Final Thesis

Escher Levels Documentation

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Table of Content

Introduction and concept

In the final thesis about the MC Escher-inspired levels, I want to create puzzle designs in complex spaces with advanced player orientation. I want to explore an idea for a game *(Fig. 01)* that I proposed for the third-semester project. At that time the concept was rejected due to technical reasons. Since I found the ninja character plugin after the gold master of the third-semester project, it was possible to implement it now.

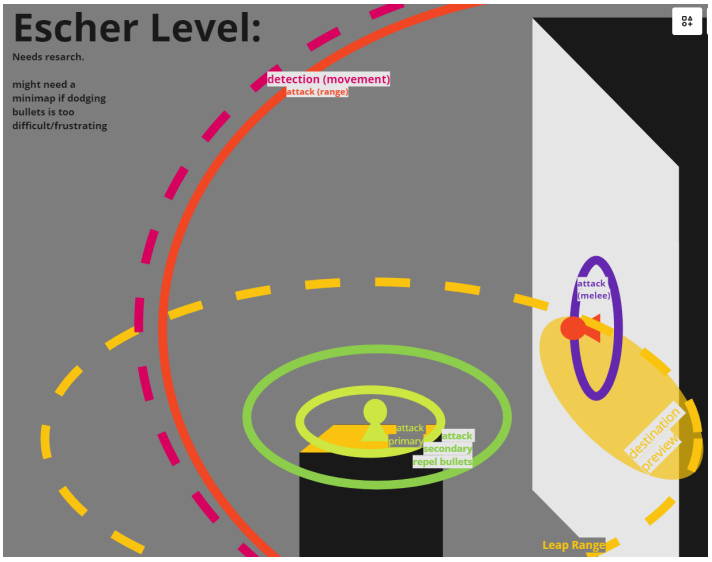


Figure 01: The original Concept included combat in the Core Game loop.

As a basis, it was necessary to design simple mechanics that use the reorientation of gravity. For this purpose, I go into the individual features that I implemented in the chapter “Game Design”.

The final thesis focuses on the level design: From the tutorial to the visual player guidance to gradually more difficult puzzles, I created and iterated several levels over 9 weeks (5 weeks effectively because of the application process for the internships). Iterations were always based on feedback from playtesters. Since other aspects of game production such as UI/UX, sound design and Q&A are not the focus of my work, I will not go into much detail about these processes, even though they were also subject to several iterations based on playtest feedback.

Design References

For the feel of the games, I chose MC Escher's Relativity from 1953 because it is a very memorable work and evokes in me the desire to explore these impossible worlds.
As game references, I initially chose Super Mario Odyssey and Manifold Garden by William Chyr, because I assumed I could learn from their level design and incorporate individual elements. Later I also looked at Portal, It Takes Two and the Depulso puzzles from Hogwarts Legacy.

MC Eschers Relativity

From this Image *(see Fig. 02)* I wanted to transport the impossible architecture into a sensible level design.
I left out large round archways for the most part, as they could have broken the levels. If the player character walks in the concave of the archway, he can reorient his gravity with them. Only doorways were small enough to make this situation rather unlikely. With separate collision meshes I could have avoided this as well, but that would have shifted the focus too much to asset creation.

To imitate the woodcut style, I also worked on a cross-hatching shader *(see Fig 03)* on weekends. This did not achieve the desired quality. I would have had to invest a lot more time in it and didn't see the added value for the scope of my project.

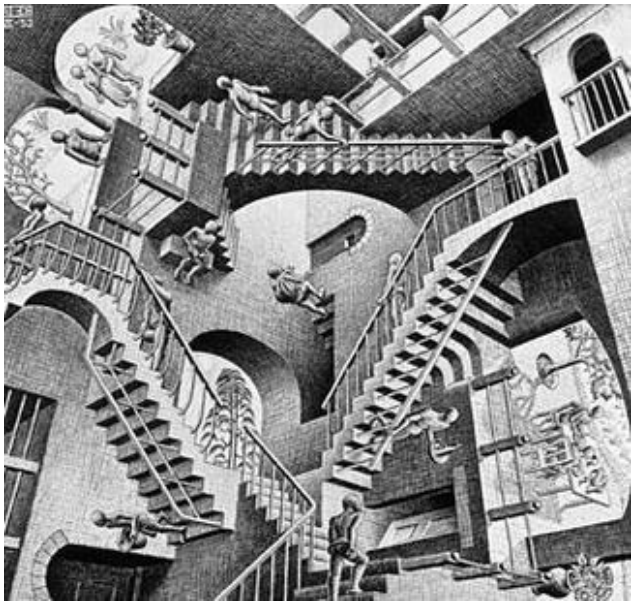


Figure 02 (left): “Relativity”, Woodcut, 1953, By MC Escher
Figure 03 (right): The crosshatching shader in a test level

Super Mario Odyssey

From Super Mario Odyssey I took over the possibility of centring the camera manually to facilitate gamepad controls. Spherical levels were not planned as they would not match the

game feel and could potentially break the puzzles into six orientations. I was hoping to find other elements that could help me with the level design as well as system design. Still, Super Mario Galaxy used the extended orientation more like wrap-around screens in arcade games for backtracking. You can walk around a Planet or inside a sphere. On that scale, it exists to avoid player confusion.

Manifold Garden

Manifold Garden inspired the cubes, which have their gravitational direction limited in the six axes.
I didn't want to be guided by the infinitely repeating levels. If the player character could fall infinitely, level instances would have to be loaded and deleted very quickly. That would have put too much focus on performance.

Portal

Portal was also an inspiration for Manifold Garden. It remains a prime example of how to create game tutorials. Since the first puzzles were to remain simple, and cubes and pressure plates were important elements in Portal, I looked at the introductory levels for Portal where these mechanics are taught to the player.
I primarily looked at the first levels of Portal (see Fig. 17) to teach the mechanics to the player. I therefore changed my intro level to a more linear version so as not to overload the player with too many objects.

It Takes Two

In this game, there is a space level[1] in which the gravitational direction of the player characters can also change and is therefore limited to the six axes. The levels are often more expansive than in my game to give the players visual guidance.

Hogwarts Legacy

There are a lot of different puzzles in Hogwarts Legacy. However, I have only taken a particular approach to solving one type of puzzle: In the third Depuslo room[2], you have to reset the puzzle in the middle to solve it.

Approaches to puzzle creation: Jonathan Blow and Arvi Teikari

I have tried to adopt the approaches of the two solo developers Jonathan Blow and Arvi Teikari to create my puzzles. Teikari's (Baba Is You, 2019) strategy is to build a puzzle from the back to the front: “When I've got this idea of hey, that would be cool to see in a level', I try to build so that when the player is playing the level they have to use that interaction.”[3] The puzzles are mostly defined by what the player can't do.
Jonathan Blow's (Braid, 2008)[4] time travel mechanic, on the other hand, was somewhat unconventional. So he had to play with the mechanics first to figure out how to integrate them into systems. "Rules and Puzzles were discovered through programming and playtesting rather than designed through the implementation of some pre-conceived idea."[4] This helped me to create some puzzle rooms, as two-dimensional-level sketches were insufficient.

Used Tools:

I chose the Unreal Engine 5.3 version for several reasons.

- It was already known to me from the last semester project and was the latest stable version that supported the Ninja Character Plugin by Xaklse[5].
- The plug-in was the main reason for choosing the engine, as it saved a lot of coding effort with the NinjaCharacterClass and the NinjaCameraManagerClass.
- The standard Cubemesh tool in Unreal allowed for fast iterations

For the creation of 3D assets, I used Blender after I decided on the scale with the help of the cube grid tool from Unreal.

To stay organised and measure my progress, I used Trello with a “Done” column for each week *(see Fig. 04)*. Labels indicate the importance of a feature or task. Tasks that did not affect the game directly, like applications or documentation received a fully covered cover. Issues like bugs were marked with a red Cover. To outline my concept and needed features I used a miro board.
For Level Design, I attempted to use Miro as well, but the 2-dimensional concepts were not ideal.

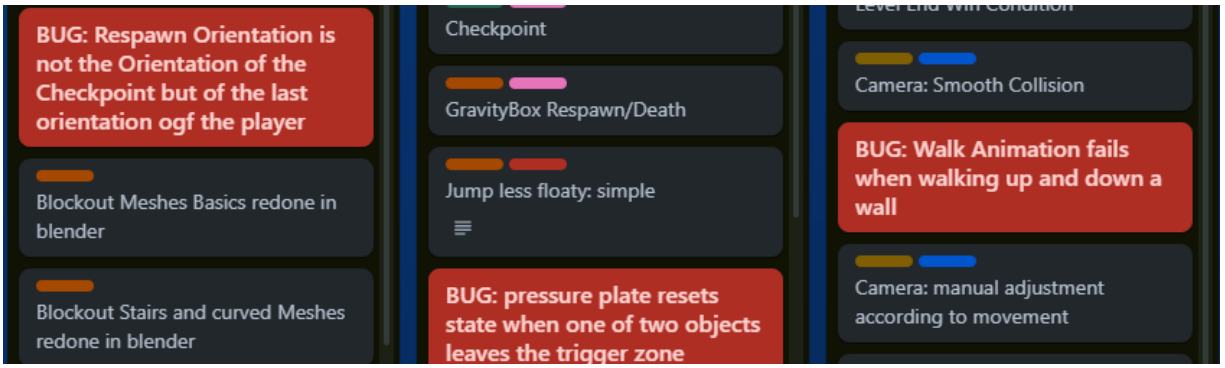


Figure 04: Use of different colours for Covers and multiple “Done” columns

Restrictions:

To ensure that the scope of the final project does not exceed the time frame, I have limited the levels to a size of 30x30x30 meters. I justify this with the experience from the level design exam from the third semester, where a 50x50 meter level block out took a good three days, even without the additional orientation. This also forces me to design the puzzle elements in narrower spaces. On top of that, I was able to use rooms several times because of the gravity orientation.
The player character cannot move through the level in more than 6 different orientations: X, Y, Z, and -X, -Y, -Z.
Only a few platformer situations were implemented to minimize the amount of time I would spend on balancing the jump behaviour.

Mechanics:

In addition to the basic movement of the player's character, the game teaches the player how to interact with doors, pressure plates, moving platforms and two types of blocks that can change their gravitational direction. These objects are introduced throughout the game and are combined in different ways.
After the player has seen a mechanic for the first time, I wanted to continue, expand and combine it so that the utility and limitations are memorized.

Game Design

Progression Gameplay

The player solves puzzles to get to the end of a level. For this, the player must open doors with pressure plates to unlock new areas or new orientations.

Core Gameplay

To activate the pressure plates, either the player or a Gravity Cube must be positioned on them.

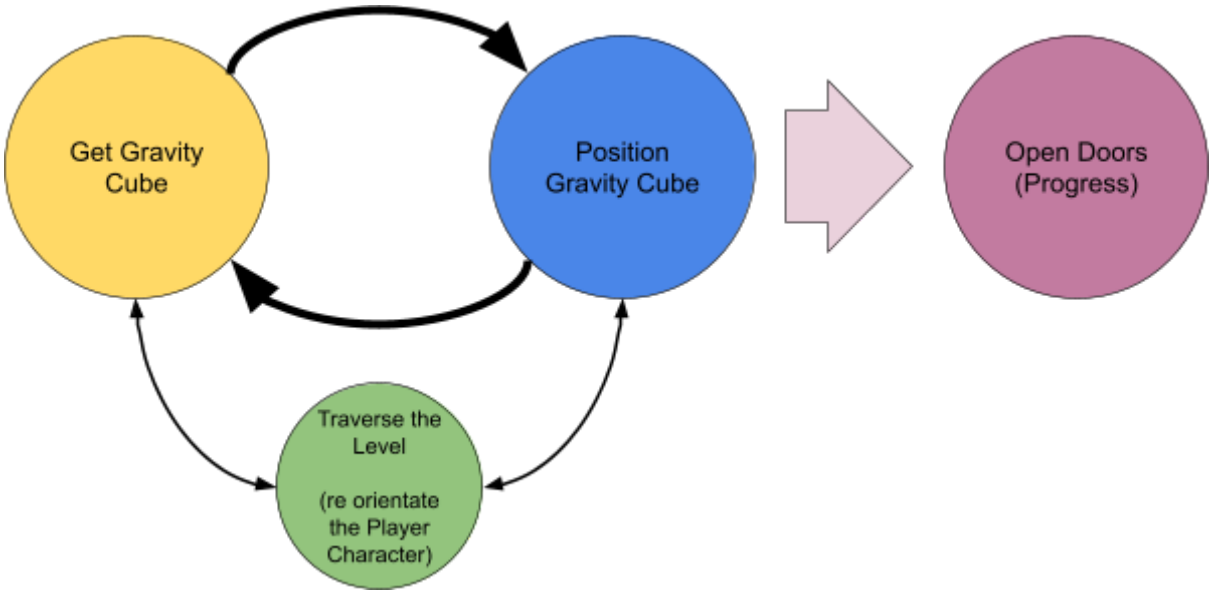


Figure 05: Core Gameplay Left and immediate progression right

Feature List

Player Movement

The player character has two movement speeds and jump heights.
By default, the player can jump 7 meters horizontally and 2 meters vertically.
If the Character player is carrying a Gravity Cube, the player is supposed to feel its weight and can therefore only jump 3 meters horizontally and 1 meter vertically.
This is achieved by changing the running speed and JumpForce values.

The movement I tested in two levels. The first level was a general playground map and the second was a GYM where I documented also scales, distances and timeframes *(see Fig. 6 and 7)*.

Figure 06: Excerpt from GYM: The scale of assets was first tested with the Unreal starter content and later redone to translate the scale.

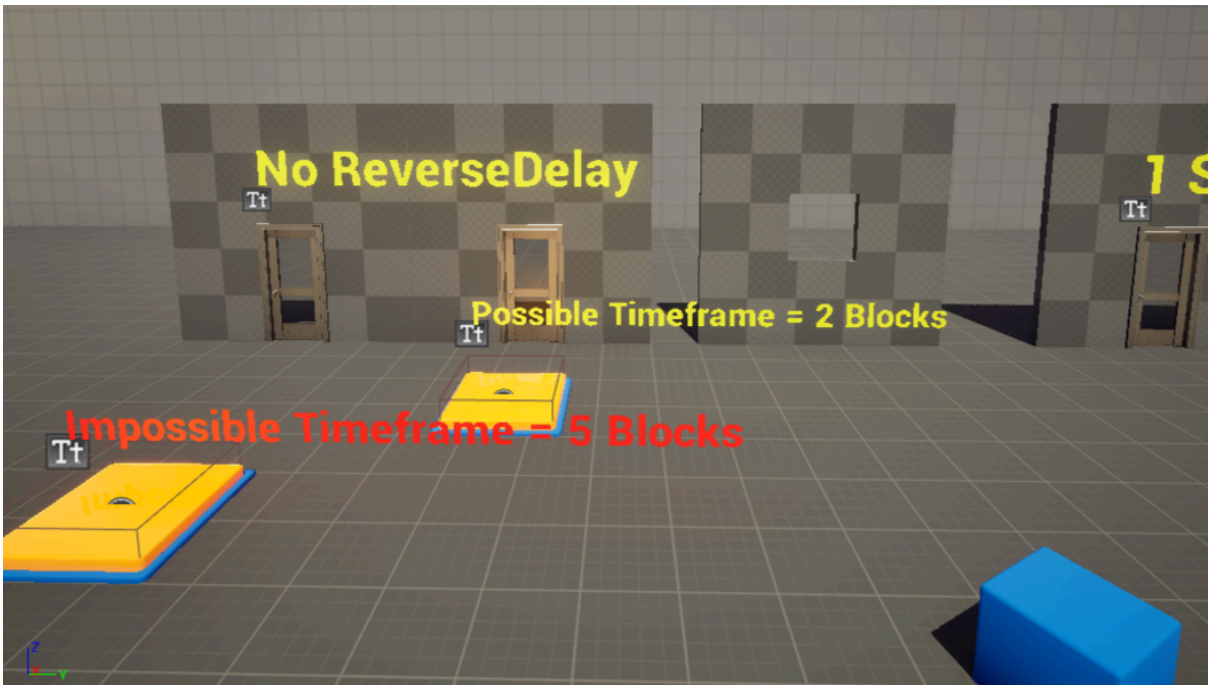


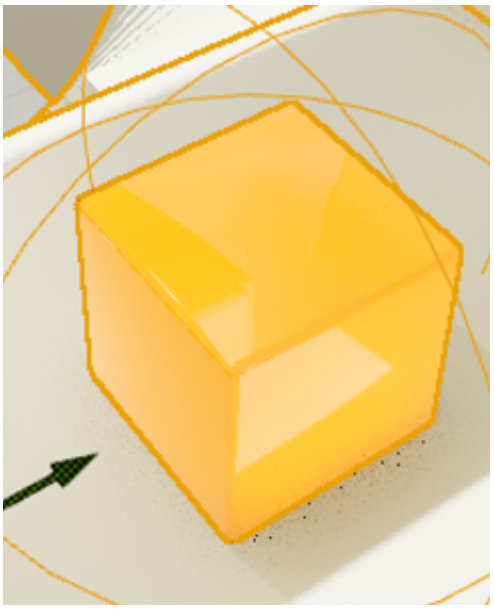
Figure 07: Excerpt from GYM: I tested here the distance of how far I can place activating platforms to the linked door.

Gravity Cube (yellow)

The player can pick up the Gravity Cube with a left click of the mouse and carry it through the level. Left-click again and the player drops the Gravity Cube. *(see Fig 08)*
When the player character comes close to the cube, a prompt is displayed, signalling the possibility of interaction.

Locked Gravity Cube (blue)

This Gravity Cube does NOT change gravity direction when dropped by the player. However, the gravitational direction can still be changed by Pressure Plates. This cube was introduced later to allow for more complex puzzles. To distinguish both cubes, this one is coloured blue.



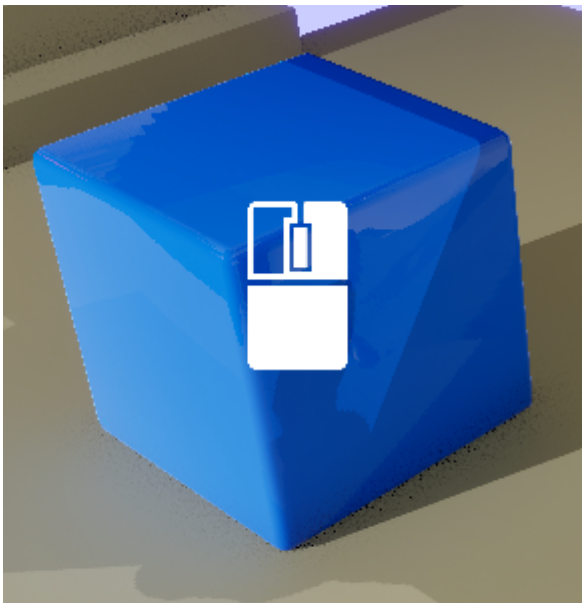


Figure 08 (left): The basic Gravity Cube with collision sphere for interaction-prompt.
Figure 09 (right): Locked Gravity Cube with visible interaction prompt.

Pressure Plate

When the player or a gravity cube lands on a pressure plate, it sends a signal to connected objects. When the player or a gravity cube leaves a pressure plate, a return signal is sent to connected objects. The return signal can also be sent after a delay to give the player more time to reach another area in the level.
A pressure plate that is connected to a gravity cube indicates the gravitational direction that the cube will take when activated. Originally, the new direction of the gravity change was shown when it was activated. (see blue arrow in Fig. 10) I changed this to a permanent display because the player character often blocked the view of the short feedback.

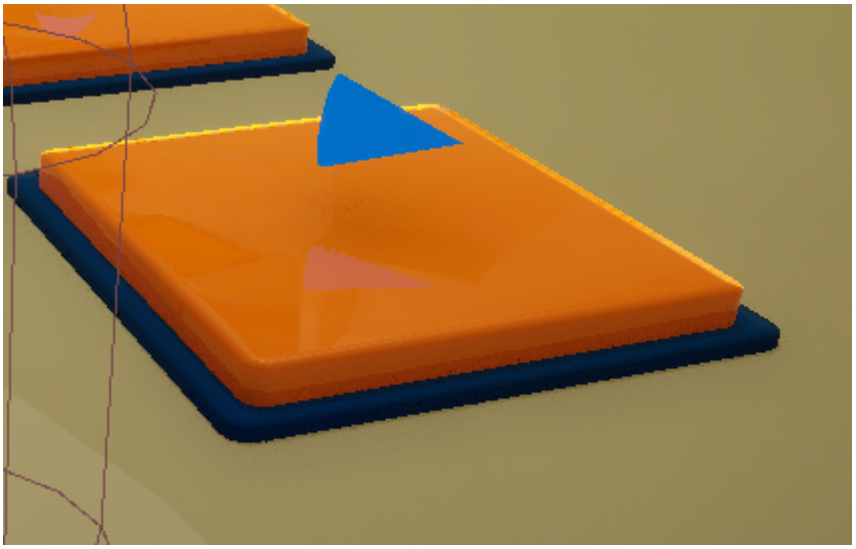


Figure 10: Pressure Plate with gravity direction arrow pointing to the right.

Doors

The player cannot interact directly with doors. Doors can be activated (opened) and deactivated (closed) by pressure plates. The time of the opening animation always remains the same. A delay can be set.

Shrinking/Growing Objects

These objects function similarly to the doors. Pressure plates activate and deactivate them. Any mesh can be used instead of the stairs here. These objects can be used to allow or deny the player areas in the level or reorientation options. (See Fig. 30) A delay can also be set.

Reorientation Platforms

These static platforms serve to orient the player's character. The player character only has to walk over them and rotate with the curvature of the platform.

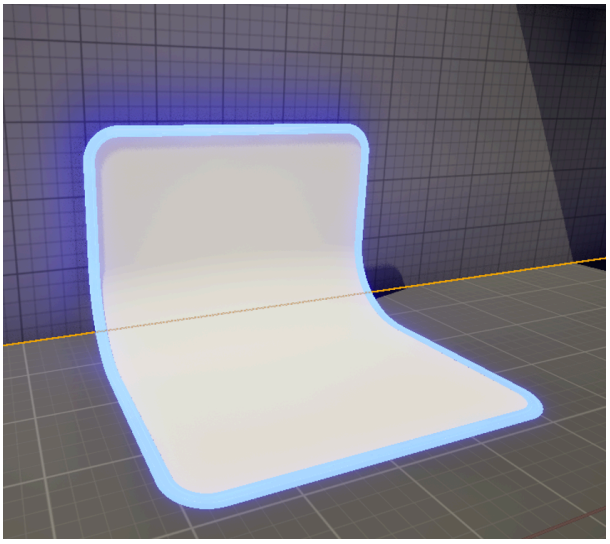


Figure 11: Excerpt from GYM: Reorientation Platform with the regular wall material

Curved Stairs

In addition to the usual use of stairs, these meshes can also be used to reorient the player character when used like a staircase. A staircase rotated 90° can bring the player to an adjacent orientation, and a staircase rotated 180° can bring the player to an opposite orientation.

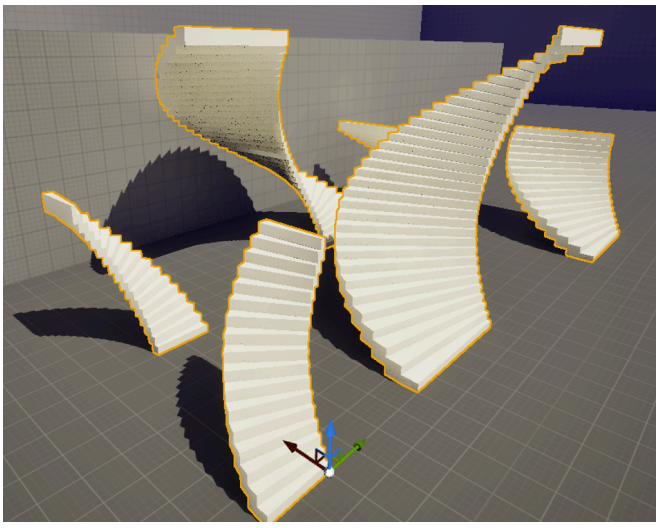


Figure 12: Excerpt from GYM: Of all the curved stairs, these six variations remained.

Moving Platform

Moving platforms can move between two transform points. These can also reorient the player character if the rotation of the start and end points differ.
It is possible to activate a moving platform using only a pressure plate. If a moving platform is inactive, it always stops at the start point.

The movement times between the points and the waiting time at the points can be set.

One-Sided Moving Platform

To avoid reorientations that are not planned in the level design, there are moving platforms that are tagged as unwakable on one side. For the player, this area is marked with a red reflective material.

Collectible (cut)

Collectables were an additional part of the level progression. They were necessary to activate the end of a level. They were cut because they interrupted the flow of the game. Exploring a level shouldn't feel like a mandatory activity if it doesn't have anything to do with solving the puzzles. In Figure 22 you can see the first version of the collectible that only had a faint pink outline.

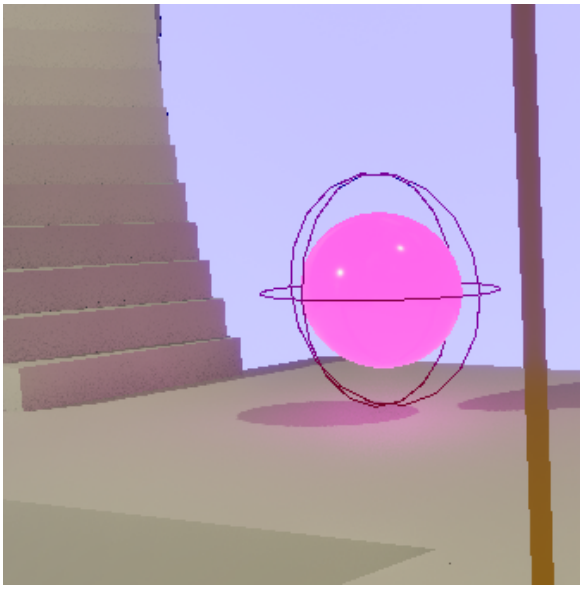


Figure 13: Second iteration of the Collectible before it was cut entirely.

Level Transition

The Level End Zone (or Level Transition) must be entered by the player character to complete the level.
When the zone is active, it glows purple to stand out from all other objects in the level. Initially, the player had to activate the zone by collecting all collectables in a level. In the final version, the target is always purple. I changed the dark surface colour (see Fig. 14) to the regular walkable material that is also used for walls, floors, and ceilings because it was interpreted by testers as a hazard.

Active = Level can be completed. The player has collected all collectables in the level
Inactive = The Player must collect more collectables before he can complete the level

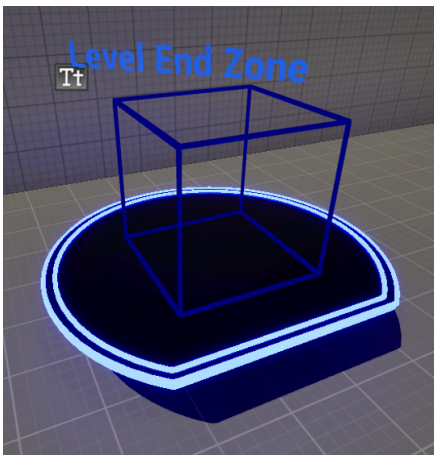


Figure 14: Excerpt from GYM: Inactive Level Endzone is blue. An active Level End Zone is purple

Checkpoints

Checkpoints are necessary in the later levels where the player can fall out of the map. Checkpoints can be reactivated.
If the player character dies after reaching a checkpoint, he spawns at that checkpoint. The checkpoint gives the player his own orientation with the “Change Char Axis” function. When activated for the first time, checkpoints change their colour to mark level progress.

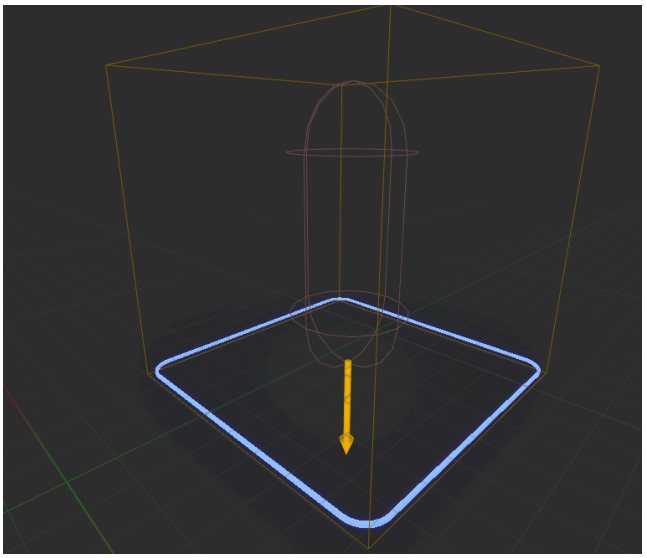


Figure 15: Checkpoint - The player only sees the glowing square on the ground.

Gliding (cut)

Gliding was a mechanic that I tested in the first week. However, due to the planned level size (see restrictions) and the reduction in platformer elements, this did not make sense and was removed.
The player gained more control in the air by gliding. In this state, the character maintained their orientation. The effect was visible with an animation where the player character held an umbrella. Both of which are from the same tutorial[6] I followed for this mechanic.

Manual Camera Focus

This feature is intended for a possible but untested gamepad control. The player can manually centre the camera behind the player character using the Ctrl key.
An automatic camera focus was planned but was not implemented due to lack of time.

Smooth Camera Collision

To avoid disorientation caused by the camera shake, I implemented smooth camera movement and dithering materials using a tutorial[7]. To do this, I had to remove the camera position over the shoulder[8], which I had implemented earlier, as the smoothing would have caused even more shaking on many object edges.

Dithering Materials

These materials were created to prevent the camera from abruptly cutting through objects when moving slowly.

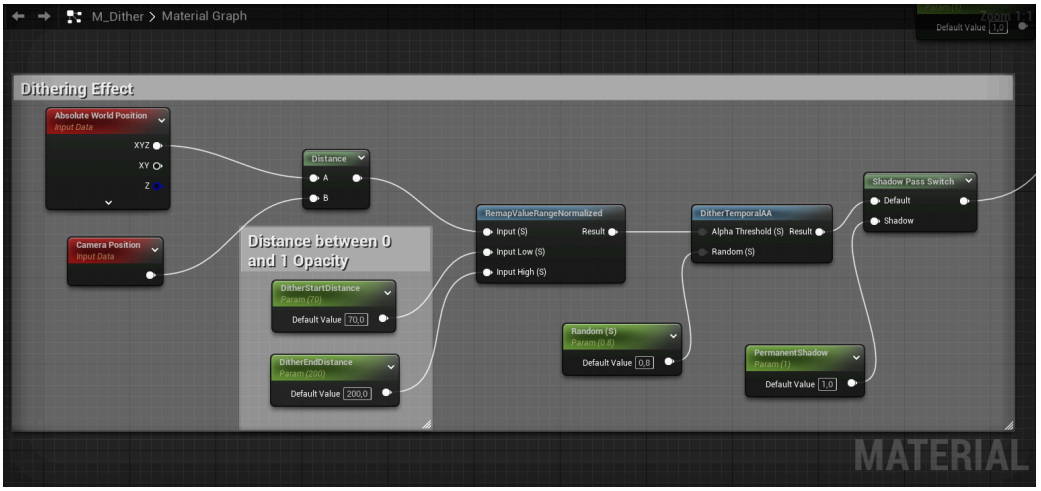


Figure 16: Dithering effect strength can vary by camera distance.

Feedback for the Player

UI

There is no permanent HUD. For collectables, I implemented a counter that is only displayed when you collect them. There is a loading screen between levels and a win screen when the last level has been completed.

There are one-time tutorial prompts that explain the key assignments to the player and a prompt that is always visible when the player picks up a gravity cube.

I created a main menu and a pause menu where the player can adjust sound settings. It is also possible to view the game's controls and freely select levels.

Figure17: Explanation of basic controls

SFX and Music

To begin with, I used the sound files that already existed in Unreal as feedback sounds for all interactions the player has with the world. Later I added pieces of music from Abstraction and an option to adjust sound settings. Buttons emit an SFX when they are pressed and in the sound settings, there is a test sound for the SFX setting.

Visuals - Colour Coding, Animations

When carrying the gravity cube the player's character has a simple carry animation. The hover feedback of all buttons is the built-in Version of Unreal. I added a Throbber (UI Element to indicate loading) to the loading screen. Pressure plates indicate when they have been pressed and are similar colours to doors and gravity cubes, allowing the player to mentally build a connection. Unwalkable Objects are marked as red and reflective as seen in Figure 18.

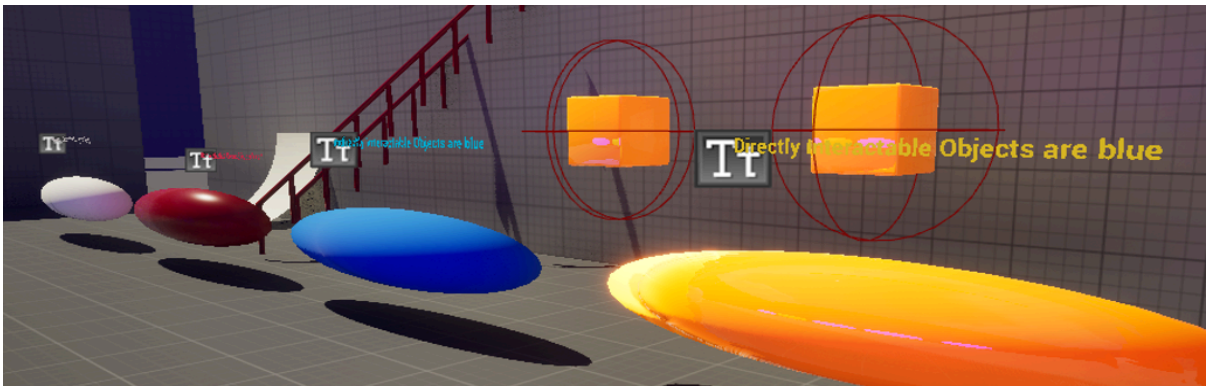


Figure 18: Excerpt from the GYM: Color coding. The yellow cube changes colour depending on a bool set in the Engine.

Asset Creation

I initially created objects for the player's reorientation in Blender. These were tileable, but much too large. The player spent too much time walking. At this scale, I alone couldn't make the levels interesting. *(Fig.19)*
That's why I decided on one of the level design constraints: The player can move in a maximum of a 27,000 m3 cubic meter cube. To convey a sense of progress, the player

character moves predominantly 'upwards' within a gravitational direction. They jump onto elevations (upwards) more often than they fall or jump down.

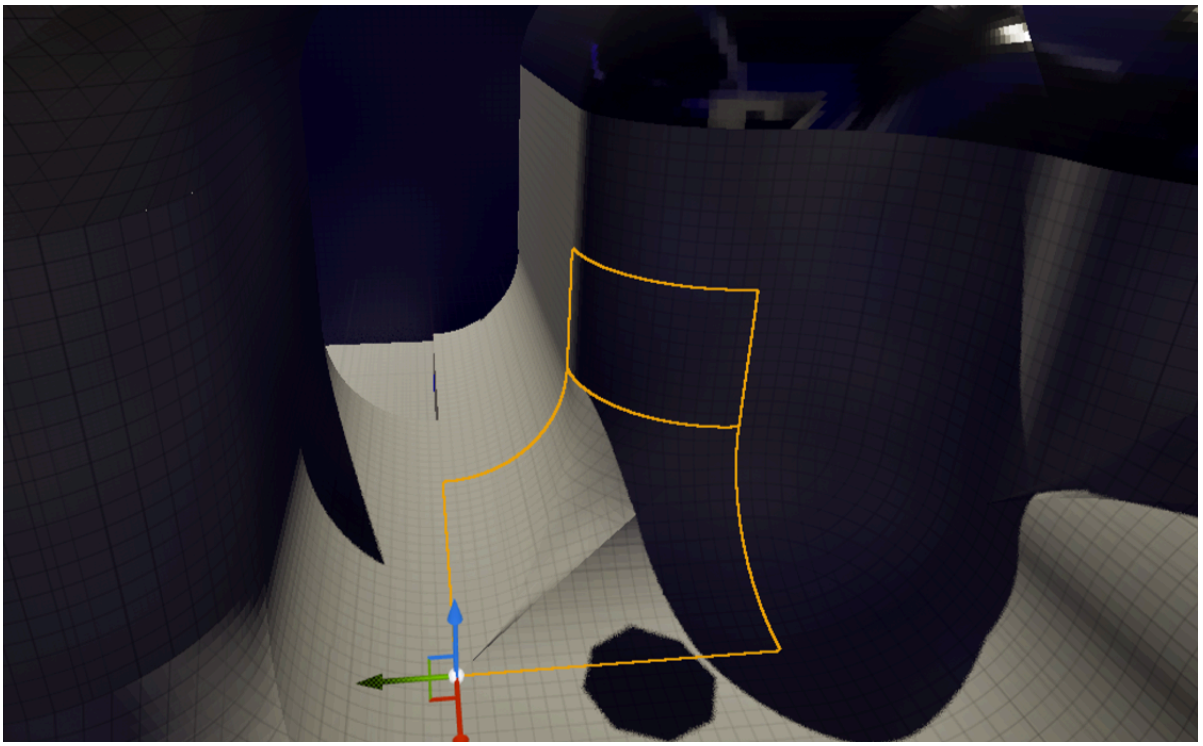


Figure 19: Excerpt from the playground level: One reorientation piece measures around 10 meters in diameter.

Problems

After choosing the scale of my assets using Unreal's Starter Content Architecture, I created assets such as stairs, walls and archways using Unreal's CubeGrid and Spiral Staircase tool. However, this meant that I could no longer use the PlayFromHere function on these assets. It also broke my PlayerRespawnCode. I consulted David Ruf about these issues. After trying to clean up the code, the problem did not go away. I suspected that line tracing and sphere tracing were not working consistently with the CubeGrid assets. After exporting the assets to Blender, reducing the vertices and edges and importing them back into Unreal, PlayFromHere and the respawn logic worked again.
Only rarely does the engine seem to crash if no vector for reorientation was found during respawning. I attempted fixing this by giving the player character a default Vector if the checkpoint doesn’t provide one.

Level Design

Level Design Goals

The goal is to guide the player through the levels, introduce the mechanics and present puzzles that take into account the reorientation of the player and the Gravity Cube. With clear points of interest, I want to lead the player to his goals. From the second level onwards,

I don't want the solution to a puzzle to be too open. The more options the player has to try out, the more difficult the puzzles are.

Reorientation of the Player Character

The player can reorient himself in three ways:

- **Reorientation platforms** bring the player character into an adjacent orientation through a pitch rotation. For example: From the floor only to the walls, but not directly to the ceiling.
- **Spiral staircases**: The spiral staircases which only wind around 90° have almost the same effect as the reorientation platform. Instead of taking the player to the orientation they are walking towards, it is one of the two lateral orientations (roll) 180° spiral staircases takes the player to the opposite orientation with the roll movement: from the floor to the ceiling.
- **Moving platforms**: These can take the player to any orientation. Care must be taken with the positioning of these platforms so that the player character does not end up in an unwanted rotation or the player loses orientation.

Reorientation of the Gravity Cube

The player can change the gravitational direction of the Gravity Cube in two ways.

- **Pressure plates** (if connected): As a level designer, I can connect all cubes with pressure plates. The new gravitational orientation is set with the pressure plate. There is only one orientation per pressure plate. When the pressure plate is activated, the gravity direction of the gravity cube is overwritten.
- **Drop** (only yellow): If the player drops a yellow gravity cube, the cube takes over the gravitational direction of the player character.

Intro Level

As the name suggests, this is the first level and remains linear to avoid overwhelming the player with too much information at once. Every element in this level is essential for the progression in future levels.

Rooms one and two

The basic controls are explained at the beginning. Looking around and running must be understood before the first reorientation through L-platforms is shown.
In the next room, the key assignment for jumping is shown and a trivial jumping passage tests whether the player has learned this. The first puzzle is introduced in the following room.

First puzzle

It is inspired by the level “Test Chamber-00” from Portal *(Fig. 20)* where the player is first led to the Pressure Plate to spawn the cube and open a door. The player sees a pressure plate directly in front of them. Running over it opens a door on the ceiling. On the wall to the door, the player sees a reorientation platform and a cube. The cube has the same colour as the pressure plate to indicate a connection. The door closes when the player leaves the pressure plate. If the player reaches the cube via the reorientation platform, they will see an icon showing a possible interaction.
The player can now pick up the cube and take it to the pressure plate on the floor. If the player now presses the interaction button again, the cube will drop on the pressure plate and the door will remain open so that the player can step through it.
The glowing purple object here is the end of the level. If the player steps through it, they have completed the level and can start the next one.

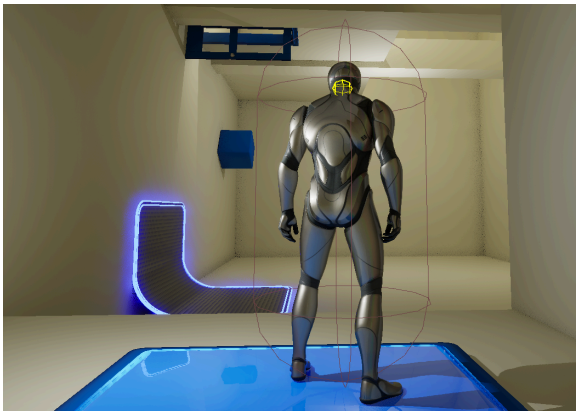



Figure 20 (left): Test Chamber-00 from Portal, Test Chamber 00 - Portal Guide - IGN
Figure 21 (right): First puzzle: The Pressure Plate and Gravity Cube are introduced.

Iterations

Initially, two of the rooms here were intended to be traversed more than once. The collectable and Level End *(Fig. 22: on the right)* are only reachable through the moving platform *(Fig. 22: centre top)*. This version doesn’t include the shrinking stairs yet but has another Level End placed in the room of the jump tutorial *(Fig. 22: left bottom)*.

After the cube puzzle room, I wanted to introduce moving platforms and collectables with an additional orientation. In addition, the cube from the first puzzle should be used again to activate another pressure plate to “shrink” a staircase and thus get back to the room of the jump passage. I removed the moving platform and the shrinking stairs puzzle as it was too confusing at this point. The end of the level was placed there in such a way that the player could see it the first time they entered. However, he could only reach it after the puzzle rooms with this new orientation.

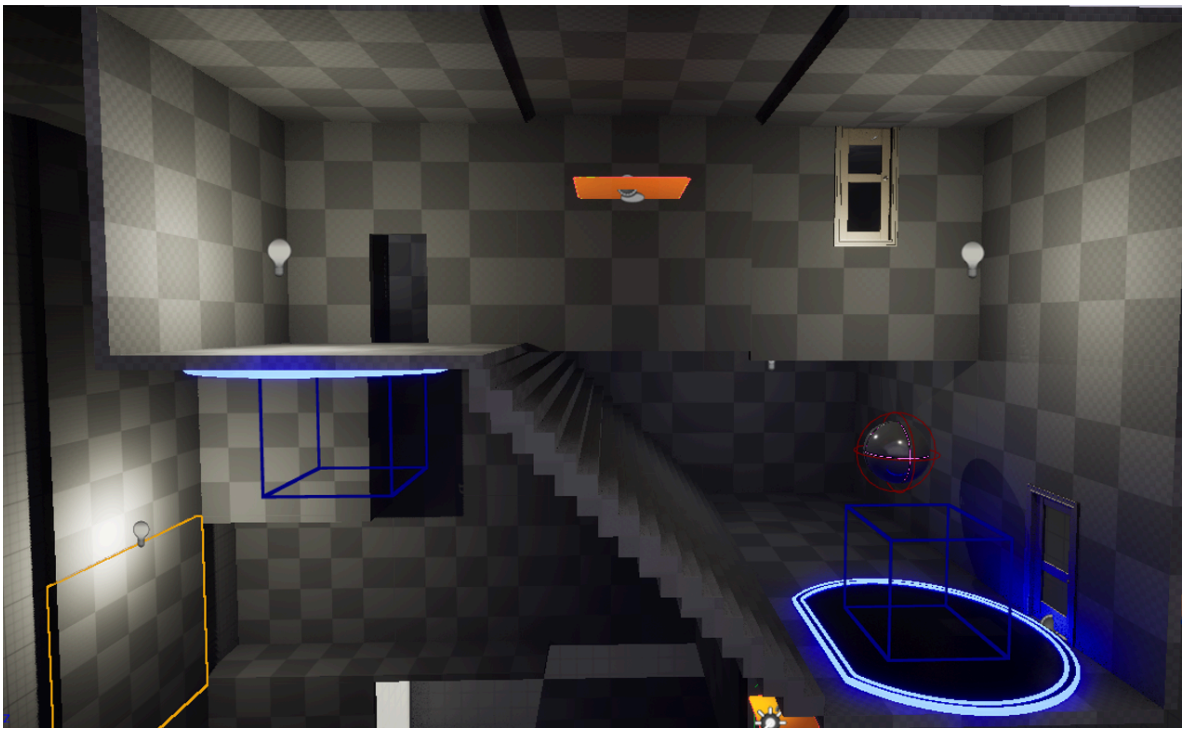


Figure 22: First Version of the Level

However, this multiple usage confused the testers because too many things were placed in one room that were irrelevant to the puzzle directly in front of the player. The multiple use of a room for several puzzles was better suited for later levels.
Testers found new ways to bring the cube to the platform, which is taken up again as a necessary solution in the DoubleInput level.

Later I also tested other re-orientations where the player reaches the cube and the door from the back wall. This did not have the desired effect of making the player's gaze fall on the puzzle elements more quickly. This version was therefore rejected.

Double Input

This level has two rooms with three puzzles, with elements of the second puzzle being reused in the third.

Puzzle 1: Difference

In the first room, the player is shown the difference between the two Gravity Cubes by presenting both at the same time *(see Fig. 23)*. The player can only place one of the two on the pressure plate in the room because the blue cube always falls against the wall. If the player uses the yellow cube, he can move on to the next room. (see Bait and Switch[9])

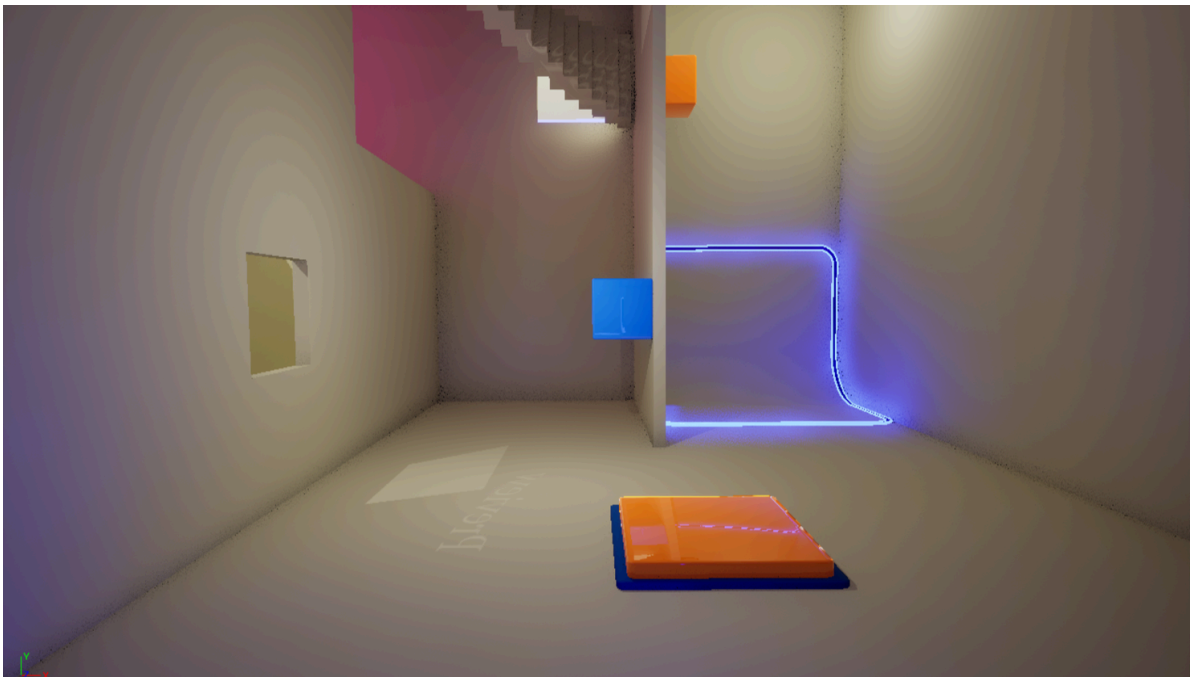


Figure 23: Room one of the Second Level. The locked cube is easier to reach for the Player, but both Cubes are visible from the beginning.

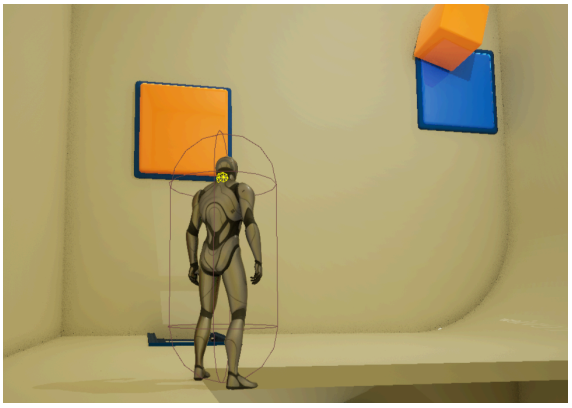
Puzzle 2: Double Input

Im zweiten Raum soll der Spieler lernen, dass manche Objekte (hier eine Tür) mehrfaches Input benötigen um aktiviert zu werden. Der Spieler sieht zunächst zwei Druckplatten und eine geschlossene Tür.
Beide Druckplatten lassen einen Gravity Cube von der Decke fallen. Der Spieler muss den Cube auf der Druckplatte ablegen, welche am weitesten von der geschlossenen Tür entfernt ist. Wenn auch der Player Character auf der anderen Druckplatte steht, öffnet sich die Tür. Der Spieler muss nun schnell durch die Tür springen um zum nächsten Puzzle zu gelangen.

Puzzle 3: reuse

The blue gravity cube has a fixed gravity. The player can see the last door from here (Fig. 25), which he can activate with a pressure plate in front of him. A floating text tries to remind the player of the differences between the cubes without explaining them explicitly. The blue

cube in front of him is once again used as a decoy and not for solving the puzzle. Instead, the player must use the yellow cube from the second puzzle (Fig. 25 top right) to open the door. Then this room and the level are also completed.



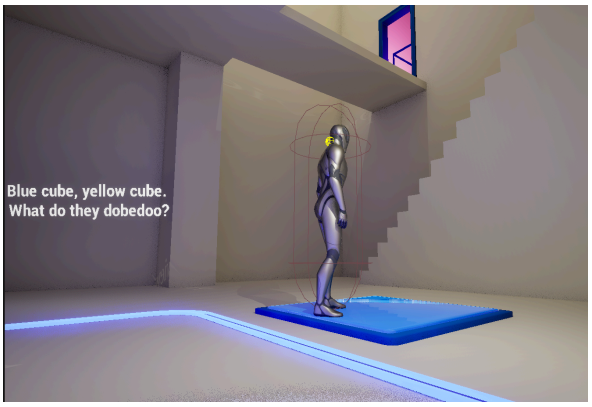


Figure 24 (left): Third Puzzle in the second Room of the second Level. It involves retrieving the yellow cube from the second puzzle.
Figure 25 (right): The door is visible from the pressure plate and the player is guided up the stairs.

Iterations

The level was not initially planned, but it was necessary to implement it to teach the player the difference between the two gravity cubes.
As there was confusion with the cubes in the second room, I introduced the first room where the two cubes are compared directly in a safe environment.
As the blue cube was stuck too close to the 'floor' on the wall, it was not clear to the tester which fixed orientation its gravity had. To prevent this in the future, gravity cubes are placed at least one meter away from a wall that does not block them from 'falling'.

Moving Platforms

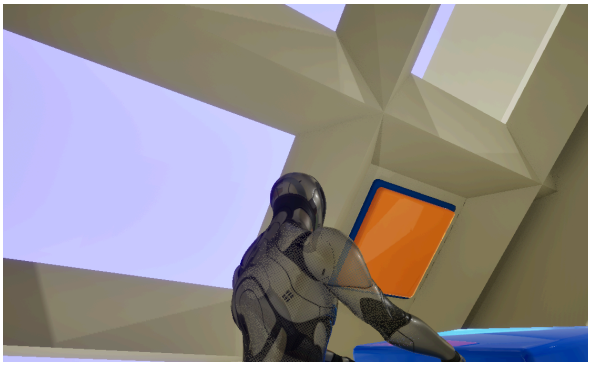
Before I started this level, I had already created the puzzles 1, 2 and 3 as level instances in a different map. This level introduces moving platforms and the reorientation with spiral staircases. The first two rooms are quite easy.

Puzzle 1: Cube and Stairs

In this room, a cube spawns repeatedly and falls sideways past the player character into a dead zone. A pressure plate is attached to a wall which can only be reached via a reorienting spiral staircase.
The player must quickly grab the cube and carry it up the spiral staircase *(Fig. 26)* so that the player character is standing directly under the pressure plate. Now let go of the cube and open the door to the next room.

Puzzle 2: Moving Platform as Elevator

Here, the player is confronted for the first time with a moving platform that is still lying on the ground. If the player stands on the pressure plate in front of it, the moving platform starts to move upwards.
The player has to press the pressure plate *(see Fig. 27)* and jump up quickly to get to the next room.



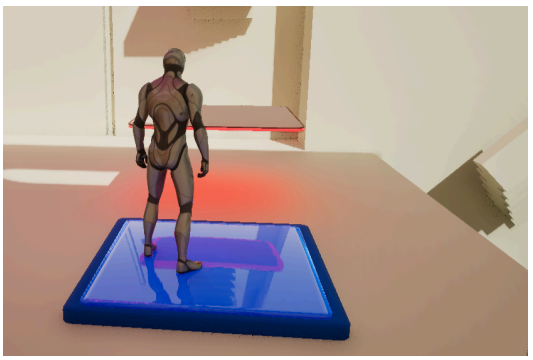


Figure 26 (left): The Grid prevents the locked Cube from being stuck in a place where the player can’t reach it.
Figure 27 (right): Moving platform introduction - From this room is also the Level end goal visible.

Puzzle 3: Catch and Traverse

The first thing the player sees in this room is a moving platform that is constantly moving and reorienting. The player can use a pressure plate to drop a blue cube to the left. The first part of the puzzle consists of retrieving the cube with the moving platform. The player can then use the cube to reach the other side of the level and a new orientation via the platform. Here the player only has to place the cube on a pressure plate to get to the next room. *(see Fig. 28)*

Figure 28: Puzzle 3 Room: The potted plants mark the intended path for the player and serve as the point of interest

Intermission for Reorientation:

In this room, the player completes a simple parkour to rotate 180° and return to the room of the third puzzle through a new door. *(see Fig. 29)*

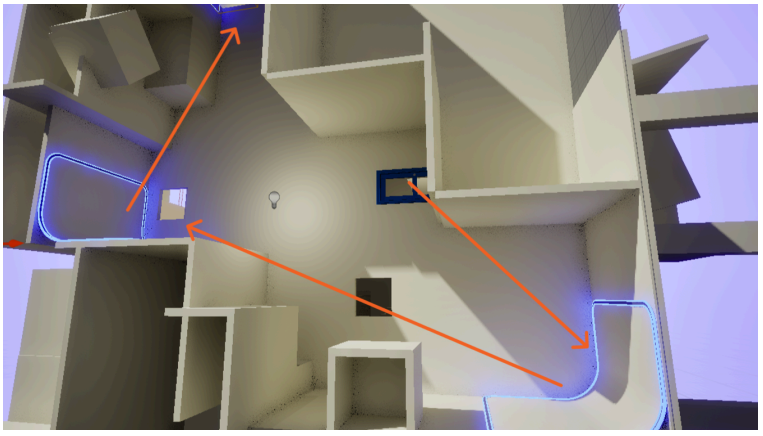


Figure 29: Intermission: Side view of the Intermission section with the player path in orange

Puzzle 4: Delete to progress

This puzzle is inspired by one of the Depulso rooms from Hogwarts Legacy. There, you had to reset it in the middle of the puzzle to move on.
After the jump section, the player arrives in the room where he placed the last cube, but in a different orientation. Now the player can pick up the gravity cube from the third puzzle. A pressure plate in the room opens the door to the end of the level. However, no pressure plate can change the gravitational direction of the cube. The solution is to drop the cube on purpose and force a respawn to reset the previous changes. Now the cube can be placed and the level can be completed.

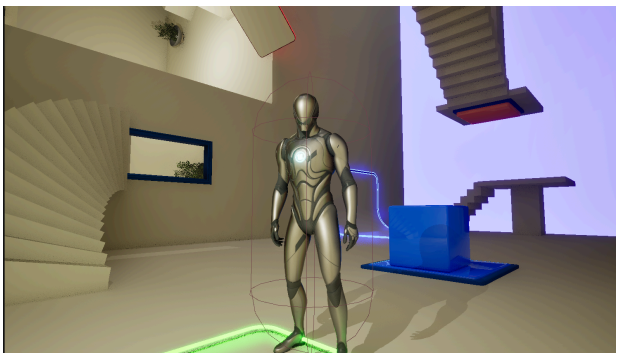


Figure 30: Puzzle 4: Delete to progress - The cube has the correct orientation after the reset.

Iterations

After putting the first three puzzles in a reasonable sequence, I added puzzle 4. To lead the player from puzzle 3 to 4, I had to turn the player 180° in a confined space. For this, I created the jump passage Intermission for Reorientation.
Tests showed that players made good progress in the first two puzzle rooms, as they only allowed a few options.
The third puzzle has two direct options: Go to the moving platform or go to the pressure plate. The moving platform leads to a dead end (as long as one does not yet have the cube) and the way back is not too long. Sometimes players have accidentally activated the pressure plate at the right moment and then do not see what happened. I have provided this part with an elevation for the pressure plate, which can now only be reached with a jump passage where the player's view is directed by 90°. *(see Fig. 31)*

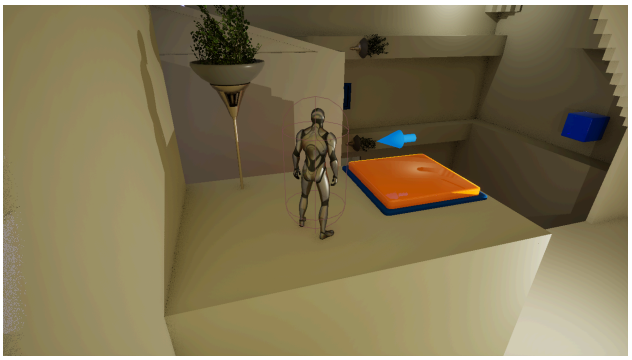


Figure 31: Puzzle 3: The player looks at the Cube when reorienting it via the Pressure plate.

Now the player looks at the position where the moving platform catches the cube or falls away. So it should be obvious what the pressure plate activates.
Because players could break the 4th puzzle I added a backtracking option where the player could start the 3rd puzzle again *(see Fig. 32: Backtracking Section)*.

Figure 32: This Section allows backtracking if the player puts the cube in an otherwise unreachable position.

I also added a possibility to undo an unwanted reorientation with the spiral staircase *(see Fig. 33: Backtracking 2: Spiral Staircase)*.

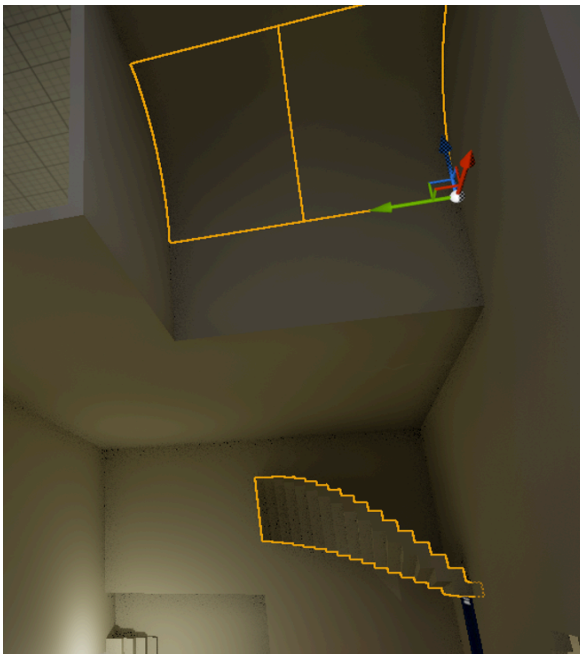


Figure 33 (left): First version of the backtracking section
Figure 34 (right) Final version which prevents the puzzle from being unintentionally solved.

I changed the position of the pressure plate for the door of the 4th puzzle to a more obvious position, where the pressure plate is no longer perceived as a direct target by the 3rd puzzle section and directly shows what it activates. With this, I also had to change the drop-off position of the cube and remove some surfaces that would break the 4th puzzle more often. *(see Fig. 34)*

Initially, I wanted to add another puzzle after the 4th but decided against it to reward the player with the level completion directly after this solution. All that remains is to complete a jump and turn to the right to reach the goal.

Stairs And Towers

At this level, I wanted to present a more open environment and introduce more parkour elements.
There is less security for the player, but checkpoints are given more value.

Start and Stairs

At the beginning, the player sees the goal of the level in a 90° orientation and a pressure plate as seen in *Figure 35*. When the player presses this pressure plate, a reorienting spiral staircase emerges. However, the player has no way of traversing these at the moment.

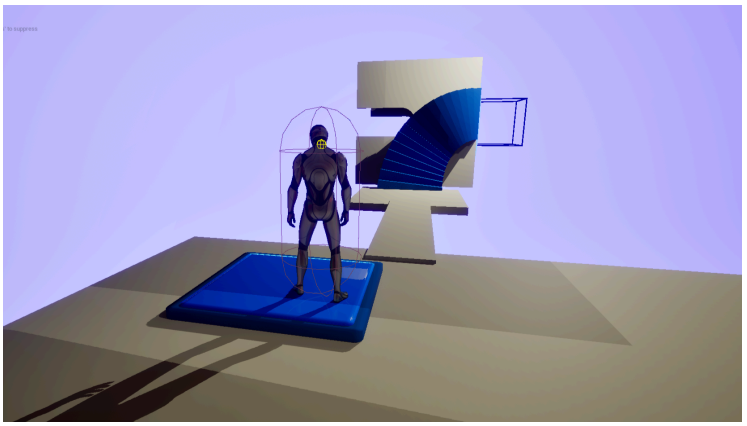


Figure 35: looking at the unreachable goal from the starting position

If the player turns to the right, they will see several spiral staircases that form a longer path. If the player follows these stairs, the player character reorients 180° and arrives at a platform with a blue cube.
Behind the cube, a staircase leads to a raised platform which is placed directly under the pressure plate that activates the spiral staircase at the start of the level. On the right is an inert moving platform and a raised pressure plate, which the player cannot reach with the cube. If the player activates the pressure plate, the gravity of the cube is reoriented by 180°.

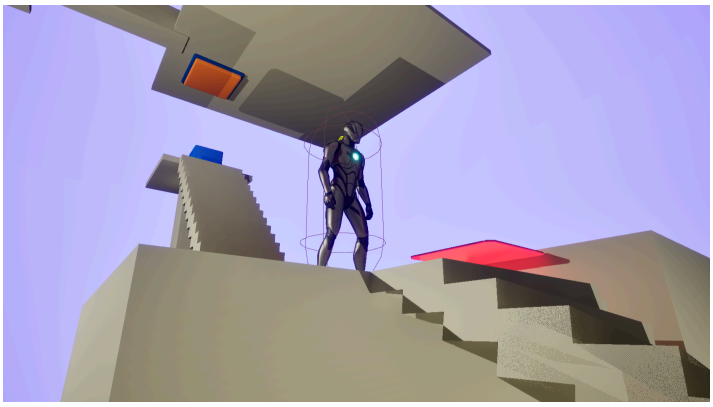


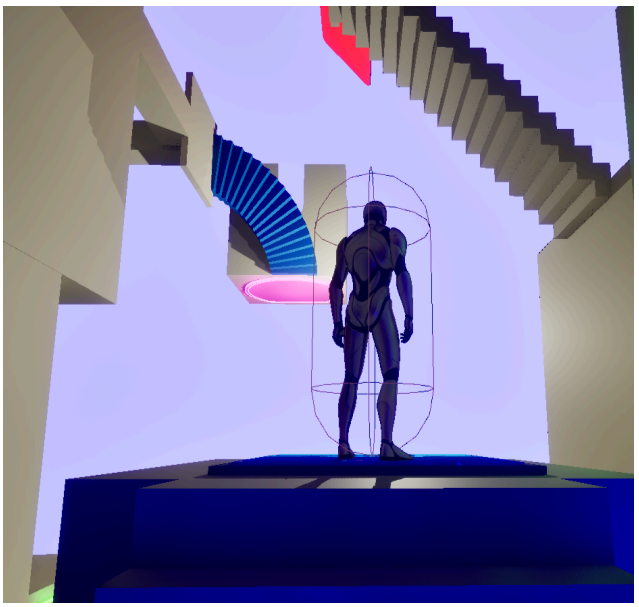
Figure 36: The player already placed the cube below the Pressure plate seen in Figure 34

Present and reorient Cube

The player must carry the cube to the raised platform and place it there as seen in *Figure 36*. Then he must go to the reorientation pressure plate and drop the cube upwards. At the same time, the moving platform is activated and enables a shorter route to the start of the level, where the spiral staircase *(Fig. 35*) to the end of the level can now be accessed.

Iterations

The first testers had problems with the many jump sections, which were necessary to advance or even to reach collectables that were not placed on the main path. I removed all the jump sections, making the pressure plate accessible for reorientation if the player character was carrying it. This is confusing as the pressure plate reorientation is not activated if the cube is not the first object to enter the plate.
Since I wanted to use this bug as a mechanic elsewhere, I made it impossible to reach the pressure plate with a simple jump section when the player character was carrying the cube. The moving platform, on the other hand, was moved to a different position. In addition, as in the moving platform level, I direct the player's gaze in such a way that the effects of the pressure plates are immediately visible. *(See Fig. 37)*



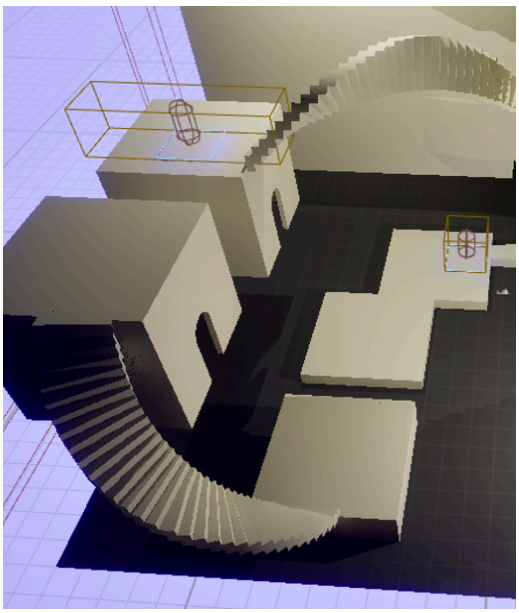


Figure 37 (left): The player sees either the Activation of the stairs and the moving platform or the reorientation of the cube's gravity.
Figure 38 (right): Jump section to discourage the player from carrying the gravity cube back.

Testers have tried to carry the cube over the long spiral staircases to the beginning because the colour coding was not established at the beginning. To mitigate this behaviour I introduced a simple jump section which discourages backtracking as seen in *Figure 38*.

Problems

I have tried to design concepts for the puzzles in Miro, but it is hardly possible to represent such three-dimensionality in a suitable form.

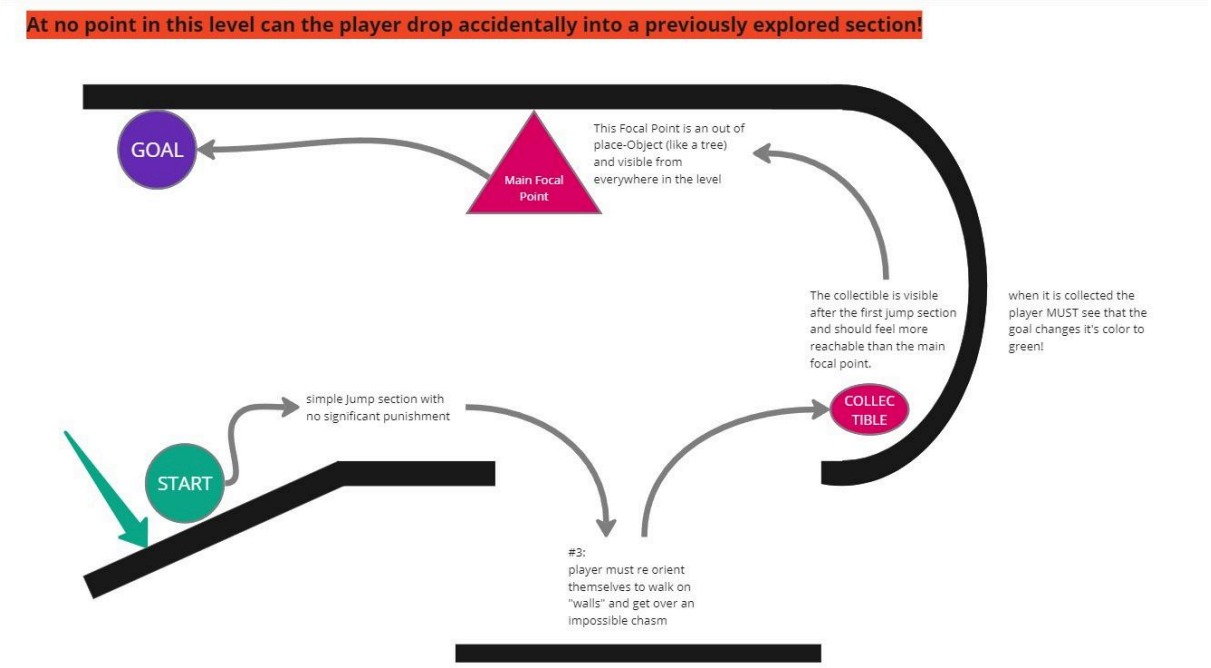


Figure 39: Early Side view concept with notes.

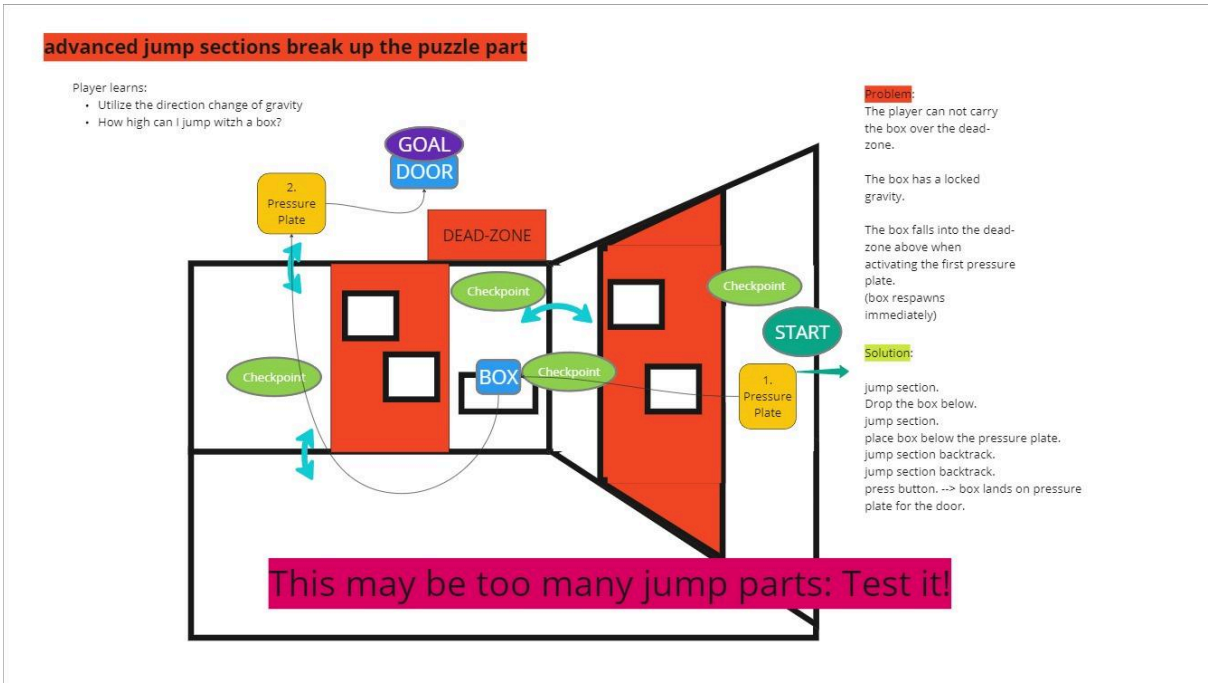


Figure 40: Concept for “Drop from above” Level with notes.

The lecture on the game Braid[4] led me towards simply playing with the mechanics and finding the puzzles that way. This is faster, but less conceptualised and structured.
If one designs puzzles with blockouts directly in the engine, one often has to move things around. To reduce the amount of moving and reselecting, I have tried to use level instances. However, this does not allow multiple use of the rooms. As soon as changes are made to accommodate one level. It breaks in the others.
Linking the pressure plates is only possible within the same level instance. In addition, reorientations break as soon as the level instance is rotated.

I am sure this approach is helpful for more traditional level layouts but here it was not particularly helpful.

The mechanics that I implemented led to numerous bugs, the fixing of which cost time that I would rather have spent preparing playtests. Playtests were largely unstructured.
Only with a few testers was I able to anticipate and evaluate decisions, such as whether moving platforms should be larger or whether the platforming sections in the Stairs And Towers level were too difficult.

Cut Level - Marbles

In this level, the player should navigate a locked gravity cube through a labyrinth. *(see Fig. 41)* The inspiration for this is the physical marble balance games for children. First, the player has to bring the gravity cube from another room into the maze room. Once this is accomplished, the player must use the four pressure plates to change the gravity of the cube to navigate the maze and place it on a fifth pressure plate.

The main reasons why I am not including this level are as follows:

1. The level has a very different feel to all the other levels
2. The number of levels was already larger than I initially planned and I was worried that I wouldn't have time to polish all the levels to a satisfactory level.

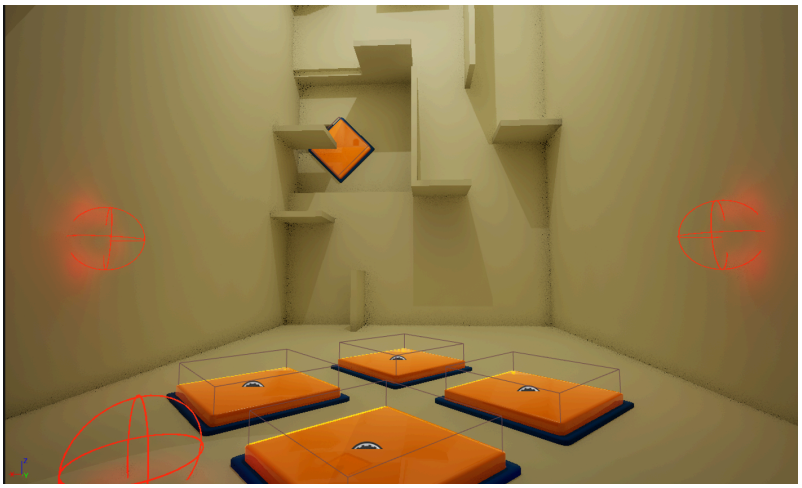


Figure 41: Marbles Level - The Pressure Plates below reorient the cube’s gravity. The top Pressure plate (on the wall) can only be activated by the cube.

Learnings

Design and Coding

Game design and coding alongside level design can't lead to modular code when you have that kind of time pressure. The ability to create child blueprints saved me, but I would make the interaction system more modular if I had the time again.

More structured Testing and Iterations

Initially, I thought the iteration process was more about changing elements in the level. However, individual mechanics were often broken or even the engine crashed.
Bug-related test results like these and their fixing delayed the testing of the level design. When I made major changes to the levels, I made copies of them so that there was a playable level at all times.

Limitations through Scaling

While many of the limitations were intentional, a few I would have preferred to avoid with better reference analysis. For example, the width of the door frames did not allow a cube to fit through without the player character carrying it. This meant that certain dynamics were no longer possible. I could achieve something similar with the help of the moving platforms, but it's not ideal.

It was important to me to keep to the level size limit, which also made the visual guidance of the player difficult. Turning the player towards a point of interest is easier when the level is not confined to such a small size.

Thinking too complicated

The intro design has almost become routine for me. Only the controls are explained directly and the player is free to figure out everything by themselves. However, I went straight on to the advanced puzzles and had problems getting the player from the first level.
Through testing and subsequent iterations, I was able to simplify the more difficult sections, but I later learned of other approaches such as Civilization's Decision Tree, an undeniably complicated game that asks the player to make one decision, and then two, and then three, and so on. This way the player is not overwhelmed and is slowly introduced to the complexity.

Distances between Actions and Puzzle solutions

The Stairs and Towers level breaks up the otherwise quite dense room size with its long walkways. The longer the path, the more the player disassociates puzzle elements that belong together. I have mitigated this break somewhat with the previous level Moving Platforms, where the player has to reuse elements of a puzzle later and with a jump section.

Conclusion

In my final thesis, I present the player with extended orientations and through an iterative process and playtests I improved the experience to a more guided experience.
The Level Design presents very unique problems. Some of these problems are:

1. The guidance of the player's view up a wall or down a pit presents puzzle elements or paths that were in another orientation.
2. When the player reorients themselves they often lose the sense of where they are and where they have been because our sense of

3. Building levels where the player can fall accidentally with the wrong orientation into a later level section.
4. The editor's camera is not suited for this type of level design, because the camera can’t be pitched at 360° or rolled at all.

I can conclude, that extended Orientation in Level Design is not without reason a lesser-used feature in video games. Creating meaningful gameplay comes with many risks and is therefore mostly attempted by smaller indie studios. In other cases is the extended orientation often misused as a simple gimmick that utilizes the disorientation.

If I worked on the same project again with the knowledge I have now, I would not constrain my levels so harshly into a grid of 30x30x30 meters because it made U-turns for level guidance at some places difficult or even impossible.
Now that I have played quite a bit with the implemented and cut mechanics of my game, I would be able to create a more structured user journey to create a more satisfying difficulty curve.
With the acquired knowledge I could now create better reorientation objects (moving platforms, pressure plates, gravity cubes), that when placed and rotated in level instances, would not break.

References

Figure List

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Figure 02 - Wikipedia: https://en.wikipedia.org/wiki/Relativity_(M._C._Escher). Brigham Young University - Museum of Art.
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Figure 03 - Sample Project
Figure 04 - Trello Board by Toni Winkler
Figure 05 - “Core Gameplay Left and immediate progression right”, Toni Winkler
Figure 06 - Sample Project
Figure 07 - Sample Project
Figure 08 - Sample Project
Figure 09 - Sample Project
Figure 10 - Sample Project
Figure 11 - Sample Project
Figure 12 - Sample Project
Figure 13 - Sample Project
Figure 14 - Sample Project
Figure 15 - Sample Project
Figure 16 - Sample Project
Figure 17 - Sample Project
Figure 18 - Sample Project
Figure 19 - Sample Project
Figure 20 - IGN Mediawiki: https://www.ign.com/wikis/portal/Test_Chamber_00, IGN Game guides
Figure 21 - Sample Project
Figure 22 - Sample Project
Figure 23 - Sample Project
Figure 24 - Sample Project
Figure 25 - Sample Project
Figure 26 - Sample Project
Figure 27 - Sample Project
Figure 28 - Sample Project
Figure 29 - Sample Project
Figure 30 - Sample Project
Figure 31 - Sample Project
Figure 32 - Sample Project
Figure 33 - Sample Project
Figure 34 - Sample Project
Figure 35 - Sample Project
Figure 36 - Sample Project
Figure 37 - Sample Project
Figure 38 - Sample Project
Figure 39 - Miro Board by Winkler
Figure 40 - Miro Board by Toni Winkler
Figure 41 - Sample Project

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