Tampere University of Applied Sciences

Level Design in Virtual Reality

Veikka Saaristo

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ABSTRACT

Tampereen ammattikorkeakoulu
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SAARISTO, VEIKKA:
Level Design in Virtual Reality

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This thesis studies level design methodology and best practices regarding both traditional and virtual reality level design, as well as the author’s own professional experience as a virtual reality level designer with the objective of creating a custom map extension to Half-Life: Alyx (Valve 2020). The purpose of this thesis was to introduce virtual reality level design and to display how virtual reality levels are designed and created through a documented example. The thesis focuses on methods and practices that are applicable to work outside of a specific engine or editor. Data was collected from various sources, including several online publications, the individual views of industry professionals, developer websites of headset fabricators, and from literature.

The map extension was created as a part of this thesis. It was developed using Valve’s own Hammer editor, which enabled building the level based on an original design. In addition to theory, this thesis addresses the design and creation of this map extension, offering excerpts from the process in form of in-editor screenshots and descriptions.

During the creation of this thesis, the superiority of the Hammer editor compared to other editors and game engines used before was noted due to its first-class built-in level design tools. Learning a new work environment from the beginning and the choice of virtual reality headset used in the development proved challenging as the older Oculus Rift headset caused issues while working with a game as new as the one used as the case study.

This thesis offers a basis for becoming familiar with level design practices, especially regarding virtual reality design. The custom map extension created for this thesis embodies the implementation of these practices in a proper work environment, acting as an example case.

Key words: level design, virtual reality

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Tietojenkäsittelyn koulutusohjelma
Pelituotanto

SAARISTO, VEIKKA:
Level Design in Virtual Reality – Kenttäsuunnittelu virtuaalitodellisuudessa

Opinnäytetyö 68 sivua
Marraskuu 2020

Tässä opinnäytetyössä syvennyttiin kenttäsuunnittelun metodologiaan ja parhaisiin käytäntöihin niin perinteisen, kuin virtuaalitodellisuuteen sijoittuvan kenttäsuunnittelun suhteen, soveltaen opittua sekä tekijän omaa kokemusta kenttäsuunnittelijana virtuaalitodellisuusympäristöissä tavoitteena luoda kokonaan uusi kenttälaajennus Half-Life: Alyx -peliin (Valve 2020) tätä opinnäytetyötä varten. Työn tarkoituksena oli tutustuttaa lukija virtuaalitodellisuuskenttäsuunnittelun maailmaan ja osoittaa dokumentoidun käytännön esimerkin kautta, kuinka virtuaalitodellisuuskenttiä suunnitellaan ja luodaan, painottaen työn fokusta sellaisiin työskentelytapoihin ja suunnitteluteoriaan, joita voisi hyödyntää mahdollisimman laajasti myös kyseenomaisen editorin ulkopuolella. Työhön kerättiin tietoa muun muassa useista verkkojulkaisuista, pelialan ammattilaisten omista näkemyksistä, virtuaalitodellisuuslasien valmistajien kehittäjäsivuilta, sekä muutamasta aihetta käsittelevästä kirjasta.

Kenttälaajennus toteutettiin osana opinnäytetyötä. Kehityksessä hyödynnettiin Valven omaa Hammer-editoria, jonka sisällä kenttä oli mahdollista rakentaa tekijän suunnitelmien pohjalta. Työ käsittelee teoriaosansa lisäksi kyseenomaisen kenttälaajennuksen suunnittelemista ja käytännön toteutusta syventävästi, tarjoten otteita prosessista kuvien ja selitteiden muodossa.

Työssä havaittiin Hammer-editorin paremmuus muihin, tekijän aiemmin käyttämiin editoreihin sekä pelimoottoreihin verratessa tämän tarjoamien ensiluokkaisten sisäänrakennettujen kenttäsuunnittelutyökalujen vuoksi. Haasteita työhön tuottivat tekijälle uuden kenttäsuunnittteluеditorin opettelu alusta pitäen sekä virtuaalilasien valinta vanhan Oculus Rift -mallisen visiirin tuottaessa ongelmia näinkin uuden pelin parissa työskennellessä.

Opinnäytetyö tarjoaa lähtökohdat kenttäsuunnittelun käytänteisiin perehtymiseen eritoten virtuaalitodellisuuskehitystä ajatellen. Työtä varten kehitetty kenttälaajennus ilmentää itsessään näiden käytänteiden toimeenpanoa todellisessa työskentely-ympäristössä, toimien esimerkkitapauksena lukijalle.

Avainsanat: kenttäsuunnittelu, virtuaalitodellisuus

CONTENTS

GLOSSARY

TAMK	Tampere University of Applied Sciences
Level Design	a discipline of game development, consisting of the design and creation of video game levels
VR	Virtual Reality
Mantisbite	Mantisbite Ltd., an indie game studio based in Helsinki
Bandit Point	an action-packed shooter game set in virtual reality, made by Mantisbite
FPS	first-person shooter
Greyboxing	the early process in level design where the level designer models the base geometry of the level, mostly traversable surfaces, obstacles, and such. The level will look like it is made of grey boxes at this point as no textures are in place yet, hence the name. Also known as “whitebox” or “blockmesh”, as no industry standard has been set
Spawner	an entity in a video game that works as a point where objects, enemies, NPCs etc. are initiated to the game world
Vertex	a corner point where the edges of a 3D model meet
UV mapping	the process of projecting 2D image textures onto 3D surfaces. The U and V in the name stand for coordinates of the texture image, as XYZ are already in use on the 3D object
Lightmap	a type of a texture map in which the brightness values of surfaces in a game’s scene are pre-calculated and stored in the effort of saving computational costs in rendering later
RPG	role-playing game
NPC	non-playable character
Boss	a significantly more difficult enemy, often necessary to beat by the player in order to continue in the game, who often have a specific arena-type level built for the fight

Multiplayer	a game mode designed for multiple players playing at the same time, against or with each other
HMD	Head-Mounted Display, an umbrella term for virtual reality headsets
UI	user interface
Diegetic	existing within the game world rather than as something external to the world
CRPG	computer role-playing game
WMR	Windows Mixed Reality
HP	hit points, or the amount of health left on a game character before they perish
Collider	an invisible component defining the shape of a game object for detecting physical collisions with it
Locomotion	any acceleration, rotation or movement in a VR world that has not been initiated by real-world movement by the player
FOV	field of view

1 INTRODUCTION

This thesis studies both traditional and virtual reality level design methodology and best practices. The findings from this study are then used in the creation of a custom virtual reality game level in Valve’s Hammer Editor.

The inclusion of the traditional, non-VR level design in this thesis is imperative as most of the aforementioned topics apply to all level design, and thus presenting them as specific to VR design would be misinformative. Examples from non-VR games are raised to illustrate these, more prevalent points.

Virtual reality level design is then addressed, concentrating on the differences and challenges it presents comparing to traditional level design. Examples from VR games are used to highlight the more exclusive points.

The author has worked in a level designer capacity in several projects, four of which have led to release as per the writing of this thesis. Kiwi Rush (2015) and Scamper (2016) were mobile games for Android, released for free in the Google Play Store. HyperVisor (2018) is a freeware VR shooter made for the original HTC Vive headset, released in Viveport. Bandit Point (Mantisbite 2019), a VR shooter built around the concept of being able to swap bodies with any enemy unit the player sees in order to gain their weapons and health, released commercially in both Steam and Viveport.

The work on HyperVisor with other game development students from TAMK worked as a great introduction to VR, which enabled the deepening of knowledge of virtual reality design and best practices with the development of Bandit Point at Mantisbite, which this thesis is based on. Both titles also gave me valuable practice in first person shooter (FPS) design.

The author worked at Mantisbite as Lead Level Designer / Game Designer on the project and was responsible of realizing all the game's levels (10 full levels consisting of more than 20 scenes) from concept to finish. The work process was as follows: initial sketching (rough architecture / map overlook), advanced sketching (enemy placements, spawner locations, engagement design), initial greyboxing (including spawner placement & testing), polishing environment (modeling buildings, grounds, stairs, cleaning models of extra vertices etc.), UV mapping, texturing & decorating, lighting (including baking lightmaps), and finally wiring level logic (triggering for all interactions, doors, trigger areas and such, polishing spawns etc.), followed by intense testing, polishing and reiterating, returning to any of the previous steps as needed.

2 TRADITIONAL LEVEL DESIGN

2.1 Short Introduction to Level Design Principles

> *"Great level design is invisible, it doesn't force the player to do things. Great level design facilitates player expression, and guidance. Players shouldn't be in awe at the level design, they should be amazed by how smart they are when playing the game." (Oniscu 2020a.)*

Level design can consist of so many things, but like good programming, good level design should not be something a player can point their finger at. Level design is there not to create experiences, but rather to facilitate the experience of the player, to enable them to use their abilities in the game in ways that create most fun to the player. The game should preferably allow the player to solve its challenges however they wish using the tools they are given.

When level design supports the player's use of imagination by offering them multiple solutions to a problem, the player can feel smart because they figured out a way forward themselves without the game holding their hand and telling them what to do. More often than not, an extensive use of UI markers, compass arrows, automatically highlighted objects or companion callouts are used to cover for bad level design, where the developer had no confidence in the level design for the player to be able to find their way in the world without those hints.

One good example of this is The Elder Scrolls V: Skyrim (Bethesda Game Studios 2011), an otherwise critically acclaimed RPG – as can be determined by the many reviews left on the game's Metacritic page (Metacritic n.d.) – where quest markers can be quite overwhelming at times, to the point where the player does not need to even know what they are supposed to do, as long as they just chase a marker (see picture 1, below). The problem does not disappear by removing the quest markers, as the game was built around the system so much that the level design cannot stand on its own. The only hints given to the player are the very obvious and sometimes obtrusive quest markers and removing the markers would leave them baffled at where to go due to lack of environmental cues or hints given in dialogue.

PICTURE 1. The quest markers in The Elder Scrolls V: Skyrim leave little to be discovered by the player. (The Elder Scrolls V: Skyrim, Bethesda Game Studios 2011)

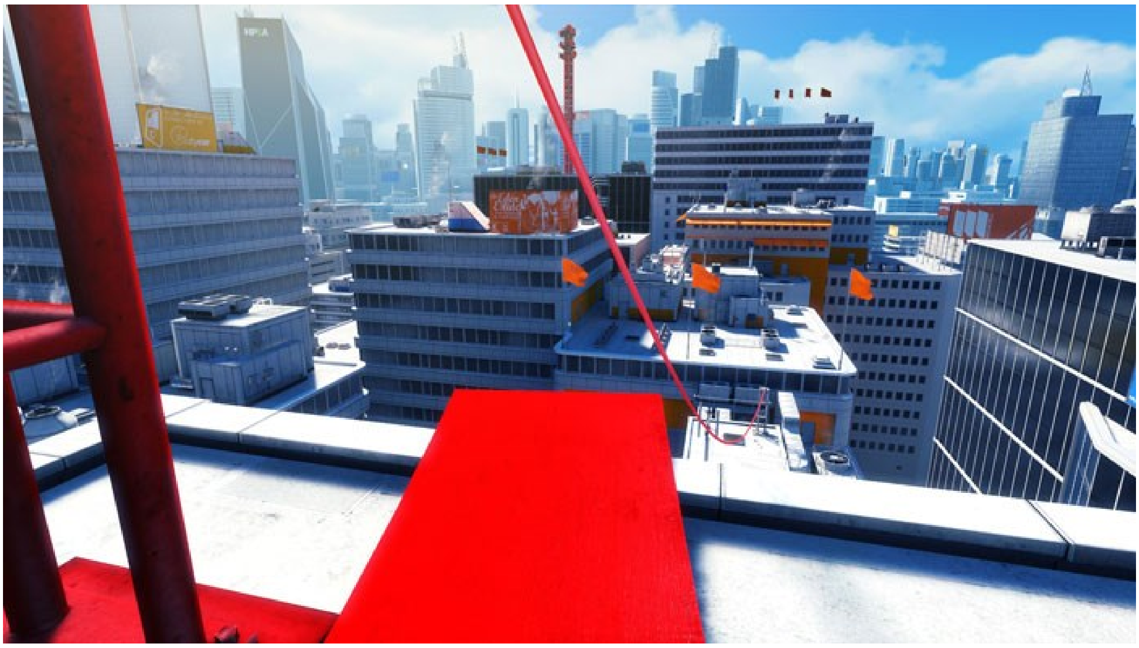
An earlier entry in the series, The Elder Scrolls III: Morrowind (Bethesda Game Studios 2002) does this much better. Instead of relying on quest markers, the game makes use of its journal system. Whenever the player gets directions for a quest from a non-player character (further on referred to as an NPC), the directions are written to the player character's journal from their own perspective, and left intentionally vague from the start, making the player discover their objectives themselves.

The directions can initially consist of just a vague request of getting the quest-giver an item from another NPC in another town. The player must now find their way to the town using directions they can get from talking to other NPCs and using the many signposts scattered along Morrowind's roads. Once there, the player must now talk to locals in order to find more about the NPC involved in their quest, in order to find out where they might live or work and what they might look like. As Zamora (2016) points out, getting lost on the way is all part of the experience. The routes and given directions are designed in a way that getting lost leads to new adventures on the side, when the player finds all kinds of places of interest, treasures and challenges on side routes they wandered onto. All this adds to the immersion of being in the world and would be lost the very minute a quest marker showing the accurate position of the NPC in the game world was added, removing all need of discovery.

2.2 Guiding the Player

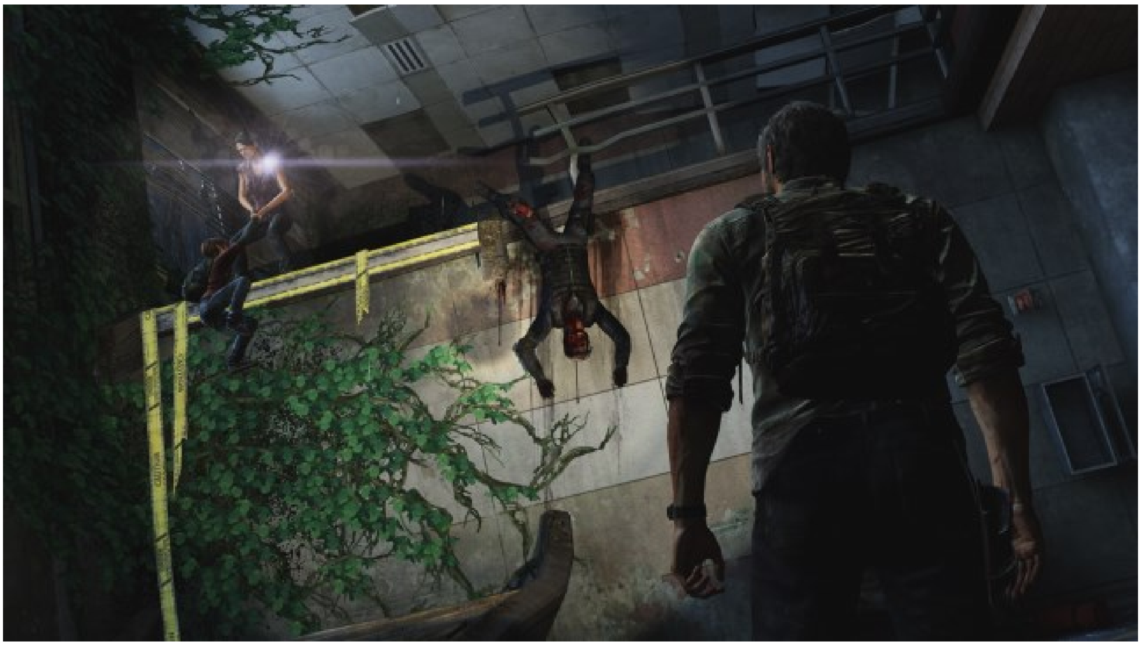
The player can be guided through the environment in more ways than just words. An important aspect of good level design is to ensure that the player can always know what they are supposed to do by just looking at the level. Ensuring that they can effortlessly fly through the level or area with their eyes is paramount (Schell 2008, 289).

In Mirror's Edge (DICE 2008), to accommodate fast-paced player movement, the world is mostly stripped of color and a bright red color is used to highlight the route forward. In picture 2 below the player can immediately see their intended path laid in front of them, minimizing the need to look for a route forward while aiming to maximize player speed in all situations.



PICTURE 2. Red is used exclusively for guiding the player in Mirror's Edge. (DICE 2008)

In The Last of Us (Naughty Dog 2013), among many other action-adventure titles, yellow is used as a highlight color for climbable ledges and other ways forward (see picture 3, below). When using highlight colors like this, though, the level designer must make sure not to include those colors in the environment art elsewhere, in order to avoid confusion (Hoffstetter 2016).



PICTURE 3. Yellow is a common color for highlighting the way forward, here pictured in The Last of Us. (Naughty Dog 2013)

Landmarks are another way of guiding the player through levels by providing them with a powerful sense of space. By building a location around or overlooking a remarkable sight, whether it be a unique building, a massive mountain, or simply the sun, the player can more easily navigate the level by orienting themselves based on the landmark. Landmarks also help create a memorable environment. (Schell 2008, 333–334.)

A good example of a world built this way is the world of The Legend of Zelda: Breath of the Wild (Nintendo 2017). Building open-world maps are a different challenge entirely, but Nintendo really pulled this one off by placing a few central landmarks in the world, at least one of which visible from almost any of the many beautiful vistas the game offers throughout the open landscape (see picture 4, below). There are also many smaller landmarks like the map revealing Sheikah

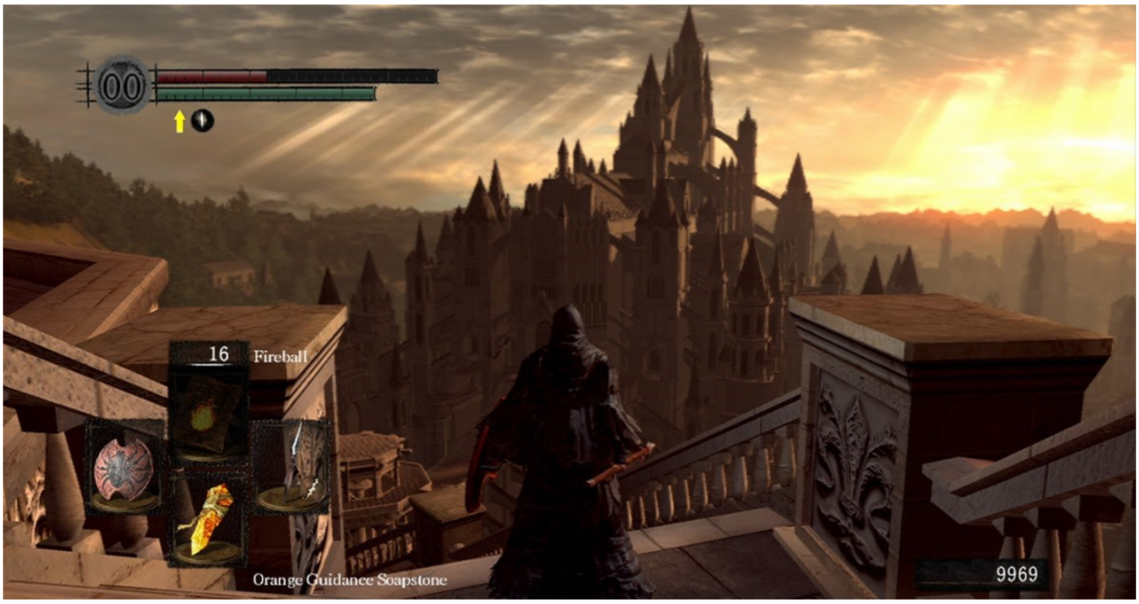
Towers, shrines and stables dotting the world, helping navigation when the player is venturing through valleys and forests with less visibility to far away landmarks.

PICTURE 4. The open world of The Legend of Zelda: Breath of the Wild is easily navigable because of landmarks like the Hyrule Castle and the massive volcano, Death Mountain, dominating the skyline. (The Legend of Zelda: Breath of the Wild, Nintendo 2017)

Another notable example of a level centered around a remarkable landmark is Half-Life 2’s chapter 6, “We Don’t Go to Ravenholm…” (Valve 2004). The level takes the player from the earlier relatively well-lit and colorful environments to a completely different atmosphere. Dark, gloomy, and scary, Ravenholm verges on survival horror, set in a peripheral town whose residents have turned to zombies. The level is relatively small space-wise, sprawling over the same location in various levels of verticality, representing an expert use of space. The main landmark on the central plaza of Ravenholm is a pyre of burning bodies, which can be seen from several points throughout the level, helping the player orient themselves in it. As the player advances, they can recognize places they were just before, fences behind which they walked just a while ago, etc. This kind of interconnectivity and reuse of space makes the level feel more realistic and makes the player feel smart as they can see earlier obstacles from the other side, getting a sense of achievement. (Stoeber 2020.)

One cannot talk about interconnectivity in level design without mentioning Dark Souls (FromSoftware 2011). The game's levels are built with an excellent understanding of space, often looping the player back and opening shortcuts to previously explored areas, easing subsequent journeys from the same save point. The environments are built in a way that, despite their complex structure and the amount of detours and side paths, rarely gets the player lost, with the levels' flow always guiding them forward (Boyd 2011). The game also uses landmarks well in order to orient the player in the game world: right from the start, the player can see the walls of the Undead Burg waiting high up in the distance, a place they will start travelling to shortly.

Later in the game, on the arrival to the mythical city of Anor Londo, the player starts the level from a vantage point where they can scope the city in the distance, the very same towers and roofs they will soon be running on (see picture 5 below). From many locations in the game, the player can see other earlier or upcoming locations in the distance, above or below their current position, sometimes even getting a glimpse of a boss to come. The world of Dark Souls feels like a fully interconnected entity that the player learns to navigate by realizing the connections between locations with no outside tips like signposts or immersion-breaking UI elements showing the intended way forward.



PICTURE 5. On their arrival to Anor Londo, the player can scope the city from a distance, a place they will soon explore by themselves. (Dark Souls, FromSoftware 2011)

2.3 Pacing

To keep their levels interesting, the level designer must pace them in a compelling manner. If a level only consists of big action pieces with no quieter moments in between, playing it can easily become quite overwhelming (Totten 2014, chapter 2).

In addition to pacing individual moments in one level with each other, interpolating between calmer and higher adrenaline moments, all levels must be paced with each other as well. Levels should vary in difficulty and intensity in order to create an interesting overall experience. This can be measured with an interest curve by evaluating each level or area of the game by their intensity and/or difficulty (see figure 1, below). A good interest curve should avoid flat parts, where the intensity level does not change between consecutive levels, creating either a dull or an overwhelming section to the game. An overall rising trend to the curve should also be kept ensuring that, by increasing difficulty and intensity towards the end of the game, the player's interest is kept throughout the experience. (Schell 2008, 250–253.)

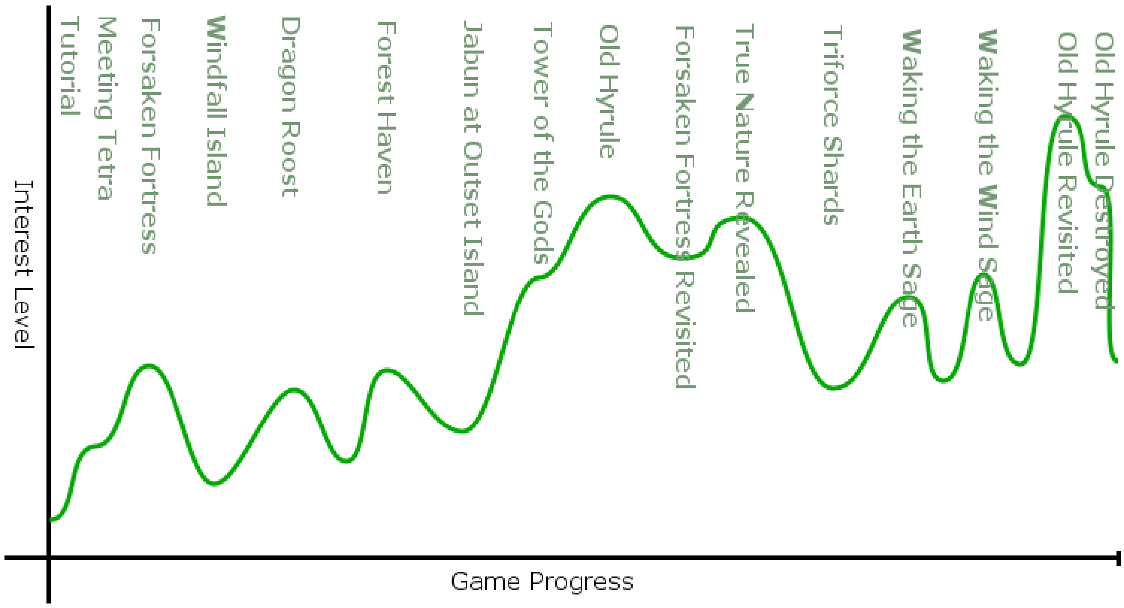


FIGURE 1. An interest curve made for The Legend of Zelda: The Wind Waker (Nintendo 2002), showing an overall rising tension in the game with interpolating levels of intensity between levels.

In a similar way, action inside a singular level can be measured, dividing the level into separate entities by narrative progression, combat encounters, puzzles, etc. These different parts of the level should be paced in a way that provides generally rising tension, aimed towards a climax. (Schell 2008, 252.)

2.4 Emergent Gameplay

Great level design allows for emergent gameplay, meaning complex situations in games emerging from interacting creatively with relatively simple game mechanics, often beyond their original design (Bycer 2015). The Legend of Zelda series (Nintendo 1986-) is great at this, being very systems-heavy games, their level designs creating a stage for the player to act on with the abilities they are given.

Another example of emergent gameplay spawning from great level design is the Hitman series (IO Interactive 2000-). The levels in Hitman 2 (IO Interactive 2018) are large, complex, and very open-ended sandboxes, allowing the player to explore them in whatever way they wish to. The levels offer multiple ways to completing their objectives, eliminating the given targets, teasing the player with challenges that require more thorough exploration of the levels. During the first couple of runs the levels can seem overly complicated, with surprising details and opportunities coming up around any corner. As the player keeps replaying the levels in order to complete challenges and achieve better scores, they learn the levels and start mastering them. The objective in the game switches from just eliminating the targets in any possible way and moving quickly through missions to trying to do so stealthily, avoiding cameras and guards to remain undetected, hiding bodies, destroying evidence of their ever being in there, and framing the eliminations as accidents so no one could suspect foul play afterwards.

All of this stems from great level design offering a multitude of ways to enter locations, sections of levels being restricted to certain characters making the player either try and sneak past guards in said section or trying to find a disguise, sprinkling the levels with a massive arsenal of guns and objects suitable for use as weapons and having the targets move through the levels with bodyguards, sometimes e.g. popping off into a toilet or a secluded room, offering the player chances to take them out stealthily. The game world keeps living around the player and offers them an ever-moving playground to complete as they wish, encouraging them to experiment in, testing its reactions to different actions (Atwood 2018).

The Far Cry series (Crytek, Ubisoft 2004-), especially from part 3 forwards, offers great emergent gameplay in form of enemy outposts sprinkled throughout the open worlds. Each outpost is different from each other, and each offer multiple ways of completing them, limited only by player creativity. One player might go in guns blazing while the other might want to complete them stealthily, avoiding all alarms being set off or even any guards detecting the player. An imaginative player might even strap a helicopter full of explosives, fly it straight at the outpost, jump out mid-air and shoot a tiger cage open while landing in a sniper's nest, ready to pick off survivors from a vantage point.

The outpost level design is centered around offering multiple tactics, giving the player opportunities in form of different elements supporting different tactics. For example, providing vantage points, sniper rifles, windows, and long sightlines the level supports sniper gameplay well. Offering lots of cover, tall grass for crawling through undetected, reduced enemy vision due to weather conditions or the time of day, light and shadow variations etc. supports stealthy gameplay. In turn, placing explosive barrels, flammable surfaces, gas canisters, explosives and rocket launchers to a location supports a loud, action-packed approach. (Oniscu 2020b.) These can be combined, providing support for multiple styles of gameplay, and Far Cry games do this well.

The games offer a scouting phase before deciding on an approach by giving the player a camera that they can zoom in on an outpost with (see picture 6 below), marking enemies, vehicles and objects like machine gun nests, alarm boxes and explosive gas bottles before heading in there. By offering this glimpse of the level design beforehand, the ball is kicked to the player's court in that they have full agency in choosing how to tackle each outpost.

PICTURE 6. The camera can be used in scouting the outposts before heading in. (Far Cry 3, Ubisoft Montréal 2012)

2.5 Innovation in Level Design

Some of the most memorable levels in videogames are those that innovate in their design, doing something unprecedented that imprints in the player's mind. These previously unseen innovations may be purely technological, like the level-altering destructible environments in Red Faction (Volition 2001) or the realistically spreading fire in Far Cry 2 (Ubisoft Montréal 2008). They may also be based on the clever ways the level itself was built, subverting the player's expectations. A notable example of a level that does this is the level "Effect and Cause" in Titanfall 2 (Respawn Entertainment 2016).

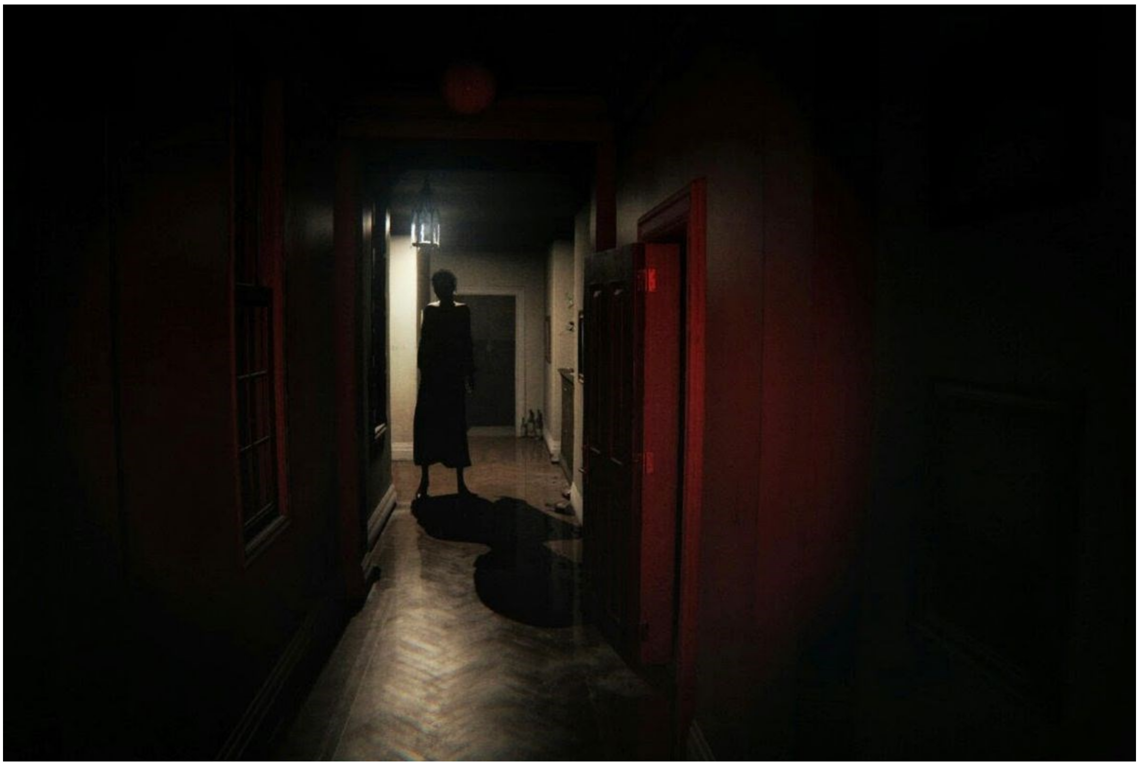
The levels of Titanfall 2 were designed from "action blocks", the results of a game jam held between the campaign development team at Respawn, each being a different kind of a prototype for a game mechanic for the campaign (Wiltshire 2017). This led to a campaign whose every level introduces novel ideas, keeping the gameplay fresh and innovative at all times. In the level Effect and Cause, the player is presented with a device with which they can travel in time between two completely different versions of the same location, a research facility before and after its complete destruction. The player can use the time-travel device to warp between these two realities in order to pass obstacles, or as a tactical advantage in circumventing enemies and gaining a better position.

Both realities offer their own challenges, with the pristine, “past” facility being filled with enemy soldiers, turrets and locked doors, and the destroyed, “present” facility being in ruins, with areas in flames, hostile robots, and monsters now residing in the remains. Moving between these two timelines could prove disorienting, but by allowing the player to see positions of enemies in the other timeline for a moment after time-traveling, they can plan their next moves and get control of the situation. The level was built by building two levels, the past and the present, and stacking them on top of each other, teleporting the player between them on command (Wiltshire 2017). The player’s expectations are constantly subverted in the level by masking one timeline while playing in the other, making them juggle with two sets of enemies and hazards at the same time, making for an excellent and very memorable level.

Another notable example of innovation in level design is the PlayStation 2 classic Shadow of the Colossus (SIE Japan Studio & Team Ico 2005). Set in a vast open world sprinkled with ruins and mountains, what sets the game apart from other open-world adventures is its innovative approach to how the game’s bosses are built. The titular Colossi are so massive the player has to climb them, trying to find a weak point to stab in order to fell the beasts. The level design is entwined with character design of the Colossi so much the characters themselves become the levels (see picture 7, below). As the Colossi keep moving during the boss fights, the levels’ geometry changes, forcing the player to react. Sometimes this can be used as an advantage, e.g. by allowing the Colossus in hand to lift the player high, allowing them to jump closer to the weak point. By being able to grab some part of the ever-moving giant, the player can have another chance even if they happen to fall from a height. (Todd 2019.)

PICTURE 7. The titular bosses in Shadow of the Colossus work as the levels themselves, with the player (right) climbing them like platforming levels in search of a weak spot. (SIE Japan Studio & Team Ico 2005)

Another type of innovative level design can be found in the nowadays infamously unattainable interactive teaser demo of the cancelled horror game Silent Hills, P.T. (abbreviated from “playable teaser”) (Kojima Productions (under the pseudonym 7780s Studio) 2014), where the whole game takes place in a single, very short level. The level consists of a hallway with one turn, a room on the side, and a doorway on both ends. Whenever the player walks through the latter door, they find themselves back at the start of the same hallway, only something in the level has changed a bit each time. At first, the radio starts talking, then the lights have gone out, then the bathroom door has opened. By altering the level piece by piece, changing it ever spookier and more haunting, the level design messes with the player’s head, simultaneously giving them a sense of progression even though they are walking the same corridor over and over again, and making them afraid of the next change.



PICTURE 8. All of P.T.'s gameplay is set in a single corridor that gets creepier every time the player passes through the door at the end. (P.T., Kojima Productions 2014)

The level design in P.T. is brilliant in its minimalism. The level is built so that the player's back is always turned to something unsafe, whether it be a window, a door, or the hallway behind them; there is no place to hide (Eisenmann 2014). There is a short, descending set of stairs between the doors, making the player descend deeper and deeper into the nightmare, while ostensibly presenting the same level to them. Tight corridors create claustrophobia and make the player want to pass the hallway as quickly as possible, hindered only by the fear of what is to come. The view from the door when entering another cycle of the level only reaches the corner, with uncertainty of the change lurking behind it.

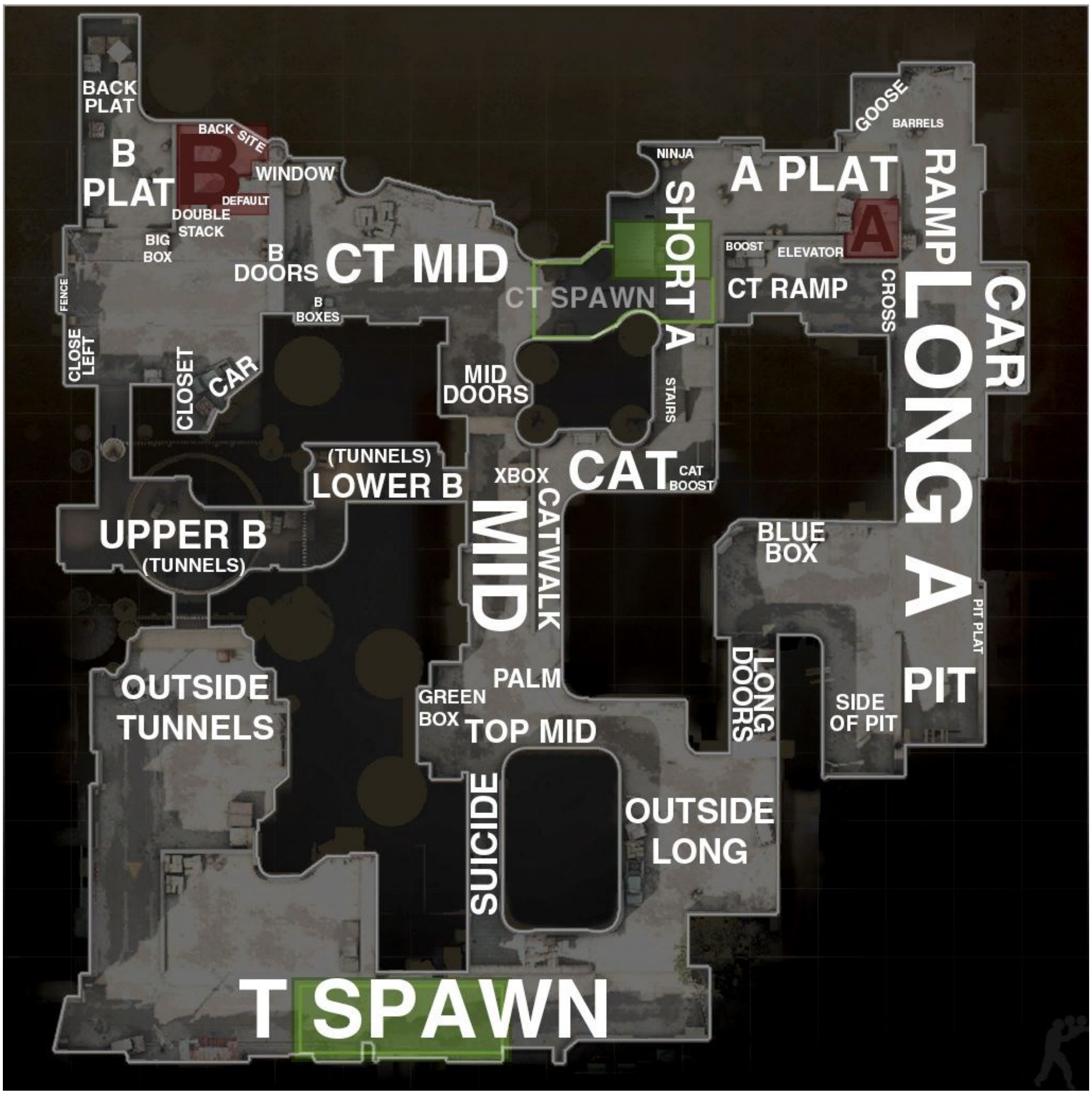
As the only game mechanics in P.T. are walking and zooming the view – there is no ways to fight the horrors, through combat or otherwise – and zooming in is the last thing a player would want to do, to look closer at the terrifying things happening around them, the level design in the game plays a major part in what makes it – according to many – one of the scariest games ever made.

2.5.1 Regarding Multiplayer

Designing multiplayer levels is a whole different topic, so it will not be touched on this thesis more than for this brief subchapter.

In multiplayer levels, the level design must support multiple players at once, so they must be designed to be fair for all. They may have strategic locations that are biased towards one side, but those must be balanced by giving other players ways of flanking them. As multiplayer levels are generally played through many more times than single-player levels, they may become so well known within a game's community that players know them through and through, testing and coming up with every possible strategy there is, in many cases more than the designers ever intended. If working on a live game, these strategies may be supported or blocked by tweaking the level on updates, trying to find a balance to the level.

Some levels become such classics that they become the most played levels in the game by far, creating a devoted fan-base around them. One level like this is Dust II (also known as de_Dust2), a competitive multiplayer level appearing in all entries of the Counter-Strike series (Valve, 2000-). Having been in rotation for the whole duration of this millennium, players know the level throughout to the tiniest detail. This affects the gameplay as players know all possible strategies each team can use, changing focus from individual performances to teams reacting and changing tactics on the fly based on psychology and the playstyle of the opposing team, based on signs as small as sighting a single player from a team of five in a specific location. (Russo 2017.) Every location on the map has its own callout sign that players learn, easing communication of opposing players' positions (see picture 9, below).



PICTURE 9. The legendary layout of Dust II, featuring callout signs for each location in the level. (Counter-Strike: Global Offensive, Valve 2012)

Dust II is a splendid example of competitive multiplayer level design done well. It supports multiple play styles, from long-ranged sniper rifle stand-offs down the long open corridor in the middle, to intense close-quarters fights on the bomb sites, narrow tunnels, and corridors. Some players have become so good in the level that they can pull off exceptional trick shots and grenade throws by measuring their aim from certain environmental objects, shooting accurately through the cloud of a smoke grenade, seeing through the cloud having become trivial as competitive players know the exact spot they must shoot in order to hit the most probable spot of the opposing player on the other side of the smoke (Russo 2017).

3 LEVEL DESIGN IN VIRTUAL REALITY

3.1 Environmental Storytelling in VR

When considering storytelling in traditional flat screen games, a lot can be told via words. Reading dialogue, journals and mission objectives is natural when dealing with a flat screen in front of the player. However, this is not the case in VR. As in VR, the screen is “wrapped” around the player’s eyes and thus is much closer to the eyes than a traditional flat screen on a table surface, reading strains the eyes quite a lot.

The lower resolution of especially older VR headsets affects this as well, either having blurry and pixelated text that is difficult to read and strains the player’s eyes, or the text having to be made so huge it becomes impractical to display more than a few words at a time, rendering reading longer passages of text nigh impossible. Considering this, storytelling should rather be told via visuals, environmental cues, and audio, instead of plain text. This is not to say all text should be banned in VR, rather than to avoid making the player explicitly read text, the content of which could be conveyed in another manner; small text elements, e.g. “HP” above a health bar, numbers on an ammo counter, or logos, are more than fine.

That said, traditional UI elements on the sides of the screen or crosshairs in the middle of it tend not to work in VR and should instead be implemented as diegetic elements wherever possible (Oculus n.d.d). Good examples of clever diegetic UI design in VR could be the wrist-mounted Pip-boy in Fallout 4 VR (seen in picture 10, below) or the hologram map in Doom VFR (seen in picture 11) (Winestock 2018).

PICTURE 10. The Pip-boy, a wearable UI hub, mounted to the player's left wrist. (Fallout 4 VR, Bethesda Game Studios 2017)

PICTURE 11. The diegetic map UI in Doom VFR. (Doom VFR, id Software 2017)

Considering accessibility for hard-of-hearing and deaf players, toggleable subtitles are essential if the game contains spoken dialogue the player needs to hear. These should however be written in a clear-cut font type, and in a large enough font to not blur out on lower resolution devices. A good font type that was used for the subtitles in Bandit Point (Mantisbite 2019) was called OpenDyslexic; what made it such a good font was how, as a bottom-heavy – or “anchored” – font, it is made specifically for dyslexic people, making the subtitles more readable for all. The togglability of the subtitles is key for those with no hearing issues and/or who do not wish to be bombarded with text elements while in VR.

As level design is tied with storytelling, these issues must be considered while working with VR, by replacing written text with environmental storytelling. While old CRPGs could get away with huge word counts – Planescape: Torment (Black Isle Studios 1998), for example, had a humongous word count of 800,000 (Kershaw 2019) – VR games cannot have players read such amounts of text due to the aforementioned issues with pixelation and eye strain. Instead, story beats, lore and location history can be told via the environment. For example, if a location has been abandoned by humans long ago, it does not need to be explicitly told to the player via text but can be seen in the environment e.g. due to human structures having been covered in overgrown plants. It does not need to be this obvious either, another way to make use of this is by foreshadowing what is about to come.

In Bandit Point (Mantisbite, 2019), there is a recurring mid-boss enemy character, the Royal Executioner (as seen in picture 12 below) that the player beats in level 4. As the same character comes back in the end of level 9, having set an ambush for the player this time, familiar elements from level 4 in level 9 were used to foreshadow the character’s return, even including a very on-the-nose graffiti of the Executioner right before the boss fight starts. The soundtrack in level 9 is also much more ominous and references the soundtrack of the boss fight in level 4, as a resemblance to the character. If the player notices these small hints, they might have a guess what is about to come, all from the environment. This kind of environmental storytelling is key in VR.

PICTURE 12. The Royal Executioner as seen in level 4 of Bandit Point. (Bandit Point, Mantisbite 2019)

3.1.1 Tutorials

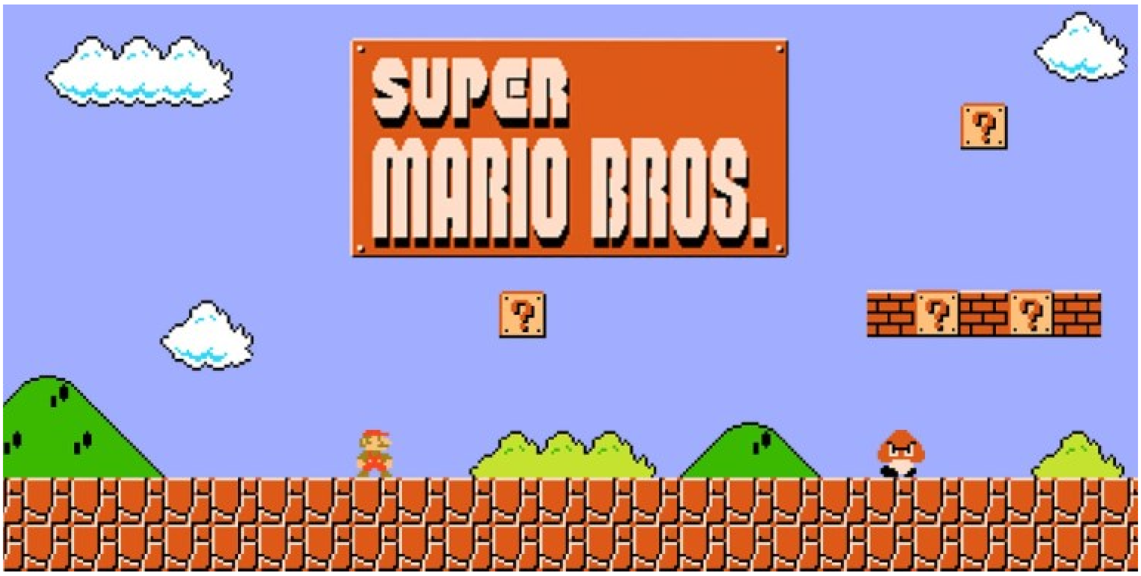
Tutorials are essential in VR games, especially because the medium is still very new and the control schemes and devices themselves might look and feel alien to players, having them at least first try and find all buttons from the controllers before being flung into gameplay. The current VR controllers are built quite differently than traditional gamepads, which are all remarkably similar in design and button layouts, the most considerable difference being in the positions of the analogue sticks. VR controllers instead have very differently shaped designs with a varying number of buttons (see below, picture 13). This leads to an awkward phase every time a user grabs a controller previously unknown to them, where they must try out the buttons.

This is made even more difficult by the fact that they are usually wearing the headset already, thus unable to see their actual hands anymore. This often leads to misplacement of the controllers in the player’s hands, not able to press the buttons correctly. Live, e.g. in a convention setting, this is effortlessly fixed as an outside observer, but it can lead to issues at home settings.

PICTURE 13. Different VR controller designs. Upper left: HTC Vive controllers, upper right: Valve Index’s Knuckle controllers, lower left: Oculus Rift’s Touch controllers, lower right: Samsung HMD Odyssey (WMR) motion controllers. (Steam 2018)

Therefore, tutorials are especially important in VR games. The issue with this is that most people seem to really hate tutorials as they tend to be either gameplay stopping walls of text or boringly long segments where the gameplay just is not fun (Nelson 2020). Why would the player have the patience to sit through a prolonged segment of studying when they could just go straight to the fun part instead? Therefore, tutorials should be as invisible as possible, like level design itself, especially in VR, where they are the most necessary.

Invisible tutorials mean segments of gameplay – usually in the first level of the game, or whenever a new mechanic is introduced – where the player is taught things without them realizing they are being taught. Good examples of both cases, if a bit overdone, are the very first screen of the first level of the first Mario game (Super Mario Bros., Nintendo 1989), another being around the first hours of The Legend of Zelda: Breath of the Wild (Nintendo 2017), where new mechanics are taught. In Super Mario Bros.' level 1-1, the very first screen introduces all the pivotal game mechanics of the whole game (see picture 14 below). Hitting mystery boxes from below gives coins or mushrooms as rewards, eating mushrooms grow regular Mario into Super Mario, goombas hurt Mario, bricks are only breakable by Super Mario. The player has time to practice jumping and running, discovering the difference in the length of the jump depending on the time they hold the jump button down and the speed they are running while jumping. The first screen teaches the player all the skills they need to complete the whole game, without any text, tutorial boxes or stopping the game once.



PICTURE 14. The very first screen in Super Mario Bros. teaches all the base mechanics of the game. (Super Mario Bros., Nintendo 1985)

The other example, teaching new mechanics whenever they are introduced, has been perfected in the Legend of Zelda series. Near the beginning in The Legend of Zelda: Breath of the Wild (Nintendo 2017) the player must lead the main character, Link, through an area surrounded by snow. However, when the player wonders to the snow, they realize they are starting to freeze to death, introducing a new mechanic to the series, temperature (see picture 15, below). Through the game there are areas with different climates that the player must take into consideration in their clothing lest they either burn or freeze.

In the beginning, the player has two options to solve this new-found problem of coldness. They can either complete a little quest for an old man nearby, creating a dish of his favorite food for him, after which the man gives their warm doublet to Link as reward, dressed in which the player can finally cross the snow-clad area, teaching the player that clothing can affect their temperature. The other option is to gather some spicy peppers from nearby bushes, cook meals out of them, and venture up to the snow eating the meals whenever the warming effects of the last one end. The game does not tell whether either option is the "right" one and leaves it to the player to teach themselves with logical solutions to a simple problem.

PICTURE 15. Link is starting to freeze without the proper clothing or some warming food. (The Legend of Zelda: Breath of the Wild, Nintendo 2017)

These kinds of invisible tutorials based on real gameplay situations are ones to go for in VR games as well.

3.2 Adding Dimensions

The breakthrough of 3D games in the 90s made level design much more complex compared to 2D games. Instead of having to worry about flat world on two axes (X and Y) the player could move in and explore, there was now a whole third dimension – the Z axis – allowing for depth and rotation in the game world.

VR has been a similar extension of perspectives; while not technically adding another, fourth dimension, the headsets' lens design brings the player inside the game world instead of just watching it on a flat screen in front of them, allowing the player to crouch, jump and circumnavigate any game objects freely by doing so in the real world while wearing the HMD. VR worlds must be created in a way that looking in a 360° arc around, up, or down does not let the player peek behind the scenes.

As the obstacles in a VR game do not exist in the real world, the player must be prevented from e.g. pushing their controller through a desk and grabbing items inside it without even opening the desk first, or pushing their head through a wall to peek on the other side. These kinds of unique VR-related issues can luckily be solved with some clever programming and the proper colliders. As moving the player's headset artificially can cause discomfort to the player (Dealessandri 2020) and any such movement should thusly be avoided as much as possible, the player's head cannot be stopped at walls in a similar fashion as the hands. Instead, specially made shaders can be enabled to obstruct the player's vision if their head collides with the game environment in ways that would allow them to peek through obstacles.

3.3 Safety and Comfort

Safety of the player is of course of the utmost importance when designing any games supporting motion controls. As the player is blind and possibly deaf to the real world while wearing an HMD and possible headphones, it is the developer's responsibility to make sure they remain safe during play. Requiring fast or hard strikes on the controllers might cause the controllers to hit something or someone in the player's real-world vicinity, especially if during play they have drifted onto the edges of their play area. The controllers may also slip out of the player's hand and fly onto something or someone, so if those kinds of movements are required in a game, the developers might want to add a reminder to fasten the controllers' wrist straps so they will not fall out of hand even if the player's grip fails.

One major concern to consider while designing for VR, if not the most important, is the issue with motion sickness and nausea. Many people get very easily nauseated while playing in VR if proper precautions have not been taken by the developers. The primary causes for discomfort and nausea in VR are artificial acceleration and movement, acceleration being especially discombobulating to the brain. (Oculus n.d.a.)

Players have vastly different tolerances for nausea, so implementing comfort options in VR games is essential. Some players get used to VR easily and do not feel sick easily when others will throw up at the first uncanny movement. The cause of the nausea is the difference between what the player is seeing with their own eyes in the game world and what their brain is experiencing from the real world simultaneously; when e.g. strafing sideways in a game while standing still in the real world, the brain gets conflicting information about the state of their movement, causing the person playing to feel sick. Luckily, there are ways to ease or circumvent this issue.

3.3.1 Locomotion

Locomotion is one of the most common causes for nausea in VR. Therefore, when considering movement systems in a VR game interchangeable options should be supported as well, or many players will be alienated from the game altogether. There are many different methods of locomotion that differ in comfort levels. There still has not been a locomotion method that would work for all players, so implementing more than one can be beneficial. (Oculus n.d.a.)

Free locomotion resembles traditional 360° movement familiar from flat screen 3D games, being similar to moving using a gamepad’s analogue stick or trackpad. It can be very discomforting because it includes the possibility of moving sideways and backwards, which as rare movements for humans in our regular lives can cause nausea (Dealessandri 2020). It is one of the freest locomotion options though, so to those who can stomach it, it can allow increased dexterity in the game world. It is not usually recommended as a good method of locomotion due to the nausea issues it causes, but some players used to traditional flat screen games actually prefer this one, even to the point of outright refusing to buy a VR game without it (Handrahan 2018), so it might be worth consideration.

Teleportation is better for players with nausea issues, as it allows them to move around in the game world by respawning them in different spots on the scene. This way the players do not have to endure any acceleration. There are many ways to implement teleportation. In some VR games, the player can freely teleport anywhere on any suitable surface. In some, there is a finite amount of predetermined positions players can teleport to. In some games, the player can also choose the direction they will face after the teleport.

A good example of a well implemented teleport mechanic is from Doom VFR (id Software 2017). While teleporting, game time is slowed down, so teleporting works as a combat mechanic itself, allowing the player to enter Matrix-like bullet time for short periods of time while moving. Teleportation can be eased by adding an option to not visualize the teleportation process, instead blinking the player to black when starting the movement and fading out of the black quickly when reaching the destination. The downside to teleportation is that it can be immersion-breaking to some players.

One of the cleverer ways to circumvent the nausea issues caused by locomotion is to move the environment instead of moving the player. This requires a specific setting to work in a game, though. A game that does this well is Echo Arena (Ready at Dawn 2017), where the players float in zero gravity, moving themselves by physically grabbing ledges and pulling themselves in a direction, giving the illusion of pulling the environment closer to the player.

All locomotion options can be eased further with comfort options. Some players prefer a tunnel vision effect whenever they are moving, narrowing their field of view (FOV) momentarily, reducing discomfort. Some prefer input latency to the start of the locomotion, giving their brains time to prepare for the motion. The movement should stop immediately when releasing the stick, though. (Oculus n.d.a.)

There is also the option of not supporting any kinds of artificial locomotion options at all. Some VR games are played entirely while sitting down in one place, or while standing still. Some games allow only physical movement in the play space, allowing the player to explore the scene by physically moving around in it. While very immersive, this only allows for small scenes due to the limitations of space in players’ homes. Because of this, games requiring physical movement tend to work best in VR arcades with more reserved space than home settings usually have.

A good example of a VR game based on physical movement is Superhot VR (Superhot Team 2017). Based on a PC version, the VR version of Superhot works similarly to the PC version in name. In the game, time only moves when the player moves. This mechanic fits VR perfectly, even better than PC, as it utilizes the possibilities of VR to support the game’s central mechanic so well. The Matrix-like slow motion action, physically dodging bullets, shooting and throwing objects at enemies, grabbing their guns from the air, and turning them against the goons, all feels amazing in VR.

This type of games can also be non-accessible for players with movement disabilities, though. For example, some games may require crouching physically to avoid objects in the game world, which may prove impossible to some players. Superhot VR is not very accessible to players with movement disabilities due to it being based on the whole idea of physical movement in the game space.

Another example of this is Beat Saber’s (Beat Games 2019) expert difficulties, which require the player to move physically sideways and to crouch in order to avoid deadly obstacles that can end their game from one hit. Players with difficulties in e.g. crouching are thusly excluded from playing such levels. This is not something that should unquestionably be fixed, though, as the game is playable without crouching and moving, only on lower difficulties.

This type of gameplay is not somehow adherently bad either, as some players like to be able to jump around and swing the controllers freely, so supporting that kind of gameplay can be beneficial, as long as the game does not force it on the player, giving accessibility options instead.

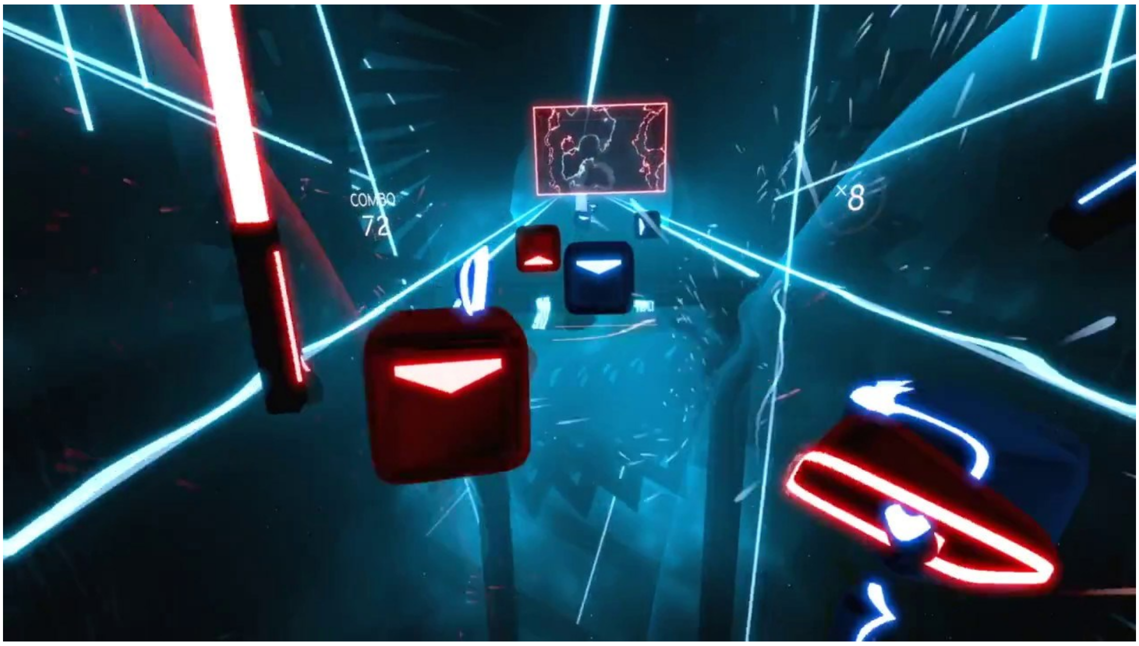
3.3.2 Reaction Times and Pacing

As VR is generally more overwhelming to the player than flat screen games, players' reaction times are much slower than they are when playing on a console or on PC. This must be taken into consideration in level design when designing encounters, scenes requiring fast reactions should be avoided in general. This does not mean that fast-paced sequences should not be done in VR; a scene can feel fast-paced without it relying on lightning-fast reflexes, instead giving the player enough of a warning before the action.

A good example of this is in Beat Saber (Beat Games 2019) where, in addition to the player seeing upcoming obstacles from a while away, they have time to get to the rhythm of the current level – or song – before they get to their most difficult parts. Even on harder difficulties, the songs usually start with a calmer intro before coming to a breakdown, where the action kicks in with everything they got.

Pacing in level design is especially important in VR, not only to uphold the quality of the experience by giving the player some breathers now and then between immense action sequences, but also because playing can be physically taxing, and sessions are generally much shorter than when playing a flat screen game. Beat Saber helps the player focus by limiting the play to one direction, removing the need of turning to left or right, instead offering a very concentrated experience (see picture 16, below), quite similar to Guitar Hero (Harmonix 2005).

Beat Saber also does a great job in using space; as long as the play area is cleared correctly, the game does not require the player to move away from their spot, or cause them to drift to the borders of their play area, as the blocks are all coming towards the center of the play area. As the main game mode of the game concentrates all gameplay in a single direction, the game works perfectly with the Oculus Rift, the – a bit primitive – tracking of which is by default supported best when facing one direction and not turning around much. A 360° game mode for most levels is supported as well, mainly targeted at the cordless Oculus Quest headset. Without cords to trip over on or restrictive 180° tracking, the player is free to move as they wish, the only limitations being the physical limitations of the players themselves.



PICTURE 16. The blocks in Beat Saber come all from a single direction, helping the player focus on what is to come. (Beat Saber, Beat Games 2019)

The average skill level of players is still generally lower in VR compared to console and PC due to the media being much newer. This must show in level design as well. Letting the player feel in control is imperative in VR as it is easy to lose that feeling when dealing with a relatively new form of media, unfamiliar control schemes etc. Especially the first levels in a VR game should be quite simple and easy for the player to get a grip of the gameplay, with later levels increasing in difficulty.

3.3.3 Changes in Vision

When the player puts on a VR headset for the first time, they are introduced to a whole new world. Everything looks much larger and closer from that perspective than what they might be used to on a flat screen. This must be taken into consideration while designing VR levels. The sizes of different objects must be even closer to reality than in flat screen games, as it is obvious that measurements are wrong if the player e.g. grabs a bottle the size of their own torso. In level design, doorways, windows, obstacles etc. must be measured correctly if going for realistic environments. A four-meter-high kitchen door might look all right on a flat screen but through a headset it will look seriously out of place.

The perspective change can and should be used by level designer in creating jaw-dropping moments, for example by offering beautiful vistas from high places or making the player feel very small in front of a huge skyscraper. A thing to remember is that due to the headsets' relatively low resolution, faraway objects are incredibly difficult to see, so when creating vistas, one should not expect the player to see anything small in the distance.

Good examples of vistas that work well in VR are e.g. views to space from a window on a spaceship, making the vast expanse feel massive in its emptiness, with distant stars glimmering through the blackness, or a sunset behind a faraway mountain range seen from a castle tower. Due to the poor depth perception on distance and low resolution of the headsets, these vistas can easily be created using flat images rendered on a single polygon, saving precious resources on computational costs. This works well due to the objects being in such a distance that moving around where the player is watching the vista would not realistically change their perspective of it. (Oculus n.d.d.) Another thing to consider is the vertical target location in comparison to the headset. In order to minimize neck and shoulder problems accumulating on players, targets should be placed between 15° above and 30° below eye height (Penumudi, Kuppam, Kim & Hwang 2020).

3.4 Designing for Different Headsets

When designing for VR, one must consider the fact that – much like in Android development – the end devices vary quite a lot from each other. Different HMDs by different manufacturers have vastly different FOVs, screen resolutions and other specifications. For example, the still very much used (see figure 2, below) Oculus Rift's field of view is a bit narrower at 110° (Kyoto 2016) than for example the newer Valve Index's FOV of 130° (Valve n.d.), the Rift also having a lower screen resolution of 1080 x 1200 px per eye (Kyoto 2016) compared to the Index's 1440 x 1600 px resolution per eye (Valve n.d.). These differences mean that all aspects of VR level design must be tested on different end devices to ensure consistency between the players' experiences of the same game depending on the headset they own.

On older headsets with lower resolutions everything looks more pixelated, and as such, far away objects are less visible than when looked through newer, sharper headsets. The level designer must thus ensure that everything relevant is close enough to be visible on all supported devices. The FOV differences must in turn be taken into consideration in that nothing relevant gets cut out by devices with a narrower FOV.

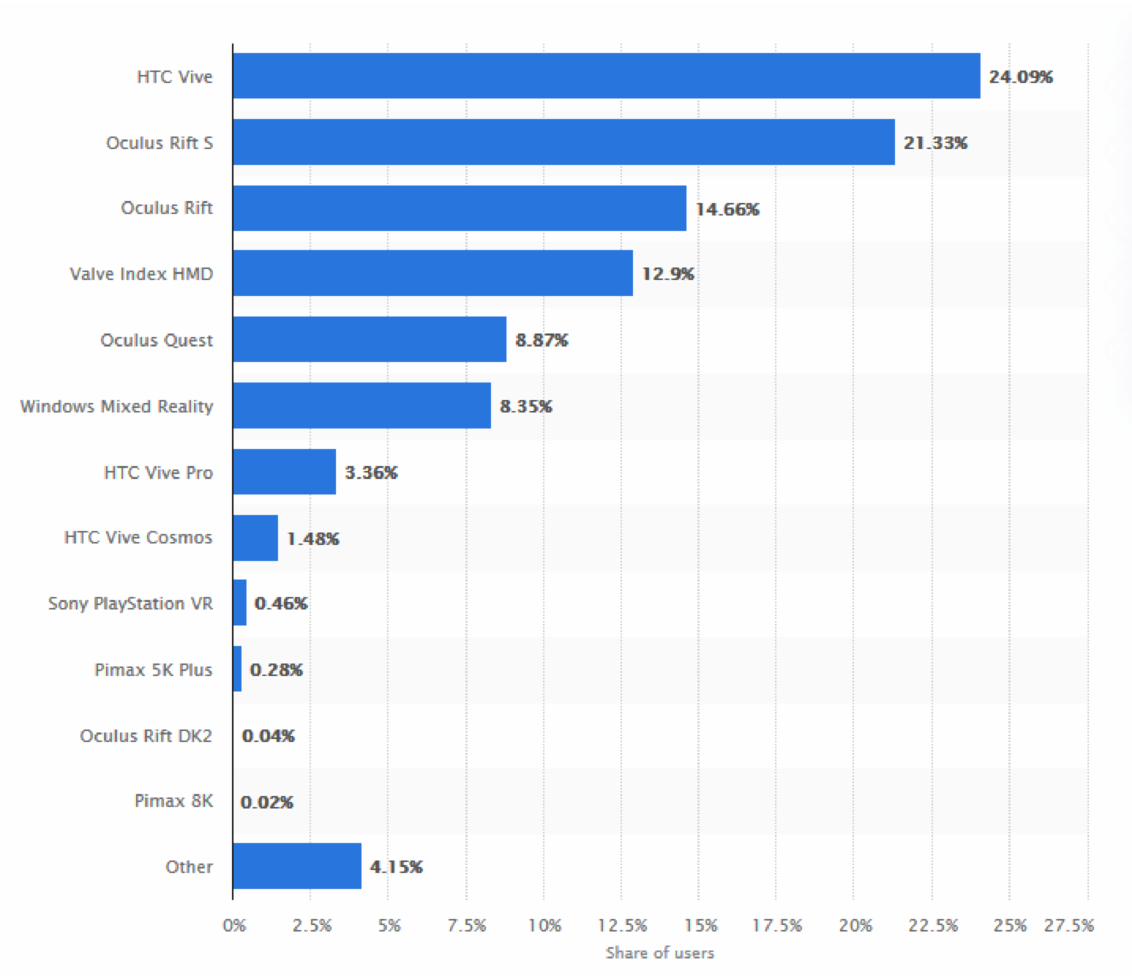


FIGURE 2. Share of Steam users with a VR headset worldwide as of June 2020, by type (Statista.com 2020)

VR level design is also affected by the differences in the amount of horsepower in the project's target devices. Most VR headsets are run through a PC or, in the case of PSVR, a console. When designing for these devices, the level design can be quite open and include more extensive and detailed levels, nevertheless keeping in mind that VR itself is very taxing in computer resources. In 2019, Oculus released the first standalone headset, the Oculus Quest. It has much lower specifications than PCs or consoles, resembling a mobile device more than a PC (Oculus n.d.b), so when designing for it, the level design must adapt in creating much more compact experiences in order to save in computational costs (see chapter 3.4.1).

Another issue raising from having many different end devices to target a game to is the fact that each have different controllers, as mentioned in chapter 3.1.1 (also see picture 13 in said chapter). As different controllers have different amounts and positions for buttons, this must be taken into consideration as well, in order to make all versions of the game as close to each other as possible. For example, the grip button on a Vive controller needs quite a bit of force to press, when on a Rift the corresponding button offers so little opposition that most new players press and hold it down on accident when grabbing the controller. As some controllers have more configurable buttons than others, the game must still work perfectly with the most stripped-down controller, often leaving the extra buttons empty, unless more than one controller configuration for one device is created to be toggleable from game options.

The different controllers offer one more issue: as each controller tracks movement a bit differently from each other and from different positions compared to the player’s own hand, these positions must be adjusted separately for each controller in order to have e.g. the player character’s weapons shoot in the right direction.

3.4.1 Technical Constraints

VR games are generally speaking twice as graphically taxing as flat screen games, as the output must be rendered on two lenses instead of one screen. This means the environments must be designed with the target device in mind; trying to hit mobile HMDs with the same level of detail as in a game designed for PCVR will result in low frame rates and lag, both of which are absolutely unforgivable in

VR games, as they cause heavy nausea. When a flat screen game can be targeted to run in 60 frames per second (fps, not to be confused with the term for first-person shooters) to be considered smooth, due to technology, VR games must hit 90 fps at minimum to run smoothly on devices with 90 Hz screens, or else there will be visible judder and tearing, which in turn, cause discomfort and nausea. The latency must also be cut to minimum, 20 ms being an acceptable amount, higher latency than that causing discomfort (Oculus n.d.c).

In VR, levels' readability must be of utmost importance, even more so than in flat screen games. This comes from the fact that due to the lenses being so close to the player's eyes, their eyes gain much more information from all sides, compared to the concentrated focal area of a screen placed some way in front of them.

Possibly the most substantial issue in making VR games as of the writing of this thesis is the fact that despite many great games coming out for VR, a good portion of the video game playing public do not have a headset, and with the current prices, will not invest in one. Some games, like Beat Saber (Beat Games 2019) and Half-Life: Alyx (Valve 2020) have become so successful they have sold headsets to people wanting to play those games exclusively despite the steep price. Still, especially making VR multiplayer games is a substantial risk as many VR players' friends may not have headsets themselves.

An example of a game that has circumvented this issue well is Keep Talking and Nobody Explodes (Steel Crate Games 2015), where only one headset is needed for playing locally with friends. In the game, one player, wearing the headset, tries to defuse a bomb in VR while other players read instructions to the defuser from a manual that can be either viewed in a browser or printed out as a physical copy. Incorporating the VR world with the real one this way was a great move to get players engaged with the multiplayer aspects of the game, even with a shortage of headsets within a group.

4 DESIGNING A LEVEL FOR VIRTUAL REALITY

4.1 Introduction

To give an example of designing and building a level for a game set in a virtual reality environment, the author created a custom level for Half-Life: Alyx (Valve, 2020) using Valve's own Hammer Editor, provided with the game itself. The game and editor were specifically picked for multiple reasons. The game is one of the most impressive games made for VR thus far (Stapleton 2020), providing a very interesting environment to work in. The genre of the game, being a first-person shooter set in VR, also comes close to what the author had done previously in his work. The Hammer Editor also happens to be one of the only accessible VR game editors available at the time of this thesis' writing. This allowed the author to concentrate on creating a level for a game that works out of the box, instead of having to program gameplay to support the level.

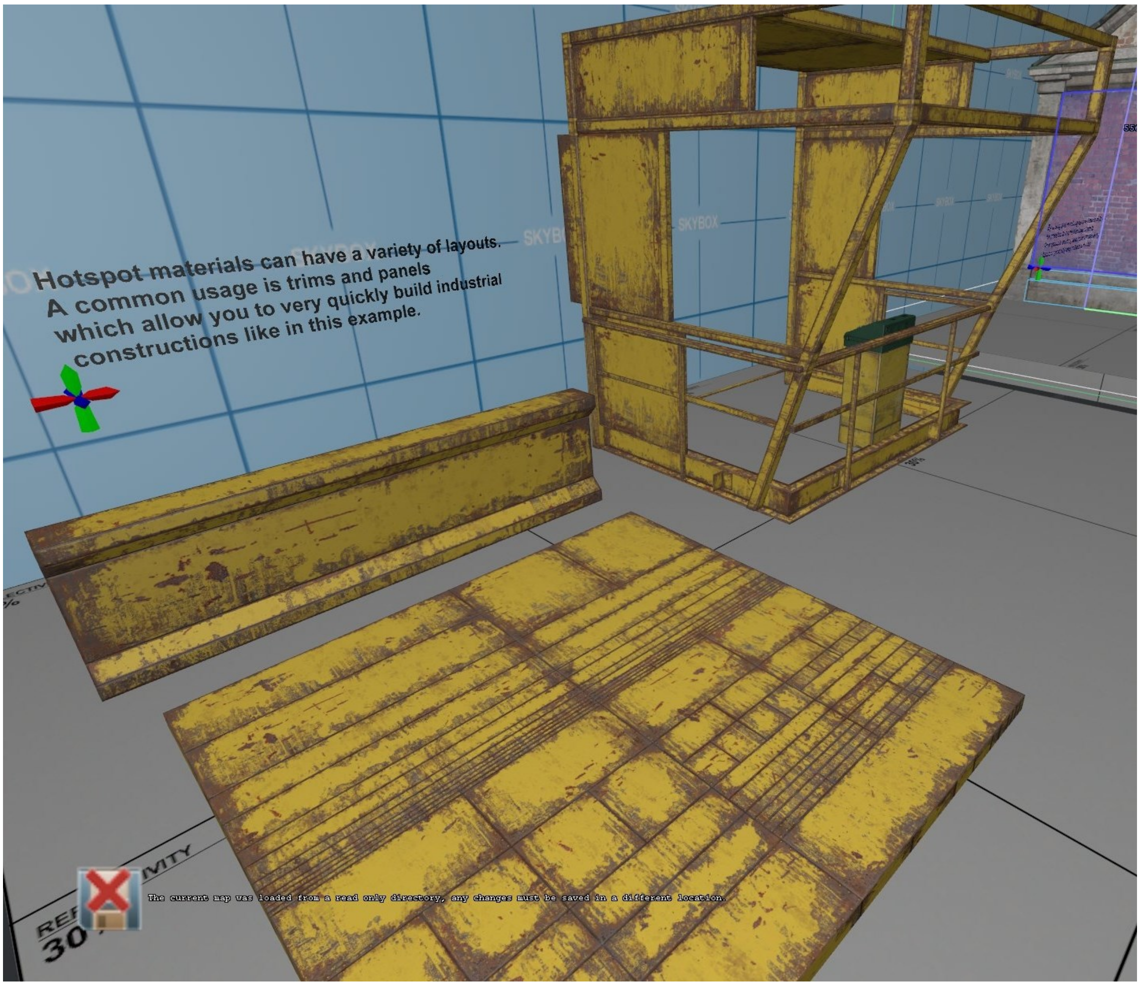
4.2 Picking the Hammer Editor

The Hammer Editor uses Valve's own Source 2 engine, and is a great tool for level designers due to its versatile assortment of tools that make level design all so much easier compared to working in other engines or 3D modelling software. Modelling and editing that geometry is extremely easy, fast, and intuitive, with hotkeys for the most used tools and their functions to make the process even faster. Some extremely useful tools for level designers that help elevate simple geometry to new heights – often even removing the need of an environment artist creating a huge number of simple assets – include hotspot texturing, tile meshes, subdivisions and displacements, and in-editor physics simulation. (Wintergreen 2020.)

Hotspot texturing makes texturing simple, rectangularly faced geometry very fast and intuitive by handling UV mapping for the designer. The technology built in Hammer allows the designer to pick a hotspot texture that has been split in different sized rectangles with texture variations in each size, and apply it to a model, the program picking appropriate rectangles from the texture for each rectangular face on the model, texturing even complex models with a good number of faces with the press of a button (see picture 17, below).

Normally texturing a model like that would require if not complex, then at least time-draining and tedious UV mapping in order to get the rectangles to match the texture correctly. Texture variations provided in hotspot textures along with the hotspot texturing technology itself make sure that adjacent, similar sized rectangular faces do not repeat the same texture rectangle on them.

Hotspot texturing is especially good for textures with some wear to them. The system makes sure the edges and corners of the model line up with the worn-down parts, creating something almost like outlines on the faces and making sure the textures match across corners, connecting with a simplistic base texture.



PICTURE 17. The hotspot texture is visible in full at the bottom, with example models textured with it above. (Hammer Editor, Valve 2020)

Tile meshes make it easy to create simple, tile-based models very quickly. A bit similarly to hotspots, tile meshes track rectangular faces and replaces them with the tile set’s predetermined 3D meshes if the faces match pre-set mesh sizes. The system also knows to pick correct meshes for corner pieces. The designer can add variation to the tile meshes by picking from different sets of tiles for specific faces. Models that benefit from tile meshes include air ducts, pipes, wall panels, or any 3D objects with repetitive faces appliable for a set. Using premade tiles for such objects in form of tile meshes makes it incredibly quicker to e.g. draw out a vent shaft without the need to model every single tile in the vent or to have to copy and paste the tile models all around, leading to a huge number of extra vertices all over the complete shaft.

Creating natural shapes is always more difficult than creating human-made structures due to natural shapes being much more unpredictable and chaotic by nature. Hammer facilitates this with offering tools to create subdivisions and displacements. Without cutting a face into multiple separate faces like many other engines would do, creating issues with vertices, eating up rendering power, and causing extra work, subdividing a face with a press of a button in Hammer creates a grid between the face’s vertices, each smaller sub-face behaving like proper faces themselves. With the displacement tool these sub-faces can be manipulated by using sculpting tools such as push/pull, flatten, smooth, and erosion, in order to create believable natural shapes that use only one face.

The same subdivision tool can be used in texturing, by painting another channel of a texture on top of a textured subdivision, the second channel painting over the subdivision’s vertices. This technique works well for painting dirt, blood, or similar effects on surfaces.

In-editor physics simulation facilitates the decorating process by leaps by allowing the designer to activate physics in editor for selected assets. The designer can e.g. place multiple props at a time, activate physics on them, and throw them around in the scene to create natural dispersion and chaos, all while remaining in editor. The physics simulation is also incredibly useful for posing ragdolls and letting a cloth fall on objects, draping around them naturally.

Traditionally, posing models like this would require meticulous placing and bending bones one at a time.

The editor offers a vast selection of premade assets from Half-Life: Alyx, including environmental models, mechanically working prefabs with all necessary scripts and references in place, as well as enemies, weapon and ammo pickups, health stations and other entities that work right out-of-the-box. Valve has also graciously made all of the released game's maps available in full, as well as providing small example maps focused on specific interactions, with instructions inside the levels on how to use different mechanics and create such systems in one's own custom levels.

Valve also has a vast series of tutorials up on their developer website regarding different aspects of level design inside their editor. There are also many tutorial videos online made by third parties that provide lessons on how to create certain systems in the editor. Making use of the premade assets and checking different systems out from example levels and tutorials makes creating custom map extensions easy and fast, and helped picking up a new engine for this thesis project quite much.

Hammer makes it easy to work the full level design stack from greyboxing to texturing, decorating, lighting, and adding AI to the levels along with triggers, puzzles etc. The editor makes working on levels so much easier than working in other engines or 3D software by facilitating doing the most mundane and simple but tediously lengthy parts as smooth and quick as possible, letting the designer focus on what matters: level design itself.

4.3 Base Game Research

Before starting to design the custom map for this thesis, research on Half-Life: Alyx (Valve 2020) was made by playing through the base game itself, analyzing it in the process. The game is well paced, fluctuating between quiet moments that allow the player to explore their surroundings and play with different kinds of interactive props, intense combat encounters that keep the player on their toes, and scary sections in pitch black darkness, with only a manually aimed flashlight to give some light to the situation.

The game is filled with interactive props that the player can lift and throw around using their telekinetic “grabbity gloves”. A good chunk of the environment itself is interactive as well, being filled with manually openable containers and cabinets that often have rewards hidden inside them. The weapons themselves also feature mechanics – mostly related to reloading them – that the player has to manipulate manually, amplifying the hands-on experience even more.

The game takes place in City 17, occupied by inter-dimensional fascists, Combine, and partly infested by the extra-terrestrial monsters, Xen. The game’s levels are set in a variety of environments, from residential buildings and hotels to industrial areas, sub-terranean sewers and subway tunnels, and even an abandoned zoo. Environmental diversity keeps the levels interesting and differentiates them from each other.

4.4 Design Pillars

In all aspects of game design, it is important to define and maintain so-called design pillars, meaning the core elements and emotions the game is exploring and trying to evoke in players. These few main points are ones the designer should always come back to in order to ensure their vision is staying on the desired path. They help define the game and keep its direction coherent. If an idea or a mechanic does not fit the pillars, it is often better to remove it than compromise the integrity of the game. (Pears 2017.) For this custom level, the following design pillars based on the research on the base game were defined to outline the intended experience of the level.

Exploration: the player is encouraged to explore the environment by hiding rewards like ammunition, health pickups, grenades, and resin (currency for weapon customizing in Half-Life: Alyx) in places that require the player to open cabinets, look inside and under environmental props, etc. The way forward is always kept quite clear but stepping off the beaten path is encouraged.

VR interactions: the player must use many different VR interactions to advance in the level. It is a no-brainer in a VR level to utilize the advantages of VR as much as possible, so including door handles that must be turned by hand, manipulatable environment including breakable windows, liftable and throwable props, drawable whiteboards etc. is essential to the experience.

Room to breathe: as mentioned in an earlier chapter about pacing in this thesis, it is imperative to offer a nice balance between quiet times dedicated to exploration, and intense combat situations.

Varying environments: incorporating several different environment styles in the level helps keep it environmentally interesting, while also making different parts of the level stand out from each other, improving the player's sense of space.

Fair but challenging combat: combat should not become tediously hard, so providing the player with enough ammunition, healing options, and multiple routes and positions around a combat arena is imperative. The enemies should also have cover and advantages they can use against the player if they are not paying enough attention to the enemies.

4.5 Level Flow

In the custom level made for this thesis, the player infiltrates a run-down hotel occupied by Combine forces in order to reach a transmitter on the top floor, and send an important message out of the city to fellow resistance members. The hotel has four distinct areas in three stories the player must go through to reach the transmitter.

Gameplay starts from a bathroom in the base level of the hotel, where the player has infiltrated the building discreetly through an air vent. They can explore the small bathroom to find several hidden rewards, mainly some ammunition, a health pickup that can be saved for coming fights, and some resin. Exiting the bathroom leads to the hotel lobby, a large, two-storied open area, with the level's first combat encounter against Combine forces (see picture 18, below). The first fight is designed not to be too hard, as the player starts the level armed only with a non-upgraded pistol. The enemies may drop ammo and the occasional grenade when defeated that the player can pick up and use in the fight. A shotgun is hidden in the lobby for the player to grab; as this is the only occurrence of the weapon, it was not made too hard to find.

PICTURE 18. An overhead view of the lobby, the first combat arena in the map.

After the fight is over, the player knows they must get upstairs to reach the transmitter. The elevator is out of order, so they must take the stairs. Reaching the top floor, the player can see the door needs a key card to open. The only possible route is downstairs, into the basement. This is also where the key card is located.

The basement is infested by Xen, and mostly swallowed by pitch-black darkness. The player’s flashlight turns on shortly after entering the floor. Enemies here are not too hard to fight against, as they are either immobile, slow, or small but weak. This balances the fact that the darkness becomes the player’s greatest enemy here, having them rely on the narrow cone of their flashlight to see what is in front of them. The objective in the area is to find a key card for the door to the top floor.

The card is hidden in an office at the back of the basement. There is a safety window overlooking the office from the starting area that the card is right on the other side of, giving the player a view of the card right from the start. After the card is found at the back of the basement, the player can return to light.

Going up the stairs again and opening the upstairs door with the key card, the player enters the top floor and is confronted by a locked Combine door. They need to solve a small puzzle involving redirecting electricity through a set of nodes to get the door to open. In the room with the puzzle, the player finds a sub-machine gun and some ammo to help with the coming fight. On the other side of the door is an impenetrable Combine force-field fence blocking the player's advancement. The opening mechanism to the fence is in an adjacent room that also houses a weapon upgrade station that the player can use resin on to upgrade their weaponry.

The force-field fence opened, some enemies spawn to attack the player. This fight is harder than the earlier one due to introducing new, tougher enemies and a narrower fighting space with less flanking options. Having beat these enemies, the player must move through a narrow utility corridor and drop down to the last area, entering an industrial hall occupied by Combine forces (see picture 19, below).

Solving a puzzle to redirect power to the transmitter, the final enemy waves spawn to stop the player. There is a two-minute timer that the player must defend the transmitter for in order for it to complete its transmission. The level is won when the transmission is complete.

PICTURE 19. An in-editor side view of the industrial hall, displaying verticality differences and the transmitter on top of the hut to the left.

4.6 Applying Level Design Principles into the Design

The map was designed with predetermined design pillars in mind. To encourage exploration, rewards were hidden around the map in places the player would naturally investigate, like cupboards, shelves, and under furniture. As it is important to provide ammunitions for the player to allow them to fight enemies, ammo pickups were placed in more obvious spots like on top of tables and as drops from enemies. The upgrade material, resin, was generally hidden a bit better due to it being mostly rewarded for exploration, offering advantages to the player if collected enough.

Advancing in the level was kept quite straightforward, being centered around the four main locations: the lobby, the basement, the top floor, and the industrial hall. Having the player explore the lobby first makes it a familiar hub that can be seen again from the stairway when coming back from the basement, heading to the top floor. The lobby works as a landmark location, connecting the level together in the player’s mind.

Another landmark in the level is the elevator, located in the lobby. As the same elevator shaft continues all the way to the top floor, seeing it there as well connects the two areas together, facilitating reorienting oneself in the map after entering the latter.

The map utilizes many VR interactions, by having the player physically open doors and containers, having lots of physics objects that can be thrown about and lifted to find the hidden rewards under or behind them, and of course by supporting the very hands-on combat style of the base game. Giving the player grenades to physically lob around the combat arenas play right into this design pillar.

The map has four distinct environments. The lobby is spacious and open with lots of cover for the player and a coverless zone in the middle, separating the player and the enemies from each other. The basement is gloomy, dirty, and dark, filled with horrors awaiting the player around every corner. The top floor has narrow hallways with many side rooms, with some walls knocked down by Combine forces, offering unorthodox routes through the architecture. The industrial hall, being the last combat arena in the map, has increased verticality changes and many routes around it, as enemies will come barging in from all directions. Differentiating all areas from each other visually and by creating a different atmosphere for each area via the use of lighting and environmental design helps support the player’s sense of space and progression.

The combat scenarios have a rising trend of difficulty and intensity. The first Combine encounter in the lobby is kept relatively easy by limiting the number of enemies present at once and by only having basic enemy grunts spawn for this fight. Another way that this first encounter was tilted in the player’s favour was by giving some of the enemies gas tanks on their backs, offering them no combat advantage, but giving the player an opportunity to take them out with a single well-aimed shot to the tank, making them blow up and possibly take out another enemy at the same time as well. The player has many opportunities for taking cover and flanking the enemies here, with additional firepower hidden around for an extra advantage over the enemies.

In the basement, the enemies have serious disadvantages to the player, being mostly slow and able to harm the player in close combat. The darkness here becomes the greatest enemy, as the player's vision is severely limited. Keeping the enemies easier to fight balances the scariness created by the dark, making it a fair fight.

The fight in the top floor, right after entering the area, is more challenging than the previous Combine fight in the lobby, introducing new enemies and keeping the player on their toes, offering less cover and no real option to flank the enemies. The player is pinned to place at the entry until they take out the machine gun enemy holding the ground.

The fight in the hall, being also the last fight in the level, is the most challenging one, with enemies incoming from several directions, forcing the player to switch positions and using every trick in their power to defeat the enemies. Enemies also have more options for using cover here, as well as having a more diverse roster of units attacking the player's position. The fight is kept fair by limiting the number of enemies present at any time, and by having them drop extra ammo, grenades, and health pickups for the player to use. The player also has time to explore the area a bit before the enemies start flowing in, as they must complete a puzzle to power up the transmitter, with the puzzle requiring them to move a bit in the area, looking for parts. Henceforth, they can get a look at their surroundings in piece, thus allowing them to perform better in the battle to come.

4.6.1 Building the Map

The process of building the custom map began with creating a brief analysis of the base game based on playing the game through earlier, summing up what worked in the game and what did not. Based on the analysis, a broad plan was created about what elements were desired to include in the custom map. The next step was to create an overview sketch of the map, dividing it into sections, separating quiet moments of exploration from high action parts. This process can also be called segmentation (Oniscu 2020c).

After sketching the map out, it was time to start building it in the Hammer editor. Keeping VR in mind when taking measurements, the greybox stage was rather fast to do, allowing the transition to texturing and decorating the environments quite fast, testing the environments often. Hotspot texturing quickly became a much-used tool, as it maps the textures on applicable meshes quite accurately. Fixing the UV maps manually became more of a rarity than a common part of the process due to the excellent tools built in Hammer. Painting with two-channelled textures over subdivided faces allowed creating custom splatters of blood and patches of dirt and alien growth onto applicable surfaces.

Static decorations such as sofas, tables, and cabinets work as level geometry, so implementing them in the greybox stage in order to get the measurements right became easy to justify. Adding dynamic decorations and physics objects such as breakable bottles, junk props etc. was more of a late stage part of the process. Again, the excellent level design tools built in Hammer came to good use when placing dynamic props by allowing the use of the physics simulation tool to let the props scatter naturally. Custom dirt piles were modelled as well using subdivisions and displacements.

Lighting, being one of the most essential parts of a level’s appearance as it basically governs what the player can see, came early on into the process in order to set the mood in different sections of the map. Different colours and volumes of light evoke different emotions from the player.

The lobby has a friendly, warm lighting, albeit being on the dim side, making the area feel relatively safe. This is enforced by the fight here being quite simple as well. The pitch-dark basement that follows plays on the player’s mind through the absence of light. The stairway connecting the previous two areas with the top floor, as well as the top floor itself, have the same warm lighting as the lobby, to bring back the sense of confidence and ease the player’s mind after the horrors of the basement. The Xen infested utility corridor before dropping down to the industrial hall has a bright red emergency lighting, bringing on a sense of gloom and doom, heightening the player’s senses by creating a sense of alertness there. The hall itself has a gloomy blue-ish lighting on par with the visual language and colouring of Combine, tying the lighting together with the space’s occupants.

AI placements, triggers and logic nodes were also essential early on, as they play a huge part in creating the gameplay in the level. Testing the AI's behaviour early and often and getting them to act roughly as desired left fine-tuning their behavioural patterns to a later stage of development, while giving a good impression of how the encounters would play out in the end.

4.6.2 Balancing Upgrades

The amount of the upgrade material resin has been balanced in the map so that the player can buy two or three upgrades, depending on whether they gravitate towards the more expensive upgrades, or prefer getting more of the cheaper ones. As the cheaper, low-tier upgrades tend to cost 10 or 15 resin, and the more expensive, high-tier ones from 20 even up to 40 resin, the overall amount of resin in the map was balanced by placing 50 resin in more obvious places, with an extra 10 hidden better, netting the exploring type with 60 resin in total, capable of buying two high-tier upgrades, or one high-tier and one to two low-tier ones, depending on which upgrades they get.

There are two upgrade stations in the map. The first one is available quite soon in the level, as it is located in the upper floor of the lobby. This one can be accessed right after the first fight against Combine in the lobby. At this point, the player may not have found much resin, so they can either opt for saving the resin they have for later, with a better upgrade in mind, or get a cheap one to help them in the following area.

The other upgrade station is located in the top floor, right before the first Combine encounter there. After this point, there will not be any more resin in the level, with the last ones being scattered around the environment in the nearby rooms. There is a clear transition out of the area that also works as a clear reminder for using all remaining resin before moving on.

4.6.3 Designing for Intensity

As noted in chapter 2.3, creating an interest curve beforehand helps balancing different sections of the level and seeing what to trim from the original plans before even building the first box in the editor (see figure 3 below for the interest curve designed for this map). The custom map was split into four sections of growing intensity, with peaceful exploration parts in between (see figure 4 further below).

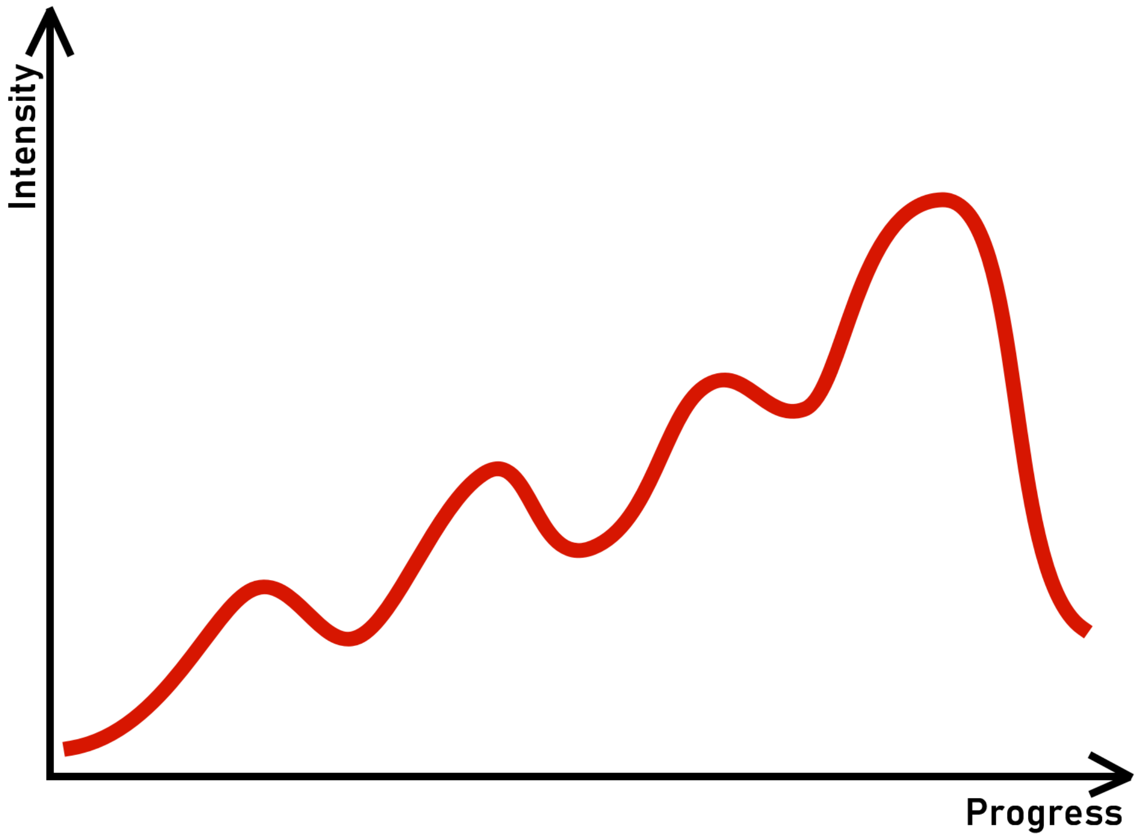


FIGURE 3. The desired interest curve for the custom map, depicting four upwards trending intensity peaks and the quieter valleys between.

The first bump in the interest curve depicts the transition from the peaceful starting area into the very next room and the map's first combat encounter there. The second one represents the gloomy and intense scene in the basement, with the third one depicting action in the top floor, and the fourth, the climax of the curve, representing the final showdown between the player and Combine forces, defending the transmitter in the industrial hall.

As the first encounter in the lobby was to be kept relatively low in terms of intensity in order to keep an upwards trending curve, the area was designed to give the player lots of options for the fight. To keep the encounter interesting, it should not be a walk in the park either. This was helped by the fact that the player starts the map with just the non-upgraded pistol, forcing them to aim carefully and reload often due to the gun's rather poor iron sights and small initial magazine size.

Regarding level design, this meant providing the player with plenty of cover and extra ammo, and good sightlines at enemy positions. As an additional treat, the shotgun can be found in the area as well, hidden behind the hotel bar's counter (see picture 19, below), providing the player with additional firepower for enemies advancing too close for comfort. As the player is crouched behind the counter picking the weapon up, enemies may try to flank them and come close to the player, providing them with an immediate chance to use their new-found weapon.

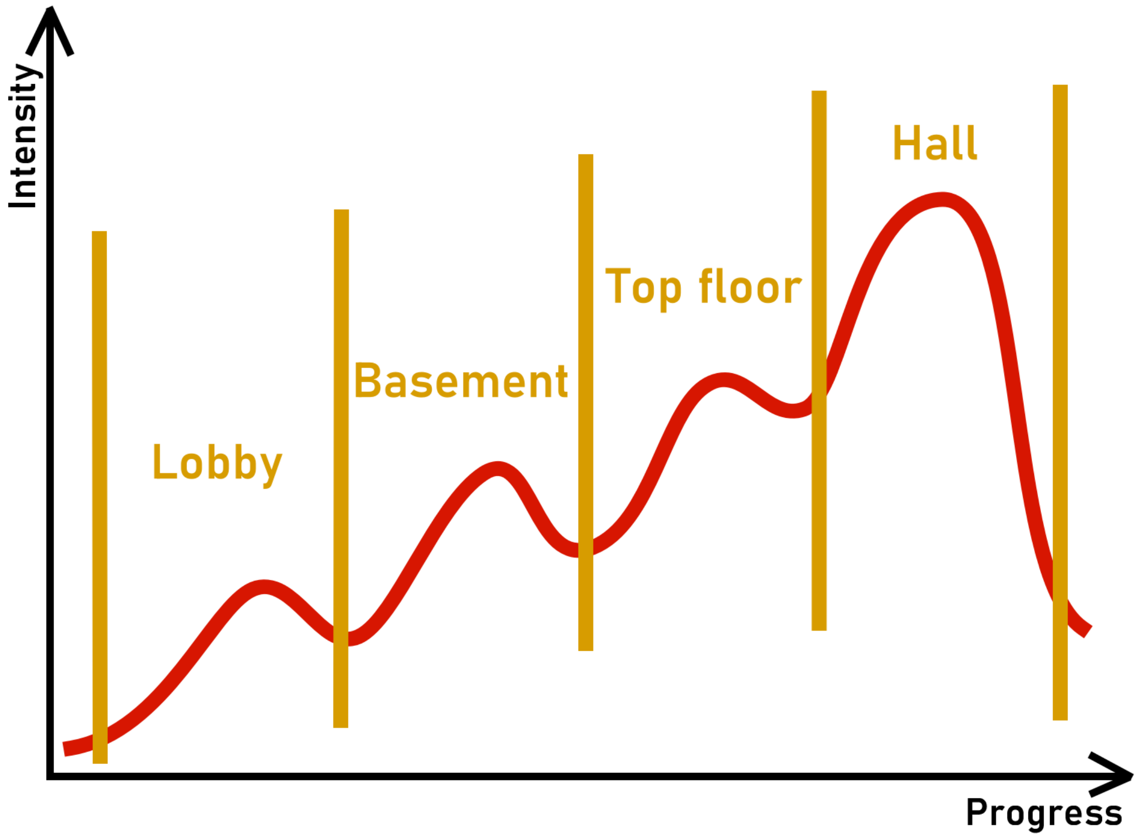


FIGURE 4. The sectioned interest curve depicting intended intensity levels per planned area in the map.

After the lobby follows a moment of peaceful exploration of the lobby area before intensity is raised in the basement again. Any horror in VR is more intense than it would be on a flat screen due to the player being surrounded and immersed in it, making the horror much more real (Graham 2016). As darkness creates such amounts of horror and suspense in itself in the game, having the player rely on the manually aimed, narrow cone of their flashlight, the player is spooked by even the smallest or slowest-moving threats.

PICTURE 19. A view from the hotel bar, located in the lobby. The shotgun can be seen hidden behind the counter in the bottom.

In the base game, horror scenes are designed to never be so scary players would stop playing out of fear (Ali 2020), so in the same spirit, the basement scene in the custom map was kept relatively low threat-wise. Jump scares, being terrible in VR (Rad 2020), were also avoided, giving the player time to detect threats themselves. Enemies making noises in the dark before spotting the player make the darkness scarier but at the same time more predictable, raising the tension while keeping the difficulty lower.

The basement scene starts on a walkway looking down at the rest of the area, making the player descend a ladder into the impending darkness ahead (see picture 20 below for an in-editor view). Descending even further from the last lights make the transition to the basement even gloomier, as the player must leave the last bit of safety they have up on top of the walkway. There are a few barnacles, immovable Xen enemies placed in strategic locations in the ceiling with their long tongues ready to snatch anything that travels below them. The player can use explosives to clear them, or just shoot them dead one by one.

PICTURE 20. The player enters the basement from the walkway (up left) and must descend the ladder into the awaiting darkness (right).

The flashlight turns on when other lights fade behind the player, as the first zombie crawls up and starts lumbering towards the player. The basement area has several of these slow but scary looking, painfully wailing enemies that offer little actual threat to the player due to their slow movements and the player's ability to back up away from their reach, but who in VR feel very threating nevertheless.

After the basement scene, there is a brief moment of relief as the player returns to properly lit areas, heading up the staircase all the way to the top floor. The level of intensity is kept lower for a bit to give the player a breather after the horrors in the basement by having them solve a couple of puzzles in order to advance. The submachine gun is located here, as well as the last upgrade station, offering extra firepower for the remaining parts of the map.

After solving the puzzles and opening a way forward, a small encounter with Combine forces follows. It works as an introduction to new enemy types not before seen in the map: the Combine Officer, who can spawn attack drones (called manhacks in the game), and the heavily armed Combine Suppressor, whose main job is holding down points with their continuous machine gun fire. The encounter takes place in a narrow hallway, keeping all enemies in front of the player to offer a clear direction of battle, while offering the player many cover spots from the Suppressor's fire.

There is a brief transition from the hallway to the last area of the map, having a little Xen encounter in the middle, nothing too difficult. The player must drop down to the last area, preventing them from retreating. As the player solves a puzzle to turn on the transmitter, enemies start to spawn for the final showdown. Intensity is kept high during this whole scene as this works as the climax of the level. After the timer is complete, the player wins the map.

4.6.4 Using Cover

In all combat encounters, it is important to provide the player with adequate cover from enemy fire. This is especially true in VR, where the player cannot just go into cover by pressing a button but must physically move behind objects to hide. As crouching for cover is physically cumbersome in VR, and slow even if tied to a button (due to having to deal with comfort issues when moving the player's view without them actually moving), the height of different cover points should be somewhat consistent with adjacent ones, so that the player does not have to crouch and stand up repeatedly when moving between covers.

Because current VR devices only track the player's head and hands, the player character does not really have a physical body in the game world and as such, the player might be able to take cover behind smaller objects that only cover their head when positioned correctly. This can be overcome by ensuring such objects do not exist in the levels, and all cover positions cover the player's whole body properly.

The combat arenas in the lobby and the top floor were designed for ranged combat with Combine forces. The enemies can use cover themselves and will try to flush camping players out of their covers with grenades. Thus, the arenas were built to have many cover points, often close to each other, so that the player could escape a grenade flung into their position by moving quickly into another cover close-by, without leaving them out in the open, where they would be free game for the enemies.

Both combat arenas have so-called “no man’s land” in the middle, meaning area without cover, making it very dangerous to be in (Norberg 2020a). In the lobby, no man’s land comes between the player and their goal (being the door to the stairway at the back of the lobby), with enemies on the other side. The player must defeat their enemies before they can safely get to the stairs. They do however have the opportunity to flank their enemies here by using smaller cover points close to the walls.

In picture 21, below, different elements regarding cover and flow have been highlighted with different colours. The orange and red arrows mark the entry and exit points for the player, respectively. The cyan circles mark potential cover points, while no man’s land in the middle has been outlined with pink. The green circles in the middle mark soft covers, that only work as visual obstacles, with bullets flying right through them.

PICTURE 21. An overhead view of the lobby, with markings for covers, entry and exit points, and no man's land on top.

The combat arena in the top floor, where the transmitter must be defended, works a bit differently. As the goal here is not to advance into another area but to defend the area for the duration of a time limit, the arena is built for a prolonged combat sequence. There are many different cover areas the player can move into, with enemies spawning from all directions, forcing the player to move often and consider multiple angles at the same time. There are multiple levels of verticality and covers of different heights, all offering different types of cover.

Elevated positions can be considered covers themselves, as they offer better sightlines and angles on opponents, as well as the psychological effects of being above them (Norberg 2020b). Alternating between full covers, able to block one's whole body when standing up, and half covers that must crouched behind, keeps the player on their toes and mobile.

5 SUMMARY

The objective of this thesis was to study both traditional and virtual reality level design methodology and best practices, and to apply these findings alongside the author’s own professional experience as a level designer to creating a custom level for Half-Life: Alyx (Valve 2020) using Valve’s Hammer editor. The purpose of this thesis was to introduce the reader into the world of virtual reality level design, and show by first-hand example how VR levels are created, emphasizing on practices that can be used when working with other engines as well, not just in Source 2.

The author’s earlier experience in creating levels for virtual reality games benefitted the creation of this thesis in many ways, by providing knowledge of the theory, and by having hands-on experience working with similar software before. As a new tool for the author, the Hammer editor proved to be worth its reputation in being at least one of the best tools, if not the best, for level designers to work in, with numerous incredible features that facilitate the process greatly, that other engines and editors simply do not have.

As building interactive 3D spaces was quite familiar to the author, the editor itself was totally foreign, and learning a completely new work environment in a limited timeframe created some friction to the process. This was hindered even further by the fact that most tutorial materials available online, on both Valve’s own developer website and elsewhere, appeared to be made for the older Hammer editor, using an earlier version of the Source engine itself, and in large parts unapplicable to VR development. Another problem arose from the realization halfway through the project that the author would not be able to compile the finalized custom map fully, as its size caused the compiler to crash every time due to absurdly high CPU usage during lightmapping. The Oculus Rift headset that was used in development also has known issues with the base game, causing immense CPU spikes at times, so this might have been one side effect caused by working on a brand new game editor while using a first generation VR headset.

Finding references for the thesis proved to be quite effortless, as there has been quite a bit of writing about the medium. There were not too many level design sources specifically about virtual reality development but applying the author’s own experiences benefitted the work greatly.

Creating the custom level turned out great in the end despite early challenges mentioned above. Working in the editor was delightful, as its many level designer friendly features eased many previously tedious processes greatly. The level itself was a manifestation of many of the best level design practices studied in this thesis, and it displays some of the author’s better work, especially in the way space and cover is used in encounter design.

As the headset of choice turned out to cause several issues when working with a game this new, its selection as the headset to use in a similar project would be advised against, instead aspiring for a newer and better supported headset when working with Source 2. In the future, the author would prefer to opt in for a more modern headset, such as a Valve Index or similar, more recent device.

Many lessons learnt while making this thesis, especially while creating the custom map, will surely find their way into the author’s own level design processes and way of thinking, leading to better and better levels in the future. As such, it is advised for level designers to read about design theory, architecture, and psychology as well as deeply analysing the games they play themselves. Some such reading would include the following works: Christopher W. Totten’s amazing 2014 book An Architectural Approach to Level Design (Boca Raton, Florida: CRC Press), Preproduction Blueprint: How to Plan Game Environments and Level Designs by Alex Galuzin (World of Level Design, 2016) and the classic, Jesse Schell’s 2008 book The Art of Game Design: A Book of Lenses (Burlington, Vermont: Morgan Kaufmann).

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