navigation. For instance, screen-based media tends to emphasize right angles and forward motion, and the edges of the screen are always present. This leads to what cinematographers call “framing” of shots. But in VR, there is no screen, no hard physical boundaries, and there’s nothing special about right angles. And there’s nothing to frame, unless you use real-world elements like doorways and windows for the user to look through.\footnote{Ibid., 36.}

Besides screen frame, with 3-D cinema and television the physical world is present. Even in a dark cinema, actual physical objects are visible in their
reflection on the screen. While virtual action takes place within a clearly marked frame, the surrounding physical objects—seats, curtains, people, the living room, or simply one’s own body—convey a different visuality compared to objects on-screen. Although they are not the main focus, they function to mark the “real” space, in contrast to the virtual one. In VR, on the other hand, physical objects are no longer visible—not even one’s own body. With the loss of these contrasting objects, the difference between virtual and physical objects concerns only the beginning and end of the VR-HMD experience.

As a result, virtual objects are no longer clearly marked explicitly as virtual. The entire scene becomes more immersive as the user quickly adapts to the visuality of virtual objects and takes it for granted. This allows for a world design that need not be oriented by the similarity of visual appearance as in the physical world. With this crucial difference literally out of sight, it is far more important that the virtual world be consistent in its visuality and provide a high degree of detail. While at the beginning of the VR experience the visual contrast to the physical world is palpable, the longer it lasts the more crucial virtual world design becomes. The more exposed users are to this virtual visuality, the more they become habituated to it, and the more immersive their experience becomes. Immersion, therefore, is not so much a question of similarity and realistic simulation as it is about a consistency that permits a certain degree of familiarity, even if it looks and feels different than the physical world.

The following relatively well-known VR demo demonstrates the previously described aspects of visuality in an atypical way. In particular, it combines an ever-changing world that follows weird rules with familiarity of a constant visuality. The aforementioned effects of VR-HMD can be observed here in praxis, as the conventional exposure to media, which involves looking straight forward, is effectively broken; the differences in frame and perspective are played out directly by placing the action out of perspective. Consistent visuality provides an immersive stability despite a constantly changing environment.

4. Sightline

Sightline: The Chair is a surreal virtual reality experience for Oculus Rift that creates a strangely behaving world that plays with perception and change.46

Depending on the configuration, the experience can last up to 15 minutes. Apart from the HMD itself, Sightline does not require a control set. Users discover how to use the HMD for controlling the experience in the first few minutes of play, during which there are no obvious challenges. The experience begins with the user sitting at a desk, being the most probable physical setting from which to begin. On the desk are old red-cyan anaglyphic glasses representing the very early days of three-dimensional vision, and next to them, an Oculus Rift Development Kit 2 (DK2). After watching a small introduction video on a computer screen, also located on that table, the experience moves into the surreal. A plant sitting on the left side of the desk changes into another plant when the user looks back at the computer screen. In this way, the basic principle of the experience is introduced: change in the environment situated beyond the user’s centre of attention. As the room becomes darker, the anaglyphic glasses start to hover over the desk and fly towards the user’s eyes. As they close in on the user, they suddenly explode, giving way to a different world of white cuboids and flying particles with a meditational soundscape playing in the background. As the user looks upon this new environment, suddenly grass appears where before there was none. Little by little an entire landscape unfolds—always where the user is not looking: butterflies fly all around, mountains and trees appear, then a tower as the first building comes into view. The scene morphs into a cityscape where a car accident occurs in front of the user. Walls then suddenly appear and the user finds him- or herself again in a room. As the user explores this new room, it begins to shrink until it takes on the claustrophobic feel of a wardrobe. Just as suddenly, the room loses its walls and the user is flying in low orbit over the Earth. At that moment, a small sign appears within view that reads: “don’t panic.” Interactivity with the environment changes as several asteroids fly around and the user can blow them up by looking straight at each one. The world then turns green and strange—alienating strings strain over the scene. The user feels nearly captivated by them. But the scene completely changes again, and the user sits atop a skyscraper a small unstable wooden beam. Finally, the beam tips over and the user plummets into the abyss. As the words “welcome to VR” flash before the user’s eyes, the experience finally comes to an end.

Throughout the experience, users can look down and see their body sitting on a chair. Moving back, they can even see a part of their head. While this may be regarded as a design error, it also gives users the feeling of being only barely attached to their virtual body. And so, looking around fulfills two functions: First, users can observe their surroundings and explore the scene. Scenes share the same visuality, which creates a degree of familiarity, even though objects change all the time. Exploring each scene through head
movement offers a sense of orientation with regards to position within the virtual scene as well as a sense of the surroundings. Second, in contrast to the former, looking around triggers changes in the environment. The point within focus is always still and controlled. Movement is assigned the same role as in the quantum Zeno effect in quantum physics, which states that a system cannot change while an observer is watching or measuring it.47

The VR-HMD, as a controller, works in exactly the opposite way a user would expect: normally, a user would use head movement to decide where to look and what is most interesting (see section 3.1). This typical use is demonstrated in Sightline’s low orbit scene, where the user can focus on asteroids within a comfortable viewing distance to make them explode (see section 3.2). Several other scenes also demonstrate this principle: the objects one looks at begin to move when they are brought into the centre of perception with the VR-HMD position.48 The stunning effect of this experience is that the scene being observed is always static and consistent in its visuality (see section 3.3). Thus, users perceive a three-dimensional world, though they can never see it in full; no matter how quickly they move their head, they can only see a section of it. Such a design in Sightline could be interpreted as a misuse of the controller that changes the centre of focus. But it also demonstrates a way of manipulating virtual worlds without losing the consistency of user perception, as change is never observed directly.

This particular virtual experience is frightening, which again raises the level of immersion. Change in elements of scenery can never be observed because they freeze once they come within the line of vision; change is triggered by not looking. This also prompts changes in ambience: from surreal to beautiful, from gloomy to frightening. It represents a creative and immersive use of the HMD as a controller, where looking becomes active rather than passive.

5. The Perceived Self: Being in Virtual Reality

After discussing the distinct features of perspective, three-dimensionality, frame, focus, and visuality, this section deals with the position of the player

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48 See, for example, the Neuro-Experience, which changes several opaque spheres into transparent ones and reveals their inside when the user looks at them (Neuro, accessed April 1, 2016, https://share.oculus.com/app/neuro).
within the VR-HMD-based world. I demonstrate the effects of positional tracking on user experience, also exploring the relationship between camera and avatar. Finally, I pose the question of the relation between the physical and the virtual body of the user.

The world external to virtual reality is only one part of the VR-HMD-based experience. Another, however, is the user’s VR body.

A virtual avatar representing the user’s body in VR can have pros and cons. On the one hand, it can increase immersion and help ground the user in the VR experience, when contrasted to representing the player as a disembodied entity. On the other hand, discrepancies between what the user’s real-world and virtual bodies are doing can lead to unusual sensations (for example, looking down and seeing a walking avatar body while the user is sitting still in a chair). Consider these factors in designing your content.

The VR body combines multiple aspects of presence. The first is the user’s physical body, which is also the primary controller. Depending on the HMD sensors and, possibly, additional controllers, not only head movement can be tracked but also the position of the physical body itself—its posture and the position of the hands. Second is the virtual representation of the user’s character: the avatar. While not every VR-HMD-based experience uses an avatar, many do. Third is the location of the user’s viewpoint within the virtual environment. If the experience uses, for example, a first-person perspective, that viewpoint is attached to the avatar’s head at eye position. But it is also possible to decouple avatar and viewpoint, for example, in a third-person perspective, where the viewpoint hovers around the avatar. And it is also possible to fix the viewpoint at a certain position in the background to provide an overview of the action. Together, these aspects form the user’s VR body as a combination of the avatar, its relation to the viewpoint, and the actual perception of the user’s physical body. The conception of the VR body has various effects on perception:

From a more practical standpoint, changing the perspective from first (1PP) to third-person perspective (3PP) allows taking a new and potentially more informative point of view within a VR application […]. The problem is that 3PP breaks the natural condition in which subjects experience self-location with respect

to their real bodies and might consequently lower the sense of embodiment and the sense of presence.\textsuperscript{50}

The sense of surprise expressed by inexperienced VR users is typically greater when they try to look down at their own (physical) bodies, which of course are “not there.” Depending on the given VR experience, a user may or may not see a virtual body, which may or may not have the same position in relation to the user’s physical body. As Morie explains: “The primary modes of embodied expressions in contemporary VEs include: no avatar, a mirrored self, a partial or full graphical personification, and an observer’s view of a graphical avatar that represents the self.”\textsuperscript{51} Therefore, body representation is crucial to the user’s understanding of VR-HMD-based experiences. A typical response, here, is to try to lift an arm or a leg, which does not result in any movement on the part of the virtual avatar—at least when no additional sensors are involved. This is confusing for many users because they are not immediately able to separate the different levels of perception and integration of virtual and physical movements.

But after gaining some fluency, users will typically play with how far it goes. They will attempt to look around (up, down, behind, etc.) and even increase the speed of head movement. At this point, many demonstrate the reflex of holding the HMD with both hands,\textsuperscript{52} not because the HMD is not properly secured but because users get the feeling the HMD is producing a perception wherein their position has drastically changed compared to previous media experiences.\textsuperscript{53} It is at this point that users get the feeling they are not simply wearing a display close to the eyes but that their head itself is tracked by it. Therefore, they become the producers of the image, as the displayed picture is directly controlled by their head movements and is not pre-produced. It is a much more intimate relationship between display and user: not only is it worn closer to the eyes than any other display, it also reacts to minute movements. This changes the common mono-directional perception of a traditional display into a bidirectional one, where the act of looking itself


\textsuperscript{52} Sherman and Craig, \textit{Understanding Virtual Reality}, 419.

\textsuperscript{53} Ibid.
changes what is being looked at. The frame is gone: the user is not sitting in front of the virtual world but inside it. User reactions span from high excitement and intense head movement to confusion and disorientation, as a result of taking off the HMD. It is at this point that the new quality of immersion emerges:

Because virtual reality is a medium that attempts to replicate one’s experience in the physical world, users are likely to have an expectation that they will be able to interact with that virtual world in the same ways they do outside of it. For the game world, it is important to guide the user experience in such a way that the player quickly understands what he or she can or cannot do.

5.1 Relative Positions

Users who get beyond basic orientation then try to explore their virtual surroundings in more detail. Virtual objects and spaces are suddenly the most interesting things to explore—even if they are just virtual representations of things we see every day. It is precisely their virtuality that fascinates and motivates the wish to explore their “nature” further. With the Oculus Rift Development Kit 2 (DK2), released in mid-2014, another means of controlling viewing has been introduced: positional tracking. With it, it is now possible to get closer to an object or further away from it by moving one’s head. It is not only perspective, but also distance that can be controlled. With DK2, a virtual object can be explored in detail by moving the head forward. Body movement and the feeling of the body moving are reflected perspectivally in the simulated world. Users need time to work out positional tracking is possible, or, just the opposite, they take it for granted. In both cases it is not realized that it is a special technical feature.

The HTC Vive takes this one step further by extending positional tracking to the size of the physical room in which the device is located. This creates a new form of positional interaction that is very different from interaction with the Oculus Rift. HTC Vive allows the player to move within a

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55 A good example for this is the Steam VR tutorial, accessed June 1, 2016, available at https://www.youtube.com/watch?v=Kg7gPiz8-SU.
56 The HTC Vive is a VR-HMD produced by the hardware company HTC in cooperation with Valve. Research began in 2012 and was subsequently shared with Oculus. HTC Vive was made commercially available to the public beginning April 2016.
room up to 15 square feet in size while being tracked correctly, and, as such, users can actually walk in virtual reality. To avoid hitting against physical objects, users are cautioned to stay within that safe zone by turning on the built-in camera to display the actual physical surroundings or by using some noticeable virtual markers, forming a cage. In this way, the body is much more integrated into the experience. With the HTC Vive controller it is also possible to track the hands, which promotes further bodily integration.

The limited space available creates the need for specifically designed virtual experiences that utilize this space without having the user feel its limits too often. That experience can be achieved, for example, by creating small virtual rooms and hallways with many turning points. Such architecture can create a sense of virtual space larger than the actual physical one. For example, the game The Legend of Luca makes use of HTC Vive and scales down VR world dimensions to fit the physical dimensions the user has available, so that they can take advantage of its full range. Movements across longer distances must be implemented differently via virtual teleporting, as physical space limitations would not otherwise allow users to walk there. In such instances, game design that deals separately with small versus large-scale motion without generating a break in the user’s sense of immersion is required.

5.2 The Avatar Position

Depending on the VR experience, the virtual body can be positioned in different ways, which has consequences for how immersive the experience is and how comfortable it feels. One comfortable choice is to give the user a steady position with no motion involved besides head movement. As this resembles the user’s physical body position while seated, motion sickness is typically avoided. However, a stationary position limits the actions and interactions possible within the experience. Still, there are compelling scenarios for this type of position, as in the game I Expect You to Die, which places the player inside a car with multiple objects and buttons, and where he or she solves puzzles by interacting with the car and its objects. The whole game offers enough complexity within the player’s reach that the absence of

movement is not perceived as a gameplay restriction. Since no movements are involved, the *Oculus Share* website rates it as a “very comfortable VR experience.”

Another way for creating a comfortable user position is to integrate into the experience a smooth predetermined movement that is not controlled by the player. The level of comfort is increased when players stand on a moving platform they are familiar with in the real world, such as a car, a wagon, a platform, or something similar. In this way, the user’s physical experience (for instance, of driving a car where the immediate surroundings pass by while their own body remains in a seated position) is recaptured. This experience helps users feel no discomfort or motion sickness, although virtual movement is happening while their physical body is still. Such an effect improves when movement stays smooth and no harsh curves or accelerations are included—similar to sitting in a car alongside the driver, the anticipation of movement increases one’s sense of comfort and safety. A well-functioning demonstration of this principle is *Titans of Space*, where the user sits in a spaceship that moves from planet to planet in our solar system.61 Users see a control panel in front of them, as well as their own avatar body in a spacesuit sitting steadily with its hands on its thighs. The smooth virtual motion through open space in a steady capsule is familiar enough to allow for comfortable movement that is not perceived as irritating by most users, even though it does not directly correlate to common physical experiences, such as driving a car or riding shotgun. Consequently, the *Oculus Share* website also rates it as a “very comfortable VR experience.”

The most challenging form of avatar positioning is user-controlled movement and the most immersive way to do that is to map body movement onto the avatar. Various approaches exist for doing so, such as the *Virtuix Omni*—a treadmill built for virtual reality.62 It allows for walking, jumping, and sitting, as it maps all these movements onto the avatar. This being the case, it still exhibits several restrictions.63 It is still impossible to integrate body movement as a form of control using the standard VR-HMD on its own; the player requires an additional controller device. Typically, this would be a standard console controller, such as the *XBox One Controller* that ships with the *Oculus Rift*. Such a controller controls moves the avatar’s body. As this

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creates a gap of experience between the physical body that sits still and the avatar’s motion, there exists the highest prospect for motion sickness and discomfort. Therefore, it is advised to slow down movement and reduce the body’s turning speed.

5.3 Head Movement and Body Movement

With the Oculus, head movement is carefully tracked to allow displayed perspectives to be adjusted. In conventional three-dimensional games, this is done with the mouse, keyboard, or controller, which adjust perspective and direction of gaze. Under such settings, there is an important difference between direction of gaze and direction of movement, which allows players to look in one direction and move in another.

Normally, the direction of movement is adjusted in the direction of gaze so that for the player directing their character to walk to the left, this direction is relative to the user’s current line of view. But there is no relevant difference between the direction of the eyes, the head, the torso, or the legs:

Immersive virtual environments “work” via perceptual mechanisms that correlate to real world experience. A virtual environment, unlike a computer screen, has no predetermined “front” to face except where the participant chooses to turn and look. This situation makes virtual environments, at their core, a medium of spatiality. In such immersive spaces, there are distances to traverse, walls to bump into, and objects that appear slightly different to each eye so that they stand out in depth against the virtual backdrop. While the virtual space is most definitely an illusion, it is one that fools our entire perceptive being. This includes the body as well as the mind.\(^\text{64}\)

With VR-HMDs such as the Oculus Rift these aspects become crucial. Suddenly, players are no longer able to instantly turn their line of sight 180 degrees. Head movement needs more muscular energy than merely pushing a button, and so, as players normally sit in front of a desk, head movement has its limitation in range. In VR applications, however, change of gaze by moving the head, and change of gaze by moving the body, must be controlled separately. In normal physical movement we use a combination of eye movement, head movement, upper torso movement, and body movement to control our perspective. Current-generation VR-HMDs can only track the position of the HMD apparatus itself. Though this includes body movement, it

\(^{64}\) Morie, “Ontological Implications,” 5.
is not comfortable to perform sitting in front of a desk. Since current-genera
tion VR-HMDs do not provide tracking of the eyes’ centre of focus, the
degree of immersion is perceptibly reduced because upper torso movement and
body movement apart from the head do not have a precise effect on perception.
Many tech companies are working on products to integrate these aspects, but,
for the time being, conventional controllers are used to emulate these
movements.\textsuperscript{65}

If there are alternative means to control for adjusting perspective other
than moving the head, the player will opt to use those instead of head
movement (and not in addition to it). A problematic double bind emerges as a
result: head movement increases the effect of VR immersion but it also limits
movement of the virtual avatar, while conventional controls allow for faster,
more flexible character movement in the virtual world, but they reduce
immersion.

6. \textit{Alien: Isolation}

The following example demonstrates the application of relative positions,
avatar position, and head movement discussed in section 5. Unlike many other
demos and experiences available on \textit{Oculus Share}, \textit{Alien: Isolation} is not a
technological demo, a test, or an unfinished experiment. It is a professionally
developed game\textsuperscript{66} released in October 2014 for various platforms. It has earned
fairly positive reviews for regular screen-based gameplay not involving \textit{Oculus Rift}.\textsuperscript{67} Though it is not officially supported on \textit{Oculus Rift}, it is nevertheless
possible to enable such support by manually altering certain values in a
configuration file of the game’s PC version. The gaming community quickly
discovered this option and shared the information across the Web.\textsuperscript{68} Unlike
other games that were made available for \textit{Oculus Rift}, such as \textit{Half-Life 2} or
\textit{Team Fortress 2}, \textit{Alien: Isolation} offers an exceptionally convenient and

\textsuperscript{65} See section 7.3.
\textsuperscript{66} The game is a so-called “Triple-A” title, which refers to a production with big budget,
realized by a major game developer studio in cooperation with a major publisher, aiming for
wider audiences. The opposite of a Triple-A title would be the “indie” title, designed by
independent developers with, often, a much smaller budget.
\textsuperscript{67} \textit{Metacritic} is an online portal, which assembles various reviews of various media forms. The
portal calculates an overall score of 81 points (out of 100) based on 41 different reviews.
\textsuperscript{68} E.g., “Be Even More Terrified in \textit{Alien: Isolation} As Modders Unlock Virtual Reality
Support,” accessed April 1, 2016, http://www.gamespot.com/articles/be-even-more-terrified-in-
alien-isolation-as-modde/1100-6422833/.
impressive VR experience. At the time of writing, it is quite likely the most immersive game experience available.

The game is based on the science fiction horror film series *Alien*. It is a survival horror action-adventure with first-person perspective. For most of the game, players find themselves alone, isolated, as it were, on a dark space station and forced to survive against an alien predator that cannot be defeated. This creature moves independently inside the space station in search of prey, which includes the player.\(^69\) Several other human opponents, hostile for the most part, patrol the space station. Players can use flashlights or motion trackers to determine movement in the dark; however, the use of these devices attracts the alien to their position. Although players can use weapons, stealth is strategically emphasized. Unlike conventional first-person shooter games, *Alien: Isolation* is imbued with a threatening atmosphere of vulnerability and unpredictability.

The exceptional capacity of the game to generate an intense VR experience is not so much in its implicit technical support for the *Oculus Rift* HMD; far more important is the design of movement, sight, atmosphere, and action. Since the preferred mode of character motion is stealth-based sneaking and hiding, the overall pace of the game is quite slow compared to many other first-person games.\(^70\) As such, the VR experience is much more comfortable, as quick movements are more likely to generate simulator sickness. The slow pace of movement, and the need to take note of hiding spots (both for the player’s character as well as for the alien), prompt the player to be more attentive to details and objects. A common example finds the player taking time to monitor a corridor or ventilation shaft for movement before entering. Users will hide behind objects, examining them closely as the alien stalks by. The *Oculus Rift* positional tracking system allows for stooping over objects, studying them in detail. Moreover, as with the film, the space station was carefully designed to represent a 1970s vision of the future.\(^71\) Studying these retro-futuristic objects in detail makes the game both more interesting for the player and creates a greater sense of immersion:

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“You can just, millimeters over the top of the environment, peek at the world around you,” he said. More such opportunities revealed themselves to Hope and his team as they play-tested their game with Oculus added in. A pile of massive concrete pipes strewn about a construction area provide a measure of cover in the console game, but Oculus lets you lean in and peer through individual pipes. You can hide in lockers like a frightened nerd in the console game, but Oculus lets you lean toward the vents in the door to glimpse the hallway beyond. While crawling through an air vent, you can crane your neck to look around the corner.⁷²

As I have argued, it is the specific role of visuality in the game that makes it appropriate for VR, and in this case essential to survival: spotting movement before being spotted. This is not limited solely to horizontal gaze but also to vertical gaze, not to mention peering through various holes and openings. The player is encouraged to look around all the time, paying close attention to what is around them:

I’m admiring the steel grey detailing of the hallway, the hum of the distant machinery reverberating through the ship, and how it all feels a bit like a VR version of Metroid Prime when something catches my eye. Uh, is that a dead body at the end of the hall? Yes. Yes, it is. I start getting anxious: Is this guy going to come back to life and jump-scare me? How close do I want to get? I approach him, cautiously. I find myself suddenly worrying about what might be behind me.⁷³

Therefore, the player is bound to make more use of head movement compared to standard first-person shooter games, where fast movement is more important than detailed observation. The player gets a sense for the field of vision he/she has available, since, often, the alien approaches from behind. This field of vision is limited as a consequence of dim lighting and the range and diameter of the flashlight’s light beam. The feeling of lacking orientation is intensified by echoes generated by the alien’s movement, which indicate a presence without getting a clear idea of direction and distance.

These features have resulted in a game that produces an intense experience of immersion and, likewise, intense player reactions:

⁷³ Ibid.
“It’s really interesting, going to watch people play and seeing them initially look around quite naturally, being interested in the environment,” said Hope. “And then as the alien gets closer, you see their body physically react. They become tense. And then when the alien does ambush them, they reel back physically in their seats.” One player, he said, upon being attacked by the alien, threw their head back in a desperate attempt to avert their eyes from the carnage. And yes, they have had testers rip off the Rift, throw it across the room, and run out screaming.\(^{74}\)

### 7. Best Practices of VR World Design

In this section I explore several familiar best practices for VR world design, of which developers for VR-HMDs should be aware in order to design immersive, comfortable experiences. While in conventional screen-based media ignorance of visual design guidelines may result in an unpleasant or annoying experience, in VR it can quickly lead to serious simulator sickness. In former-generation VR-HMDs this was mostly an issue of sub-optimal hardware. In contrast, problems with new-generation VR-HMDs are mostly in software experience design. These are especially challenging, since new-generation VR experiences are so new that they have not yet been subject to comprehensive study. This issue is particularly relevant to developers and designers, since, after some time spent in VR, they can no longer reproduce the impressions of an inexperienced user: “As a developer, you are the worst test subject.”\(^{75}\) Therefore, developers need far more user testing than for regular screen based games to make sure the experience is appealing for a broad audience: “Your audience will not ‘muscle through’ an overly intense experience, nor should they be expected to do so.”\(^{76}\)

### 7.1 Precision

In designing VR experiences, in-depth knowledge of the HMD technology is crucial. For example, using slightly different distortion shaders, or a slightly diverging projection matrix (compared to their Oculus headset analogues), developers can cause serious nausea and discomfort during longer use—though this effect may go initially unnoticed. Moreover, motion-to-photon latency, which reflects the time needed for user movement to be fully manifest on screen, should be below 20 milliseconds for the mind be convinced it is truly

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\(^{74}\) Ibid.

\(^{75}\) “Oculus Best Practices,” 6.

\(^{76}\) Ibid., 4.
operating within the virtual environment. What this means is that head movement should first be detected, wired to the computer through USB, then processed by the game engine that generates two images, one for each eye, adjusts them to VR, wires them through HDMI to the HMD, and, finally, displays them by switching each one of over 2.5 million pixels that make up the internal display screen—all within 20 milliseconds. As current hardware can deliver such speed, software becomes the crucial component of the experience. The graphics card driver and game engine itself can provide several VR optimizations, especially when it comes to processing the two (only slightly different) images. Nevertheless, experienced developers need to ensure that scene complexity does not exceed a certain level that can be measured in terms of processing time. This is particularly difficult, since processing time does not assume a constant value but one that changes with each scene and perspective. Developers must also deal with a broad variety of hardware and system configurations typical of the PC environment.

7.2 Movement

Avoid visuals that upset the user’s sense of stability in their environment. Rotating or moving the horizon line or other large components of the user’s environment in conflict with the user’s real-world self-motion (or lack thereof) can be discomforting.

To sustain a sense of immersion, it is crucial that the user maintain control of head movement at all times. At no point should the image fail to react to head movement directly, as this not only affects conventional game design but also cut scenes, videos, pause screens, menus, and even error messages. All must relate to the user wearing a VR-HMD, rather than looking at a conventional screen. Doing so will increase a user’s trust that the HMD will interlock his or her head movement and perspective. The slightest incongruity will have negative effects on users’ sense of immersion and might result in discomfort using the HMD.

Positional tracking allows users to change their point of view in ways games are normally not designed for. Users can now peek around corners, look under objects, get really close to them, or even try to move their head into them to see them from the inside. Game designers are therefore called upon to react to these new possibilities, incorporating more details, adding textures to

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objects, and avoiding clipping errors when the user tries to move their head into an object. While in conventional games acceleration is an effect widely used for stunning visuals, in VR it produces conflict between images and the user’s physical sense of balance—something that should be avoided whenever possible. Doing away with acceleration altogether, and keeping movement at a constant speed could accomplish this. However, such a choice also affects angular momentum: turning, shaking, and jumping are uncomfortable, and the same holds true for zooming in and out.

While virtual reality settings allow for a much greater scope for visual immersion than regular screen-based experiences, they also restrict movement. When it comes to VR-HMDs in general, movement is a problematic issue, as the body does not share the same sensory signals as the visual system. While in conventional game design gameplay has grown ever faster, and, accordingly, so have players’ movements, in VR such a trend would be far too uncomfortable for the user. A recent analysis of fast-pace conventional games, which were technically adjusted to VR, demonstrates that effect: “Eight out of ten people had some negative experience with Team Fortress 2 and nine out of ten had felt some discomfort while playing Skyrim at some time.”

A more comfortable speed of movement in VR should be adjusted to the average speed of walking, around 1.4 metres per second. As described in section 5.1, when distances in VR game worlds increase beyond a certain threshold, the developer should consider using some type of teleporting manoeuvre instead of increasing the speed of movement. However, this decision may generate new problems: if users are teleported too often, they lose their sense of environment, orientation, and spatial consistency. Once again, these decisions have a considerable effect on the dimensions of virtual worlds created for VR: bigger worlds produce more problems, either through speed or in teleportation. The result is that comfortable VR worlds are much smaller than their conventional counterparts.

Third-person control can also be difficult, as the user must still be able to look around freely while controlling an avatar from a top-down perspective. User interfaces, such as menus, need to be integrated as three-dimensional objects, positioned at a comfortable distance of 2–3 metres away from the user. In addition, User Interface (UI) elements should not take over the screen, as they would cause intense head movement in order for users to see them fully. Ideally, they should measure no more than one-third of the viewing area, integrated into pre-existing objects rather than as free-floating elements. Crosshairs aiming at objects should be positioned the same distance as the

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objects they target, otherwise the point of focus will vary, potentially leading to a duplicate image.

### 7.3 Next Level VR

VR has a weird learning curve: the more it’s like real life, the more difficult it is to operate the aspects that aren’t. 80

As users are visually shut out of the physical world, they cannot see the controls they are using. They must rely solely on tactile feedback, which makes it difficult to use a keyboard when users are not used to touch-typing—they might run into trouble searching for the right keys. It is better to give users controls they can either use intuitively through movement or they know well, such as a standard *Xbox* controller.

However, there are more possibilities ahead than those standard controllers specifically designed for VR. The greater the visual immersion, the more intense the user feels what is left out of his experience, like the rest of his or her body, its movement, and its feelings. A natural gesture would be to reach for a virtual object directly out in front, but users can neither see their arms nor control the object with that gesture. This is why integrating users’ hand gestures into virtual reality is one of the major challenges in developing VR-specific controls. Several approaches have been applied so far. With motion detectors, such as *Leap Motion*, hand movement can be detected without need for additional hand-held devices. 81 This allows for free gestures and movement, as hand and finger are not limited in any way. Motion detected in such a way can be mapped into virtual reality, so that a virtual arm and hand capture the position of the user’s physical hand. Every act of control then needs to be done through gestures, as no buttons or control sticks are available.

*Oculus* is following another approach: the *Oculus Touch* incorporates two lightweight controllers, one for each for hand, that can be tracked with *Oculus Rift*’s infrared-based positional tracking. Consequently, precise, quick detection of hand position is offered, and, moreover, also places several buttons and a control stick in each hand. A trigger button for the forefinger is designed to be the standard form of control for grabbing virtual objects. 82 These

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controllers are still in development and are supposed to be available later in 2016. A useful example demonstrating how these controllers could be used is VR editing of VR worlds. The designer of a virtual world is not designing at the screen in this instance, but inside virtual reality itself, wearing an *Oculus Rift* and creating, moving, rotating, and scaling three-dimensional objects with the use of the *Oculus Touch* controller.

While the integration of users’ hands into virtual reality is the most obvious approach, there are others that go further. Next to the hands, walking and jumping is the next desideratum for virtual reality enthusiasts. One way to achieve that is through movement cages, such as the *Virtuix Omnix*. In *Virtuix Omnix*, the body is fixed in an upright position while the feet are able to slide over a controlled slippery surface to simulate walking and running.

Several other groups are working on eye tracking in VR-HMDs. Such a scheme would offer a massive reduction in the necessary calculating power, since only the centre of focus of the eyes would require fully detailed rendition; the periphery could then be rendered with lower detail and resolution. Since the eyes, in any event, do not see sharply in this peripheral field, doing so would not reduce the immersive effect. This technology is known as *foveated rendering*. The *FOVE* is one of the best-known upcoming products integrating eye tracking into the HMD.

The following example shows the role and effects of movement and positional tracking in a fully developed game that was made available for the *Oculus Rift*.

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85 Paul Miller, “Testing the Virtuix Omni.”


8. Today’s Virtuality—Future’s Reality

As virtual reality has reached a high level of visual immersion, developers’ responsibility for users’ experience is an issue of increasing importance. The *Oculus Development Guide* urges developers to be aware of that responsibility:

Be aware that your user has an unprecedented level of immersion, and frightening or shocking content can have a profound effect on users (particularly sensitive ones) in a way past media could not. Make sure players receive warning of such content in advance so they can decide whether or not they wish to experience it.89

So-called “jump scares,” in particular, have a significantly higher impact on users compared to traditional media. In such a situation, psychological effects can be drastic for inexperienced users, as they find themselves in a horrific situation they cannot turn away from. A high degree of immersion can create not only scares; it can also work intensely on a narrative level that can be highly disturbing as well.

Since games and VR worlds are not limited in their duration, the psychological impact is potentially much higher than, for example, in film. Writing on the ethical implications of VR experiences, Michael Madary and Thomas K. Metzinger propose certain guidelines that developers worldwide should respect. Moreover, they reflect on the human mind itself as a virtual reality now embedded into another virtual reality:

What is historically new and what creates not only novel psychological risks but also entirely new ethical and legal dimensions is that one VR gets ever more deeply embedded into another VR: the conscious mind of human beings, which has evolved under very specific conditions and over millions of years, now gets causally coupled and informationally woven into technical systems for representing possible realities.90

Thorsten Wiedeman, founder of the game festival A MAZE, predicts that within ten years many people will spend a great deal of time in virtual realities:

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[In 2026,] it is normal that you jump into VR to meet your international friends in Social VR Rooms and go on crazy adventures together, but a long trip will be still special and could be understood as a controlled drug experience.\textsuperscript{91}

Wiedeman himself attempted staying in virtual reality for 48 hours without taking his HTC Vive off, not even during short hours of sleep.

I had no physical problems, no burning eyes, killing headaches or nausea. The path to the future is now prepared—we only need specially-designed content to get a full immersive experience, and this will take probably until 2026.\textsuperscript{92}

Creating virtual worlds that are specifically designed for VR hardware is a challenge. Increasingly, however, developers are moving in this direction. The variety of possible virtual worlds is extensive—as we have seen, many such worlds have already been explored and implemented. While VR is often a source for concern, framed as a world that alienates users from reality, it is the conception of reality as something opposite to virtuality that promotes this concern. Michael Heim followed this line of thought early on in his book \textit{The Metaphysics of Virtual Reality}:

Too much depends on searching for the true virtual reality. We should not get discouraged because a mention of reality, virtual or otherwise, opens several pathways in the clearing. Let us recall for a moment just how controversial past attempts were to define the term reality. Recall how many wars were fought over it. […] People today shy away from the R-word. Reality used to be the key to a person’s philosophy. As a disputed term, reality fails to engage scientific minds because they are wary of any speculation that distracts them from their specialized work. But a skeptical attitude will fall short of the vision and direction we need.\textsuperscript{93}

According to Heim, with VR, technology has reached an ontological shift that fundamentally changes the concept of reality, as it is no longer necessarily the same as physicality. For him, the essential concepts connected with virtual

\textsuperscript{92} Ibid.
reality are: simulation, interaction, artificiality, immersion, telepresence, full-body immersion, networked communications, activity/passivity, manipulation/receptivity, remote presence, and augmented reality.\textsuperscript{94}

The \textit{Oxford English Dictionary} includes three possible definitions for “virtuality.”\textsuperscript{95} The most archaic describes it as “something endowed with virtue or power.” The next describes it as the “essential nature of being, apart from external form or embodiment.” The third (previously mentioned) definition represents the most common usage of the word as a “virtual (as opposed to an actual) thing, capacity, etc.; a potentiality.” This latter definition invokes the opposition between original and simulated objects—true and false, or real and artificial. From this perspective, VR has the connotation of a surrogate to reality: experiences in VR will not count as much as the “real” ones, and social contacts there are just a simulation or a cover for technically induced isolation.

VR visionaries and enthusiasts might relate more to the former definitions. For them, virtuality has the power to create something beyond pure physicality: something with fewer, or, in any case, different restrictions, something that can be controlled in a different way—but certainly in no way less real. The second definition allows one to speculate on what can be seen as the “essential nature” of a thing “apart from external form.” Virtual reality technology, I think, implicitly answers this question: though the apparatus does not look like a world from the outside—it is likely to look like gigantic ski goggles—its “essential nature” is the perception it produces. If reality is essentially something that is being perceived, considering it the other way around means that perception creates reality. Having said that, things become more or less real with the quality of perception.

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\textsuperscript{94} Ibid., 109–128