Best Design Practices for Doors in Virtual Reality

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Authorship Declaration

I, Natasha Maria Handley, confirm that this dissertation/assignment and the work presented in it are my own achievement.

Where I have consulted the published work of others this is always clearly attributed;

Where I have quoted from the work of others the source is always given. With the exception of such quotations this dissertation is entirely my own work;

I have acknowledged all main sources of help;

If my research follows on from previous work or is part of a larger collaborative research project I have made clear exactly what was done by others and what I have contributed myself;

I have read and understand the penalties associated with Academic Misconduct.

I also confirm that I have obtained **informed consent** from all people I have involved in the work in this dissertation following the School's ethical guidelines

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Abstract

In both physical and virtual environments, doors serve as significant interaction points. They delineate spaces, act as barriers, and obscure what is beyond them. However, in virtual reality (VR), doors can also become obstacles that hinder navigation if not designed thoughtfully.

Considering how doors are so common an interaction point in VR games, there is surprisingly no academic research into their best practices.

This pioneering research aims to investigate best practices for interacting with doors in virtual reality, focusing on enhancing usability and minimizing navigational hindrances. The outcome is a customizable Unity (Unity Technologies, 2024) asset that can be integrated into many VR games developed in Unity (Unity Technologies, 2024) with OpenXR version 1.1 and higher (Khronos Group, 2016). The principles behind their design can also be used by developers in other game engines.

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1. Introduction

Since the launch of Oculus, VR technology, both hardware and software, has been rapidly advancing (Harris, 2019). Titles like Boneworks (Stress Level Zero, 2019) are celebrated for their realistic physics, while games such as Waltz of the Wizards (Aldin Dynamics, 2019), Hand Physics Lab (Dennys Kuhnert - Holonautic, 2021), and Let’s Create Pottery (Infinite Dreams, 2020) have embraced hand tracking, allowing players to interact without traditional controllers, further blurring the line between the real and virtual world. The recent releases of the Meta Quest 3 and Apple Vision Pro have introduced mixed reality (MR) and augmented reality (AR) experiences that seamlessly integrate real-world elements into virtual spaces (John-James, 2024). Concurrently, research into enhancing haptic feedback is underway, promising to deepen our tactile connection to the virtual world (Haseltine, 2023).

While these developments are exciting, they prompt a critical question: Does virtual reality have to mimic reality? This dissertation will argue that recreating reality within virtual spaces isn’t always necessary or desirable, and that VR is its own experience and therefore the ways we interact with the real world are not necessarily the ways we want to interact with a virtual environment.

In both physical and virtual environments, doors serve as significant interaction points. They delineate spaces, act as barriers, and obscure what is beyond them. However, in virtual realms, doors can also become obstacles that hinder navigation if not designed thoughtfully.

Despite their ubiquity, doors in VR have received no dedicated academic attention, leaving a gap in understanding best practices for their design. As the examples in this dissertation will show, there are many ways in which doors are implemented in VR games. Some doors are necessary primarily because doors are expected to be present. Other examples include doors as important game-play elements or puzzles the player must solve to progress. In all examples, the ways in which the player is expected to interact with these doors are different.

The aim of this research is to find the best common design practices for doors in VR games and use iterative design to develop a prototype in Unity (Unity Technologies, 2024) that abides by those design principles. The prototype will be highly customisable so it can be easily configured to meet the needs of many games.

1.1 Research Aim

1.1.1 Research Objective 1

- Analyse existing VR door designs from a variety of VR games to identify:
  - Common patterns
  - Uses
  - Strengths
  - Weaknesses

1.1.2 Research Objective 2

- Conduct interviews with industry experts to gain insight into professional design practices and the development process.

1.1.3. Research Objective 3

- Establish common practices and design principles for VR doors based on the findings from Objectives 1 and 2.

1.1.4. Research Objective 4

- Use iterative design to develop a prototype VR door in Unity Engine (Unity Technologies, 2024) that meets the needs of many VR games, and abides by the principles established through the prior research.

1.2 Research Scope and Prototype

This research adopts a comprehensive approach, combining analysis, expert insights, and iterative design to address the challenges of VR door design. First, a total of 21 door designs from six VR games were documented through screen-capture, and analysed to establish their mechanical behaviours, interaction methods as well as their strengths and weaknesses. Secondly, a level designer from Valve Software, who worked on Half Life: Alyx (Valve, 2020), was interviewed to provide their expert insight into VR door design and Valve's methodology for the designing doors in Half Life: Alyx (Valve, 2020). Lastly, iterative design was performed in Unity Engine (Unity Technologies, 2024) to create a customisable door that fulfils the needs of many VR games and uses the best practices established in the prior research. The iterative process allowed for experimentation with alternative door interaction methods, tested usability and ergonomics while maintaining realism where possible.

By combining analysis, expert insights, and iterative design, this research provides a unique and practical contribution to the field of VR interaction design.

1.3 Chapters

Chapter 2, the reader will read about the common interactions methods in virtual reality, the challenges of designing interactions in virtual spaces, and real-world design principles regarding doors specifically.

Chapter 3 analyses 21 doors in 6 popular VR games and documents their commonality, strengths and weaknesses.

Chapter 4 provides insight from industry expert Dean Tate, level designer at Valve Software.

Chapter 5 describes the iterative design process for exploring the best practices for doors in virtual reality.

1.4 Ethics Statement

This research fell into Risk Category 1 and posed no more risk than expected in daily life. The risk assessment was approved by the supervisor on 15th October 2024.

2. Literature Review

2.1 Interaction Methods in VR

There are many different game engines but this research will use Unity (Unity Technologies, 2024) as a standard. The design principles established in this research can be used in other game engines.

Using OpenXR (Khronos Group, 2016) in Unity (Unity Technologies, 2024), the types of interaction include direct interaction by placing hand upon the object, remote interaction through a laser pointer that can either move items without physics, or applies velocity to the objects. A gaze interactor for something to happen when the player looks at an object. A poke interactor for directly interacting with physics.

The two methods of interaction to focus on will be direct interactors and remote interactors. The latest version of OpenXR (Khronos Group, 2016) has combined these into a single Near-Far Interactor.

While methods like gaze or poke interactors have niche applications, this research focuses on direct and remote interaction due to their practicality and prevalence in existing VR door implementations.

2.2 Challenges in VR Interaction

In the conference paper Interaction Fidelity: The Uncanny Valley of Virtual Reality Interactions (McMahan et al., 2016) the authors introduce the concept of fidelity in VR interactions, which uses eight metrics to gauge how closely a simulation in virtual space resembles reality. This framework is referred to as Framework for Interaction Fidelity Analysis (FIFA) and was originally outlined in another paper (Bonfert et al., 2024). To simplify, using the joystick on a controller to walk in VR would be a very low fidelity interaction, while tracking the user's position in real-world space would be a high fidelity interaction. Factors such as lag and the exactness of motion tracking also play a role in gauging an interaction's level of fidelity.

Their research challenges the concept that user experience in VR improves with increased naturalness. Although very high fidelity interactions usually did result in the highest quality user experience, mid fidelity interactions usually performed the poorest, outperformed by low fidelity interactions. This supports my hypothesis that attempting to imitate the way we interact with reality in virtual spaces is not always desirable.

In the virtual world, the user's real world hands are not restrained to the arc of the door's motion. Many games including Phasmophobia (Kinetic Games, 2020) and Half-Life: Alyx (Valve, 2020), where the player must directly interact with a doors interaction point, try to address this by visually attaching the player's hands to the handle when it is grabbed. This leads to the motion of the player's real-world hands not matching what is happening in the virtual world.

An alternative approach may be to use a remote interactor like the far-interactor in Unity (Unity Technologies, 2024) but this comes at a cost which can sometime be unaffordable. When interviewing Valve, I asked them if they considered using gravity gloves (their equivalent of a remote interactor) for door interactions, and they did experiment with it, but decided against it. One reason was that the gravity gloves specifically interacted with loose objects (ie, objects not attached to the environment). Secondly, it would make level design so much harder. In Half-Life: Alyx (Valve, 2020), it is hard enough to design levels around the fact that the player can teleport. If the player could teleport, and use telekinesis, it would be impossible to guide the player to where they need to be.

Ultimately, achieving the right balance between interaction fidelity and practical design constraints requires consideration of the specific use case, user expectations, and the overall game design context.

2.3 Real-World Door Design Principles

Don Norman, the author of The Design of Everyday Things (Norman, 2013), has this to say about doors in the real world.

> *But why should I have trouble with doors and light switches, water faucets and stoves? "Doors?" I can hear the reader saying. "You have trouble opening doors?" Yes. I push doors that are meant to be pulled, pull doors that should be pushed, and walk into doors that neither pull nor push, but slide. Moreover, I see others having the same troubles—unnecessary troubles. My problems with doors have become so well known that confusing doors are often called "Norman doors." Imagine becoming famous for doors that don't work right. I'm pretty sure that's not what my parents planned for me. (Put "Norman doors" into your favorite search engine—be sure to include the quote marks: it makes for fascinating reading.) (Norman, 2013, p. 1)*

Norman is correct that the term "Norman doors" has been used extensively online to describe poorly designed doors (Das, 2022; Morgan, 2024; 99% Invisible, 2016; Scout Alarm, 2020), indicating that they are a common problem and widely felt frustration.

Norman describes a story of a friend who became trapped in a room that had doors that swung not on hinges placed on the sides of the door, but a pivot in the centre (Norman, 2013, p. 2). The design was unintuitive and had no affordances on the way they should be operated. Norman describes these doors as being *"Attractive doors. Stylish. Probably won a design prize."* (Norman, 2013, p. 3) suggesting that these doors were designed with form over function; doors that are beautiful or fitting for the artistic and cohesive design of space, but with user experience as a lower priority.

People have conceptual models on how doors should operate. The most common form of door people come across in daily life is a swing door. The door will be hinged on one side, and there will often be a handle or another form of interaction point placed on the door on the opposite side to the hinge. Some doors swing in both directions so it doesn't matter whether they are swung towards the user or away. Most doors swing in one direction and the user must either intuit, or discover, which direction the door swings.

A swing door will have affordances which communicate how the door operates. For example, placing the interaction point on the opposite side of the hinge indicates the axis that the door swings upon. (Figure 1). If the door requires it to be unlatched from the closed position to operate, there will be something that can visually, or tactilely, be recognised as a mechanism used as the interaction point, such as a knob or a lever (Figure 2).

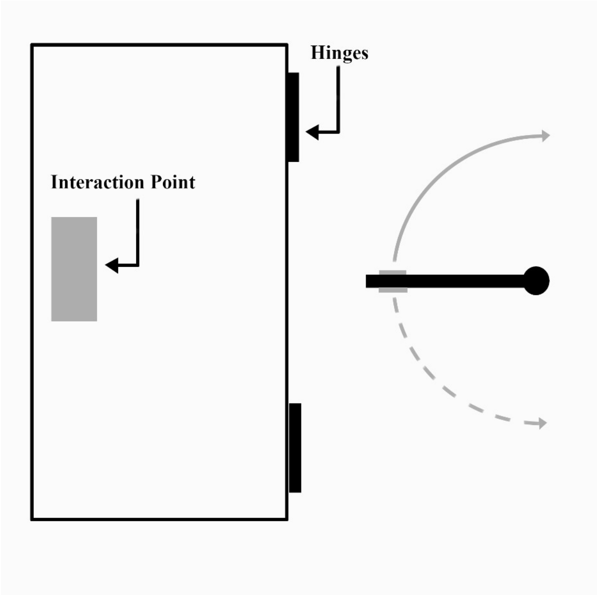

Figure 1: The interaction point is affordance to the location of the swing axis

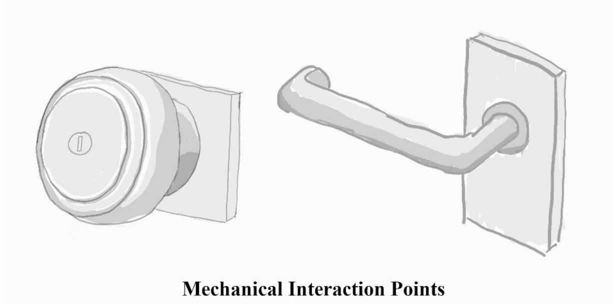

Figure 2: The nature of the interaction point is affordance on how it is to be operated. Mechanical interaction points suggest the door latches in the closed position.

Which direction a door swings can be harder to intuit. If the door has no latch, then it may simply be communicated by having a panel to press upon the side that opens outward, and a handle to grab on the side that opens inward (Figure 3). If the door does latch in the closed position, and swings in only one direction, then there can confusion since the interaction point on both sides of the door will be something the user can grab hold of. In this example, there is the true affordance of the latching nature of the door, and the false affordance of the swing direction.

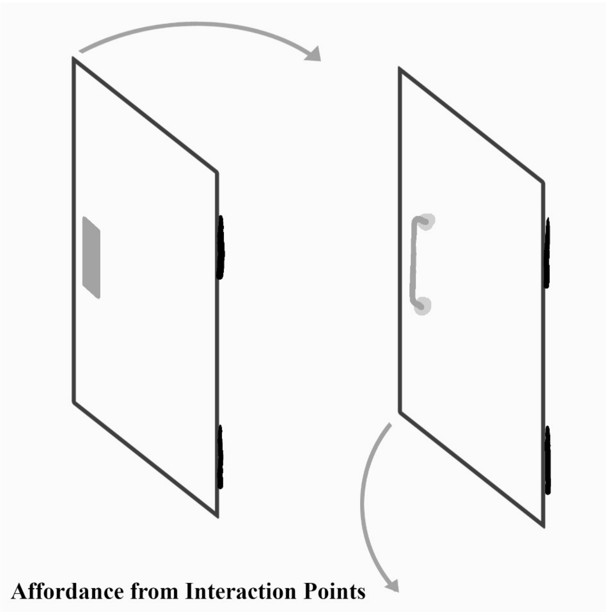

Figure 3: The nature of the interaction point may also be affordance on the direction the door swings.

Norman makes a distinction between affordances and signifiers and claims signifiers are more important than affordances (Norman, 2013, p. 19). In the case of a two-way latching door, signifiers such as signage are effective since they can unambiguously indicate how the door operates. Affordances such as how the door fits into the frame can also communicate this to the user, but that requires deduction, and therefore additional effort, from the user. The fact that Norman doors are common enough to have earned their own nomenclature indicates that such additional affordances and signifiers are not always present, or the swing direction remains obscure regardless.

Confusion can also arise from manually operated horizontal sliding doors. Without signifiers, users' conceptual model of a door can lead them to assume that it swings, and they will either push or pull upon the interaction point expecting that behaviour. Affordance of the door's sliding nature may come from the shape of the interaction point (Figure 4) which can be designed to be hard to grab in a way that can be pulled upon, but easy to push from side to side. Vertical sliding doors have more affordance because the interaction points would either be on the top or bottom or the door, and it's unlikely a user's conceptual model of a swing door will include the possibility of a horizontal axis of rotation.

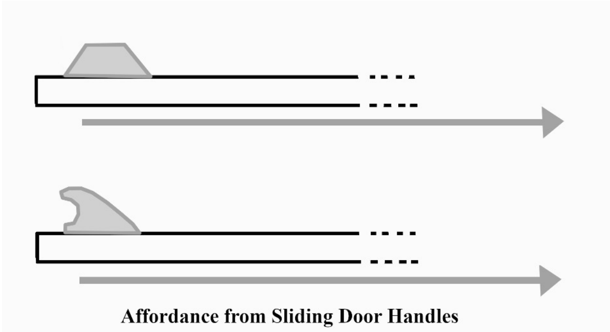

Figure 4: The shape of the interaction point can provide affordance that the door slides.

In the physical world, confusion about a door's operation can lead to mild frustration. However, in VR, where players lack tactile feedback and rely solely on visual and audio cues, the absence of clear affordances or signifiers can be game breaking.

3. Primary Research: Analysis of Doors in VR Games

This chapter examines how doors are implemented in six popular VR games to identify patterns, strengths, and weaknesses. By analysing 21 examples, this research seeks to extract design principles that will inform the iterative development of the prototypes. These games were chosen based on their popularity, and they have doors that fall within the scope of this research. 12 of the doors analysed are from one game, Half-Life: Alyx (Valve, 2020).

3.1 Phasmophobia

According to the website SteamDB, Phasmophobia (Kinetic Games, 2020) is the sixth most played VR game on Steam, however Phasmophobia can also be played outside of VR, so the actual number of VR players is unknown (SteamDB, 2025).

3.1.1 Video Demonstration of Phasmophobia's Doors

https://www.youtube.com/watch?v=bLB9ab0-Wlk (Natasha Handley, 2024)

3.1.2 Analysis of the Doors

Phasmophobia (Kinetic Games, 2020) uses one-way swing doors that require direct interaction with the door's interaction point. The player's hand becomes attached to the door handle when it is grabbed. The doors do not have physics, so they behave as kinematic objects.

Despite not having physics, the doors are consistently buggy. On every door, there is a clear divergence between how the player intends for the door to behave, and the resultant behaviour of the door. The doors would become unaligned from their hinges, refuse to move as intended, or disappear entirely.

The issues appear to be a result of Unity's (Unity Technologies, 2024) joint system. Attempts were made to reproduce the issues shown in the video by reverse engineering the doors in Unity (Unity Technologies, 2024) but the resultant doors did not have the same unintended behaviours. This could be due to Kinetic Games using an earlier version of either Unity Engine (Unity Technologies, 2024) or OpenXR (Khronos Group, 2016). Kinetic Games were emailed to ask what software versions they used, but no response was received.

3.2 Wanderer

Wanderer (Mighty Eyes, 2022) is a VR game available on Steam and made in Unreal Engine 5 (Epic Games, 2022).

3.2.1 Video Demonstration of Wanderer's Doors

https://www.youtube.com/watch?v=rjGLPWMoBFU (Natasha Handley, 2025b)

3.2.2 Analysis of the Doors

Five doors were analysed in Wanderer (Mighty Eyes, 2022).

One Way Swing Door

https://youtu.be/M9ekMCTxTyY (Natasha Handley, 2025a, 00:00:00-00:00:56)

A swing door that swings in only one direction. When the door is near its closed angle, the door becomes sticky to the closed angle range which creates the latching effect. The door has physics so it continues moving after an interaction has ended due to momentum. While the interaction point is grabbed, the player's hand model is attached to the handle. The door requires direct interaction with the interaction point to unlatch. The door also has a physical interaction with the player's hands so it is possible to push on the door itself when it is not latched in the closed position. The hinges have convincing audio effects that appears to be dependent on the speed of the door.

Vault Door

https://youtu.be/M9ekMCTxTyY&t=57 (Natasha Handley, 2025a, 00:00:57-00:01:29)

The vault door is similar to the one way swing door. The player must turn the crank into the open position for it to unlatch. Once the crank is in the open position, it can't be turned back again. The crank is attached to the door itself, and can be turned using just one hand.

Lift Door

https://youtu.be/M9ekMCTxTyY&t=91 (Natasha Handley, 2025a, 00:01:32-00:02:09)

A twin horizontal sliding door that opens and closes automatically. Requires an object to be placed in a slot in the correct orientation for it to become enabled. When enabled, the player can push a button beside the door and the door will open by itself after a short delay.

This is an example of a door being a puzzle element within a game. It also provides an alternative method of operation where the player doesn't manually open and close the door.

Glass Door

https://youtu.be/M9ekMCTxTyY&t=131 (Natasha Handley, 2025a, 00:02:11-00:02:24)

This door is technically a window, though it serves the same function as a door. There is a sticker on the window that says "Emergency Exit. Break glass in emergency." which Don Norman would describe as a signifier for how it operates. There is also a baseball bat in plain sight, which is an affordance for how the glass is to be broken. When the player hits the glass, it falls away and the player can pass through the window.

Vertical Sliding Door

https://youtu.be/M9ekMCTxTyY&t=146 (Natasha Handley, 2025a, 00:02:24-00:02:57)

This door slides vertically between the open and closed position. There are two handles at the base which are shaped similarly to Figure 4, indicating that these are interaction points and that this is a sliding door. The two handles could suggest to the player that it requires both hands to open, though it only requires one hand. It does not latch in either the open or closed position. Like the swing doors, this door also has momentum but very high drag.

3.3 House Flipper VR

House Flipper VR (Frozen Way, 2020) is a VR game available on Steam built in Unity Engine (Unity Technologies, 2024).

3.3.1 Video Demonstration of House Flipper VR's Doors

https://youtu.be/-Nic_RKXLRc (Natasha Handley, 2025e)

3.3.2 Analysis of the Doors

A two-way swing door that softly latches in the closed position when approximately at the closed angle. This door has benefits over a door that swings in only one direction. In order to reach the door handle, the player will more than likely be standing in front of the door. If the door swings in only one direction, and that direction is towards the player, the door will need to be swung in the opposite direction to the intended movement of the player, and the player is standing in the path of the door.

A door that can swing in both directions allows the player to always push the door away from them (the direction of travel), regardless of the direction they are approaching the door. This is illustrated in Figure 5. A door like that shown in the video may be expected, in the real world, to swing in only one direction. The soft latching mechanic helps provide the illusion that the door is one-way and that the player simply chose correctly whether to push or pull upon it. The player may never even realise that it is a door that swings both ways.

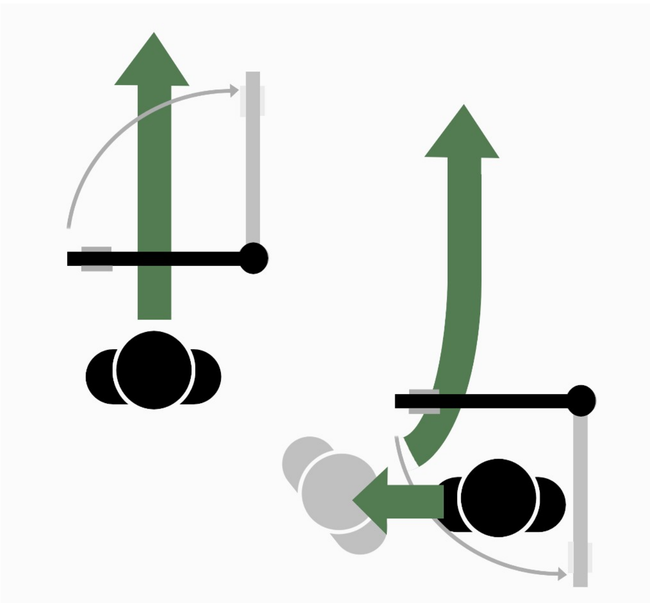

Figure 5: A door that opens outward has less impediment to the direction of travel than a door that opens inward.

The use of two-way doors is supported by Kerry Davis from Valve. In a talk from DigiPen in 2019, during the development of Half Life: Alyx (Valve, 2020) , he stated:

“Use two way doors whenever possible. It feels like a cheat but here’s the interesting thing; when players played through a bunch of doors that open both ways, they very rarely realised that they could have opened the door in the other direction. … and that’s because the experience was accurate.” (The Passionate Gamer, 2019, 00:20:29 – 00:20:51)

Another interesting feature of this door is that tapping the door’s handle appears to automatically fully open the door. This is a far easier method of opening the door than grabbing the handle and trying to replicate the arc of the door’s swing with your hand. This would be an example of a low fidelity interaction having better usability than a high fidelity interaction, but it comes at the cost of realism.

Yet another feature that stands out is that the hand model doesn’t lock onto the door handle when it is grabbed, so the hand model is always in the position of the player’s real world hand. One the one hand, this provides better fidelity between the position of the player’s real world hand and what they are seeing in the virtual world, but on the other hand it diverges from our expectation from how doors behave in reality that when we hold a door handle our hand remains upon it.

Between the self-opening behaviour, and the player’s hand model not becoming attached to the door handle, this door is an interesting example of how usability has taken a relatively high priority compared to other doors that were studied.

3.4 Arizona Sunshine

Arizona Sunshine (Vertigo Games, Jaywalkers Interactive, 2016) is a VR game available on Steam built in Unity Engine (Unity Technologies, 2024).

3.4.1 Video Demonstration of Arizona Sunshine’s Doors

https://www.youtube.com/watch?v=iGRlIeKAjaA (Natasha Handley, 2025c)

3.4.2 Analysis of the Doors

One way swing doors that have momentum and drag when released. The player must grab the hold of the interaction point directly. Circles appear over the interaction points when the player gets close, providing signifiers. A sound effect is used when the door is grabbed while in the closed position. The doors have momentum.

3.5 Red Matter

Red Matter (Vertical Robot, 2018) is a VR game available on Steam and built in Unity Engine (Unity Technologies, 2024).

3.5.1 Video Demonstration of Red Matter's Doors

https://youtu.be/Y3DdcOwzu6E (Natasha Handley, 2025f)

3.5.2 Analysis of the Video

Automatic twin sliding doors which are operated on one side by a push button the player needs to directly interact with, and on the other side a scan function through a terminal needs to be used.

3.6 Half-Life: Alyx

Twelve doors were analysed in Half-Life: Alyx (Valve, 2020), a VR game available on Steam and built using the Source2 Engine (Valve, 2015).

3.6.1 Video Demonstration of Half Life: Alyx's Doors

https://www.youtube.com/watch?v=g_xkWF2YV0o (Natasha Handley, 2025d)

3.6.2 Analysis of the Doors

The doors shown in the video can be described in five categories.

Swing Doors

https://www.youtube.com/watch?v=g_xkWF2YV0o (Natasha Handley, 2025c, 00:00:00 – 00:02:27)

The vast majority, but not all, of the swing doors open two ways. There is at least one door that swings in only one direction. The player must directly interact with the interaction point to unlatch the door from the closed position. The visual of the player's hand is attached to the interaction point while it is being grabbed. When initially unlatched, the door can swing in either direction until a certain angle is reached, from which point it behaves as a one way door and will latch again once the closed position is reached. Unless the door exceeds this angle, the door will not latch.

The doors have momentum so continue to swing when they have been released by the player. They are affected by external forces even when not being grabbed such as the force of the player's hand or weapon pressing against them.

The model of the player’s hand conforms to the shape of the doors, and the doors can be grabbed from their edges and not just the interaction point.

Only doors that can be interacted with have handles. There are other door models that are visually similar throughout the game, but if they are only for set dressing they do not have handles so the players not only knows that they can’t be interacted with, the players can not even try.

Manual Sliding Doors
https://www.youtube.com/watch?v=g_xkWF2YV0o&t=169s (Natasha Handley, 2025c, 00:02:49-00:05:20)

The first door shown is a door that rolls horizontally on rails. It has momentum and visually latches in the closed position. It feels heavy, in that its movement doesn’t perfectly match the speed the player’s real-world hand moves at and needs to accelerate.

The second door behaves similarly to the first. This door has a hook latch that the player needs to unhook before the door can open. The door is on a spring that pulls it into the open position. The door will only remain closed if the hook latch is in place. It also feels heavy, has momentum, and bounces when it reaches the end of its railings.

The third and fourth doors are vertical sliding doors. The third door requires only one hand to move, while the fourth requires two hands and this is communicated to the player by the number of handles that are present on the doors. Both are affected by gravity and will fall back to the closed position if the player isn’t holding onto the handles. Once in the fully open position, both remain fully open permanently.

The fifth door behaves similarly to third and fourth doors, though does not latch in the fully open position. When the player first encounters it, there is a plank that is propping the door open. If the player removes the plank, the door will fall down, and the player will need to hold the door open for them to be able to pass through.

Mechanical Sliding Doors
https://youtu.be/g_xkWF2YV0o&t=321 (Natasha Handley, 2025c, 00:05:21-00:07:00)

The manual sliding doors required the player to interact with the doors directly to manipulate them. The mechanical sliding doors use a separate mechanism that the player interacts with in which the motion of the mechanism is proportionally translated into the motion of the door.

The first door is a vertical segmented sliding door which is controlled by a vertically sliding handle on the left hand side. As the handle is pulled up, the segments slide up concertina-style towards the fully open position. The amount the segments move is proportional to the movement of the handle. The door has momentum.

The second door requires the player to retrieve a crank handle that is hooked on a fence and to place it upon the crank shaft on the right hand side of the door. Once it is in place, it can't be removed. There is a green sign next to the crank shaft showing the direction the crank needs to be turned for the door to operate. The crank can be turned with one hand and its motion is translated to the vertical sliding door. If the crank is released before the door is fully open, the door will fall back to the closed position and the crank will turn as expected. Once in the fully open position, it is impossible to close again.

Automatic Sliding Doors
https://youtu.be/g_xkWF2YV0o&t=421 (Natasha Handley, 2025c, 00:07:01-00:07:21)

The automatic sliding doors open and close automatically when a separate controller is activated or deactivated. The first door shown has a button on the wall to the left of a twin horizontal sliding door. When the button is pressed, the door opens.

Locked Door
https://youtu.be/g_xkWF2YV0o&t=440 (Natasha Handley, 2025c 00:07:21-00:07:32)

This door behaves as a manual two-way swing door, but a keycard needs to be placed against a sensor on the right-hand side for the door to become operable.

Broken Glass Door
https://youtu.be/g_xkWF2YV0o&t=453 (Natasha Handley, 2025c, 00:07:32-00:07:56)

Like the glass door referenced in section 2.4.2.2, this is a window that needs to have the glass broken away. Once that is done, the player can pass through.

3.5 Summary of Findings

The broken glass doors in Wanderer (Mighty Eyes, 2022) and Half-Life: Alyx (Valve, 2020) are mechanically more like obstacles that the player needs to move out of the way than they are doors so they won't be part of the summary. All other doors can be described primarily by their motion, operation and physics. In addition, the doors could also be described by whether or not they have some form of locking mechanic.

- **MOTION**
  - **Swing**
    - One-Way: Swings in only one direction.
    - Two-Way: Swings in both directions.
  - **Sliding**
    - Vertical: Slides along the vertical axis.
    - Horizontal: Slides along the horizontal axis.
- **OPERATION**
  - Manual: The player directly interacts with the door to manipulate its movement.
  - Mechanical: A separate mechanism is used to translate motion to the door.
  - Automatic: The door moves on its own when activated or when conditions are met.
- **PHYSICS**
  - Kinematic: Does not move unless the player directly interacts with the door, or it only moves programmatically.
  - Non-Kinematic: Has momentum and/or is affected by specific external forces like gravity or springs.
  - Dynamic: Similar to non-kinematic, but also responds to collisions and impulses.

All manual doors required direct interaction with the door's interaction point. All mechanical doors required direct interaction with the door's mechanism.

All manual and mechanically operated doors had momentum except for Phasmophobia's (Kinetic Games, 2020), though House Flipper VR's (Frozen Way, 2020) doors had very high drag so they had minimal movement after they had been released by the player.

Phasmophobia (Kinetic Games, 2020) and Wanderer (Mighty Eyes, 2022) used one-way swing doors. Half Life: Alyx (Valve, 2020) and House Flipper VR (Frozen Way, 2020) used two-way swing doors.

Arizona Sunshine (Vertigo Games, Jaywalkers Interactive, 2016) also used one-way doors though these were for cupboard doors and car doors; areas the player doesn't walk into.

Half Life: Alyx (Valve, 2020), House Flipper VR (Frozen Way, 2020), and Wanderer (Mighty Eyes, 2022) allowed for physical interactions between the doors and the player when they were not being grabbed.

The analysis of these 21 doors across six VR games reveals a wide variety of interaction methods, mechanics, and design choices. Common challenges include bugs in physics-based interactions, unclear signifiers, and the trade-offs between realism and usability. These findings will guide the iterative development of a customizable VR door prototype, prioritizing usability, immersion, and adaptability across different game scenarios.

Door Examples	Motion				Operation			Physics			Locks
	Swing Doors		Sliding Doors		Manual	Mechanical	Automatic	Kinematic	Non-Kinematic	Dynamic	
	One-Way	Two-Way	Vertical	Horizontal							
Phasmophobia A (Natasha Handley, 2024)	X				X			X			
Wanderer A (Natasha Handley, 2025a, 00:00:00-00:00:56)	X				X					X	
Wanderer B (Natasha Handley, 2025a, 00:00:57-00:01:29)	X				X					X	X
Wanderer C (Natasha Handley, 2025a, 00:01:32-00:02:09)				X			X	X			
Wanderer D (Natasha Handley, 2025a, 00:02:24-00:02:57)			X		X				X		
House Flipper VR A (Natasha Handley, 2025e)		X			X					X	
Arizona Sunshine A (Natasha Handley, 2025c)	X				X				X		
Red Matter A (Natasha Handley, 2025f)				X			X	X			
Half-Life: Alyx A (Natasha Handley, 2025c, 00:00:00 – 00:01:01)		X			X					X	
Half-Life: Alyx B (Natasha Handley, 2025c, 00:01:02-00:01:49)	X				X					X	
Half-Life: Alyx C (Natasha Handley, 2025c, 00:01:49 -00:03:20)				X	X				X		
Half-Life: Alyx D (Natasha Handley, 2025c, 00:03:20-00:04:05)				X	X				X		X
Half-Life: Alyx E (Natasha Handley, 2025c, 00:04:05-00:04:28)			X		X				X		
Half-Life: Alyx F (Natasha Handley, 2025c, 00:04:28-00:04:47)			X		X				X		
Half-Life: Alyx G (Natasha Handley, 2025c, 00:04:55-00:05:21)			X		X				X		
Half-Life: Alyx H (Natasha Handley, 2025c, 00:05:21-00:06:16)			X			X			X		
Half-Life: Alyx I (Natasha Handley, 2025c, 00:06:16-00:07:00)			X			X			X		X
Half-Life: Alyx J (Natasha Handley, 2025c, 00:07:00-00:07:20)				X			X	X			
Half-Life: Alyx K (Natasha Handley, 2025c, 00:07:20-00:07:30)	X					X				X	X

Table 1: Labelling the doors analysed and documenting the features that describe them.

4. Expert Insight: Interview with Dean Tate

Half-Life: Alyx (Valve, 2020) stood out among the games researched for its extensive variety of mechanically unique doors and their exceptional level of polish. To gain deeper insights, Dean Tate, the level designer responsible for the Jeff chapter in Half-Life: Alyx (Valve, 2020), agreed to an hour-long interview conducted via Zoom on December 20, 2024. An abridged transcript of the interview is available in the appendix.

When asked about the significance of doors in game design, Tate emphasized how their complexity is often underestimated:

> *"If you ask a lot of designers in the industry what is one of the things that you're going to end up putting in a tonne of time, energy and work into, that players probably have no idea is such a time sink, it's doors.*
>
> *"Doors are just such an insanely massive work sink. So much work gets put into doors and the interaction between the player, and the interaction between doors and the world, in particular NPCs and doors, the ways they interact with them, path through them, are aware of them, have their line of sight blocked by them, and just mechanically there are so many games out there that I think people don't realise that doors are a massive part of the game's design."*

This insight underscores how seemingly simple game elements like doors require a significant attention to get right.

4.1 Two-Way Swing Doors and Player Expectations

Tate supported the use of two-way swing doors, citing their ergonomic benefits outweighing the downside of them no conforming with reality. He explained that a player's expectations in game may not be their expectations of reality. In the case of a door, a player expects that a door they can pass through isn't going to be a hindrance to them. If the door were to open in one direction, and that wasn't the direction the player tried to open the door, then suddenly it has become a hindrance. This highlights the need for VR door designs to strongly consider ease of use over strict adherence to realism.

4.2 Technical Implementation in Half-Life: Alyx

The polish of doors in Half-Life: Alyx (Valve, 2020) was attributed to meticulous attention from developers like Kerry Davis, who rigorously tested and refined door mechanics throughout development. There were many door experiments which were play-tested regularly throughout development and any problems found, no matter how small, were addressed. The main reason they put so much work into doors specifically was because they were so frequently encountered by the players.

Tate revealed that doors in the game operated in two primary ways:

1. **Physics-Based Objects (Phys-Props):** These doors, such as most of the swing doors, interact with other physics objects and respond dynamically to player-applied forces.
2. **Animated Objects (Anim-Interactables):** These were mainly used for sliding doors and played through animation frames based on the distance between the player's hand and the door handle. This approach ensured deterministic behaviour, which was important when doors were connected to external events, sound effects, or other level elements.

There were several advantages to using anim-interactables over physics objects. Anim-interactables are deterministic so have very clear states they can be in, whether that's open, closed or part of the way open. He says if you need a door to operate in a very specific way, then it is better for it to be animated than to rely of physics. An advantage of the physics based doors is that they can interact with other physics objects or the forces applied by the player's hands.

4.3 Experimentation and Interaction Design

Tate said they did experiment with other interaction methods such as using the gravity gloves to interact with door handles. There were pros and cons to this method. It would help usability since they player would not have to be standing within reach of the door handle and need to move it a particular way for the door to open. However, this was also a downside from a level designer's perspective. Half-Life: Alyx (Valve, 2020) was hard enough to design around the fact that the player could teleport. If the player could also control doors from a distance, it would be impossible to ensure the player is where a level designer needs them to be when certain events occur. Additionally, the gravity gloves only interact with loose physics object found in the world. It would be logically inconsistent for them to also interact with door handles.

This insight highlights a broader design trade-off: maintaining logical consistency over prioritizing player convenience. Half-Life: Alyx (Valve, 2020) ultimately opted for interaction methods that were grounded in the game's internal logic, ensuring that door mechanics blended well with the overall gameplay experience.

4.4 Relevance to Research

Tate’s insights revealed the depth of effort required to design highly functional doors in VR, emphasizing frequent play-testing to identify bugs and understand player behaviour. His commentary on two-way swing doors directly informed the iterative design process of this research, supporting the idea that it’s preferable for player’s to have a better in-game experience than for games to be perfect simulations of reality.

Furthermore, the comparison between physics-based and animated door mechanics lead to the exploration of techniques in Unity, and highlighted the importance of selecting the right approach for right scenario.

5. Iterative Design Process

The iterative design process aimed to create a modular door system in Unity capable of fulfilling all the needs for motion, operation, physics, and locking mechanisms outlined in section 3.5. Appendix B provides detailed descriptions and configuration options for each door module developed during this process.

One thing revealed by the primary research was the diversity of doors found in current games. Five of the six games studied used manual swing doors, whereas only three used sliding doors, suggesting manual swing doors had the widest use so the decision was made to start with them.

The development process was conducted in Unity 2022.3.49f1 (Unity Technologies, 2024) using OpenXR 1.12.1 (Khronos Group, 2016) and the XR Interaction Toolkit 3.0.3. The initial setup included a Synty low-poly door and frame model, as well as the XR Origin prefab that came with Poke Interactors, Near-Far Interactors, Teleport Interactors and a Gaze Interactor. Only the Near-Far Interactor was going to be used for the interactions with the doors and it was configured to interact with different layers for the near interactions and far interactions.

5.1 Manual Swing Doors

To begin developing the swing door, experiments were done to see if there was any difference in behaviour between having the door’s interactor attached to the door via a fixed joint, compared to having the door model a child of the handle gameObject. In terms of physics, there was little difference, but it was easier to replace both the door and the handle model with other assets if they were not in a parent-child relationship, so for customisability they were kept separate and attached by a fixed joint.

Initially, a one-way swing door was made and experiments were performed to gauge the usability of interacting with the door with the near interactor (a direct interaction) versus the far interactor (a remote interaction). Both techniques had their benefits and it was a simple matter of changing the layer the door was on to switch between the two.

The one-way swing door was extended to function as a two-way swing door with the addition of a custom script. The script allowed the door to work as either a one-way door or a two-way door, with a latching mechanism, a toggle to switch the door between kinematic and non-kinematic, and an optional spring that can pull the door open or closed when not being interacted on by the player.

To make the door act as a dynamic object, sphere colliders were added to the hands of the XR Origin prefab that would only interact with object in the Physical Interaction Layer. To make the door respond to forces from the player's hands it was a simple matter of switching the door's collider to that layer.

5.2 Manual Sliding Door

A manual sliding door was made with the lessons learned from the swing door. A script was written that could easily configure the door to operate on any axis, and springs provided forces to pull the door open or closed.

5.3 Mechanical Sliding Doors

A series of mechanical sliding doors was then developed that used a horizontal sliding handle, a lever handle, and a crank handle. The horizontal sliding handle and the lever handle operated in a similar way. Both used a configurable joint and transferred their motion to the door. The crank needed to use a different system. Because of the limitations of Unity joints, a script needed to be used that controlled the rigidbody of the crank and kept track of the signed angle. These mechanisms communicated with the door through interfaces and had the same functionality and the manual sliding door. Another script was made that could open and close the doors automatically through an additional interface.

5.4 Lock Mechanism

A feature that was missing on all the doors thus far was a method to lock and unlock them, so another interface was made that could communicate with the door and handle mechanisms and verify the presence of a key before enabling door operation.

With the core mechanics of motion and locking systems established, the next focus was on enhancing player interaction through hand attachment points.

5.5 Hand Pose Module

In Half-Life: Alyx (Valve, 2020), Phasmophobia (Kinetic Games, 2020), and Wanderer (Mighty Eyes, 2022), the player’s hand model would become attached to the door handle when it is grabbed. In Arizona Sunshine (Vertigo Games, Jaywalkers Interactive, 2016) the hand model disappeared when the handle was grabbed, and in House Flipper VR (Frozen Way, 2020) the hand model remained visible but did not attach to the handle.

This left open the question of what would be the best technique to use. Referring back the The Uncanny Valley of Virtual Reality Interactions (McMahan et al., 2016), it could be argued that having the player’s in-game hand attached to the door handle could cause the uncanny valley effect because the motion of their in-game hand would not follow the motion of their real world hand.

Having the player’s hand attach to the handle would match what the player would expect from reality, though referring back to the conversation with Dean Tate, a player’s expectation of reality is not necessarily their expectation within a game.

To look further into the question, an optional hand pose module was developed that would attach a player’s hand to the door handle. It was expanded to work with the crank that had multiple interaction points and required two hands to turn. For the experiment, trail renderers were added to see what path the in-game hand takes compared to the player’s real world hand. That experiment is demonstrated in this video (Natasha Handley, 2025a).

It is still unclear which technique is preferable and it may depend on the individual use case. For example, it’s use on the crank mechanism is useful to show that both hands are holding onto the crank. This highlights the importance of considering both realism and gameplay expectations when designing door interactions. While the hand pose module offers a useful option for specific use cases, its implementation should be guided by the context and intended player experience.

5.6 Modular System

Because of the various ways doors can be used in games, the iterative process used composition over inheritance which kept each of the systems modular and expandable. The network of interfaces can be described as shown in Figure 6.

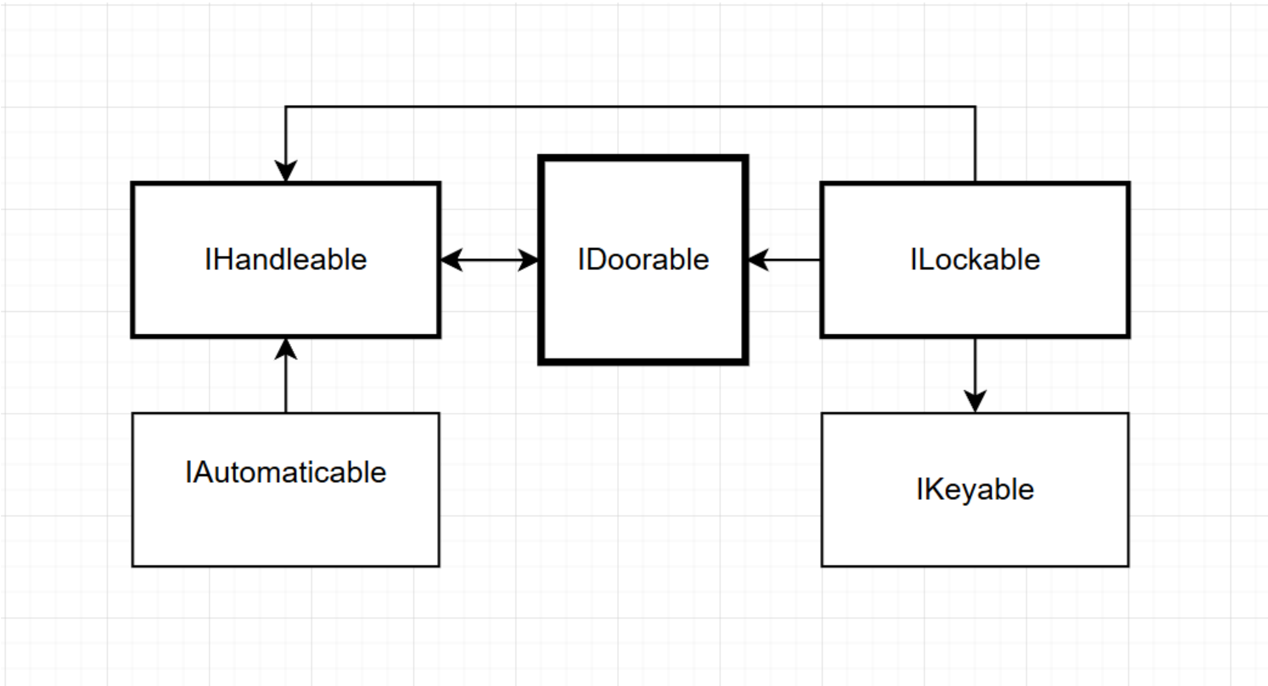

Figure 6: The network of interfaces used for the door system.

This approach not only simplifies the development of new door types but also ensures greater flexibility for adapting the system to diverse gameplay scenarios. For instance, developers can seamlessly integrate doors with complex locking mechanisms, dynamic interactions, or unique motion requirements without significant changes to the underlying architecture.

5.6 Video Demonstration

This video (Natasha Handley, 2025g) shows the various doors that were made during the iterative design process, demonstrating the modular system's versatility. Through combining the various modules in different configurations, more than 30 distinct doors can be made from the prefabs in the project. For the purposes of the demonstration, remote interactions were used by default, though any of the doors can be switched to use direct interaction as demonstrated on the second swing door.

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APPENDIX A

ABRIDGED INTERVIEW WITH DEAN TATE, LEVEL DESIGNER AT VALVE

DEAN TATE: If you ask a lot of designers in the industry what is one of the things that you're going to end up putting in a tonne of time, energy and work into, that players probably have no idea is such a time sink, it's doors.

Doors are just such an insanely massive work sink. So much work gets put into doors and the interaction between the player, and the interaction between doors and the world, in particular NPCs and doors, the ways they interact with them, path through them, are aware of them, have their line of sight blocked by them, and just mechanically there are so many games out there that I think people don't realise that doors are a massive part of the game's design.

INTERVIEWER: Out of all the doors I've experimented with so far, one of my favourite examples in Alyx are the two-way swing doors. They're an interesting middle ground between perfect usability and our expectations with reality.

DEAN TATE: Even if it is not realistic to do two-way swing doors, the upsides in terms of ergonomics outweigh the downsides. The player's expectation of that kind of thing isn't necessarily for it to match reality. You know that in real life that if you try to open a door both ways it won't do that. So that's your expectation of reality, but in the game it's more like 'I just want to go through this portal here so just move this door out of my way please'.

INTERVEIWER: Why is Alyx so unique when it comes to the effort put into their doors?

DEAN TATE: Kerry Davis put of tonne of time and effort into making sure that interactions with doors were really solid. Best in class. And he did the same thing with picking up and throwing physics objects. He's the guy who did all the interactions between the gravity glove and the world. Any time you point at an object, the object you wanted to point at is the one that gets highlighted, you press the button and yank your hand, it comes flying towards you. It neatly comes to the spot in space where your hand is. You press the button to catch it. All of that stuff is him.

Doors, door handles, pushing and pulling the doors, having AIs interact with them correctly, have physics interact with them correctly, all that stuff, he did all of that. It was all a laborious task of working on it and watching people play it, and watching people interact with these systems.

Looking at all these insanely tiny instances of where something doesn't go right, and going back to your desk to work on it. Any time the player grabbed the handle of a door and turned it, and they felt like they turned it far enough, but the door didn't actually open, but they push their hand forward and their hand went through the door, and now their hand's on the other side of the door and it's stuck there. Think of anything that annoys you in any other VR game that you've played those things happened in Alyx, and Kerry, or people like him decided they're going to be the people that care about this a lot. They're the people who find problems and can help make it better.

But why did we decide to do this for Alyx? Fixing problems like these are just part of Valve's DNA and the games that we ship. We make sure we get the core simple, and invisible things right. We tend to make games that are highly polished in a design sense. Some other studios may have some acceptable level of design mess from lack of polish or finesse, for whatever reasons the development team have decided is acceptable. Valve's games tend to be a lot more focused. Games like Half-Life 1 and 2, Left for Dead, Portal, are games that far more focused, and that focus is intentional. Our teams are very small compared to industry standards, but we make sure what we work on is done in a very focused fashion.

In Alyx, we decided that doors were really a core feature of the game so we're going to make sure we get it right. Doors are not a back-of-the-box feature in this game. Players are going to be interacting with doors a lot. As you play Alyx, one of the things that you're going to be doing a lot of is opening and closing doors. So we're going to put in the work to make sure we are getting them right.

Our process is really play-test driven. If you are working on a system, like doors, that is used in a level being play-tested, you are sitting there and watching every play-test. That means you are going through the pain of watching people interact with your system and have trouble. You are being confronted by the problems with your systems every day and you don't want them to be there. You want the play-tests to look really slick and for the player to have a really smooth experience. This means, over time, all of those problems get ironed out.

Any time in Alyx you are grabbing a door that has a handle, and you can swing it back and forth, that is a physics door. Anything like the freezer door that I was working on where you grab the handle and slide it, that's something different that's called an anim-interactable. It's a model of a door that has an animation that it can scrub through, and it scrubs through that animation when the player holds onto it and pulls.

INTERVIEWER: Interesting. I had in my notes how doors like those have a heavy feel to them. So that isn't from physics?

DEAN TATE: That's right. So when you grab the door by the handle you can move your hand as fast as you want and it isn't going to stick to your hand and go over there immediately. If you move your hand quickly, there's going to be some lag as the animation catches up to where your hand is. It isn't physics; the door doesn't have weight. The anim-interactable has a key value for resistance and if the resistance is set to zero, if I hold onto that latch and swing my hand around, the door is going to stick to my hand perfectly. If I add resistance, the door is going to say 'OK. Your hand is in a different position to where the handle is at the moment and we're going to try to get that handle to where your hand is.' but it's only going to move towards your hand up to a maximum rate of speed. And that's what makes it end up feeling heavy. There are sound effects and other elements that go into making it feel heavy, but it isn't heavy because it has a higher physical weight than other door in the game.

The section where you have to get the crank off the fence, attach it and turn it to open the door. That's another anim-interactable. The horizontal sliding door at the start of the game is an anim-interactable.

INTERVIEWER: So doing it through animation, is that something the Source 2 engine is better at doing than relying on physics to interact with those doors?

DEAN TATE: I'm sure Will explored doing it through physics and there were probably conversations about why to not that. I won't be a Source 2 thing. As much as anything else, it's going to be about what the requirements are for that system and how do we need it to interact with other parts of the game. All of the drawers that players can slide forwards and backwards in the game are physics objects that are constrained to a path so making a physics based sliding door in Source 2 is certainly not a problem. It's more about how to other physics objects interact with a hinged door, or drawer. How do NPCs interact with a phys-prop versus an anim-interactable. Bullets, explosions, anything that is a line-of-sight check. So whatever your needs are for a door, you might take this or that path and for the sliding doors we went with anim-interactables.

Anim-interactables in particular are built to have very clear states they can be in. 'I am closed', or 'I am open', or 'I am 50% of the way through this animation'. At what point is a doors motion does it activate a sound trigger. That's harder to do with a physics object.

Another problem is that physics is notoriously non-deterministic. If that sliding door in the blind zombie level was a physics object you can be we would have been dealing with all kinds of issues like the door got blown off of its hinges, or the zombie stuck his face through it and now its stuck at a weird angle because something went crazy in physics. Physics is something you would use in these situations if you are happy with a certain amount of chaos. If you need something to be perfectly deterministic and work every single time you are probably going to shy away using a physics based solution.

INTERVIEWER: Going back to play-testing, how regularly would you do play-testing, and would you use the same people every time?

DEAN TATE: We try to do play-tests once every week or two. Every chunk of track we are working on, we’re going to try and play-test it every two weeks at least. And it won’t be the same play-tester. You ideally want to get somebody new every time. Somebody who hasn’t played it. By the end of the project you’ve probably tested it with every single person who’s on the team who isn’t working on that particular thing. As time goes on we need to pull in other people, so people across the company who aren’t even on the team. Family and friends.

INTERVIEWER: Did you experiment with other interaction methods for interacting with doors such as using the gravity gloves?

DEAN TATE: There were some experiments. It might have even been a bug where you could use the gravity gloves to yank on a door handle. I can’t remember if it was accidental or a purposeful experiment. For sure, with the anim-interactables, when Will and others were working on those systems we had something we call zoos, which are just map files with a whole bunch or examples on how to use this system. So there is a zoo for anim-interactables. You open it up and what you see is every single sliding door that is in the game, plus a whole bunch of experiments that aren’t in the game. It’s a place you see all the different ways these systems can be used to make all sorts of content. I know those guys worked on a whole bunch of more complicated set ups with anim-interactables.

I remember for example, you know when you’d go to the playground as a kid and they’d have a sand pit and there’ll be like a backhoe which kids could use to dig out the dirt. You’ve got two levels; one for pushing it out and another for turning it. We had one of those in there you could mess with in VR. A giant corkscrew you could turn and it would go into the ground. Just a whole bunch of complicated toys that can show what those systems can do.

But when deciding where we were going to be really putting in the work, of course we were going to focus on the use-cases that were really common. We're going to do this twenty times in the game so that's where we're going to put the work. Sure, we could have sand pit in the game and a backhoe you could play with and we'd all love that, but prioritisation means we're not going to be working on that unless all this other stuff is good and ready to ship. We would love to get them all to work but you just can't justify it if it is a one off.

The zoo had loads of examples like that that just didn't ship because they were too specific. Using the gravity gloves to interact with door handles must have been in there and I'm not sure why we didn't ship that but I can imagine one reason is that it was just for design consistency. We have a rule that the gravity gloves, and the gravity gun in Half Life 2, they're limited to interactions with inorganic stuff, which a door handle is, but also you can only use the gravity guns on things that a physical and not nailed down to the world. A door handle is in that weird middle ground. Why do my gloves know that I can interact with that door handle that's attached to that wooden plank that's attached to the wall? And otherwise it can only ever interact with loose phsyics objects. I seem to remember there was a lot of debate about that and whether we were breaking our own rules.

Plus ultimately doors are one of the few tools that I have as a level designer that I can put into the world and say for the player to clear this obstacle and interact with this thing, they have to actually be right next to it. If you are saying the player can open a door from across the room, suddenly my use of that tool is kind of broken. If I want a surprise to happen when you open that door, like there's a zombie or this amazing vista, and the player can be on the other side of the room when that happens, now I can't rely on the player being where when I need them to be.

INTERVIEWER: I can imagine. Like in the Jeff level where the player is releasing Jeff from the freezer, that wouldn't have had the same level of dread if I could have opened it from a hundred feet away.

DEAN TATE: Totally. And Alyx was hard enough to design given that the player has this magical ability to teleport. It makes everything way harder. Every decision you make as a level designer was just like 'Oh my god, the player can just teleport away.' It just changes everything. And that's another thing that's invisible to most players. They don't realise that's such a huge consideration.

APPENDIX B

5.1 Physics Based Swing Door

To begin developing this versatile door, experiments were done to see if there was any difference in behaviour between having the door's interactor attached to the door via a fixed joint, compared to having the door model a child of the handle gameObject. In terms of physics, there was little difference, but it was easier to replace both the door and the handle model with other assets if they were not in a parent-child relationship, so for customisability they were kept separate and attached by a fixed joint.

The door then went through further iterations before having an end result where the developer had access to the following settings which would configure the door's behaviour through a configurable joint:

- Start Angle (Float)
- Door Opens Inward (Boolean)
- Inward Max Angle (Float)
- Door Opens Outward (Boolean)
- Outward Max Angle (Float)
- Kinematic Door (Boolean)
- Lock Door Position When Closed (Boolean)

With these settings available, the developer can configure whether it should behave as a one-way door, or two-way door, whether it should pretend to be a one-way door if acting as a two-way door, and should it's movement be kinematic (i.e. should momentum be present).

Afterward, audio integration was added through Unity Events so the developers can add their own scripts to handle key events including:

- Door Closed Event
- Door Grabbed Event
- Door Released Event

To allow for dynamic interaction, where the play can apply forces to the door with their hand without grabbing it, a new physics layer was made called "Physics Interaction Layer" and sphere colliders were added to the player's hands that were configured to only interact with other physics objects that use that layer. To have to door behave as a dynamic object, the collider of the door itself simply needs to be assigned to this new layer and the Kinematic Door boolean on the door script needs to be set to false. If the new layer is not used, and the Kinematic Door boolean is true, the door will have momentum but won't interact with the player's hands outside of being grabbed. If the Kinematic Door boolean is true, then the door won't have momentum and will behave as the doors do in Phasmophobia.

5.2 Physics Based Sliding Door

This door is a variation of the Physics Based Swing Door, but with different settings to configure the configurable joint:

- Sliding Axis (Dropdown: X, Y, Z)
- Slide Distance (Float)
- Starting Position (Range from 0-1 where 1 is fully closed and 0 is fully open)
- IsLocked (Boolean)
- Use Spring (Boolean)
- Use Latch (Boolean)
- Spring Closed (Boolean)
- Spring Strength (Boolean)

Using these settings the developer can set whether this is a vertical or horizontal sliding door, how far the door should move, and its starting position via script.

A spring mechanic was added so that the door would optionally move back to the open or closed position if not being held by the player. To compliment this, the latch mechanic was added so that when the door comes within 5% of the opposite position, it will become attract to that position instead. This means if the door's spring was configured so that it would close if not being held, it would stay in the open position if it is opened fully. For a vertical sliding door, this could be used to simulate gravity. For a horizontal sliding door it could replicate the behaviour of the door labelled Half Life: Alex D.

5.3 Mechanically Driven Sliding Door

This door module is relatively simple as their behaviour is entirely dictated by the Door Mechanism module attached to it. The script has an array that can be filled with any number of door segments, and a Transform for the open position. Multiple scripts can be added to the same door to control door panels with different end positions such as twin horizontal sliding doors often found on lifts.

The script has a MoveDoor function that takes a float between 0 and 1, and sets the door to that position. The Door Mechanism module and the Door module communicate with each other with two interfaces called IDoorable and IHandleable.

5.4 Door Mechanism Modules

Various Door Mechanism modules were made which can be split into manual modules and automatic modules.

5.4.1 Manual Modules

The three manual modules are the sliding handle module, the lever module, and the crank module. Any of these can be attached to any configuration of a Mechanically Driven Sliding Door. The sliding handle module and lever module operate similarly through a configurable joint. When they are in motion, they communicate their relative position to the door module to tell it to move accordingly. They also have settings for springs and latches which was learnt while making the Physics Based Sliding Door.

The crank module needed to be different because it needed the option to turn more than 360 degrees which would have been complicated to track through a joint. Instead this module configures the rigidbody constraints of the crank gameObject to behave as required, and tracks the rotation by getting the signed angle between frames. The minimum and maximum angle the crank needs to turn can be set by the developer.

It simulates having a spring, or gravity as it's referred to in the script, through a coroutine that returns the door, and the crank to the starting position when not being held, and the option is enabled by the developer.

5.4.2 Automatic Modules

The automatic modules are simply coroutines that move the door between the open and closed position based on a trigger from a IHandleable script. In the examples, it is used for both a push button like on a lift door, and a motion sensor like on an automatic sliding door.

5.5 Lock Module

After these modules were made, each were then designed to work with an additional module that communicates through an ILockable interface. The Simple Lock example looks for a key to be placed in an XRSocketInteractor then checks if that key contains the correct pass phrase that can be set by the developer. If the pass phrase is correct, it invokes a LockToggleEvent to tell the other modules whether they are operable or not.

5.6 Additional Modules

Several additional modules were made along the way to improve functionality.

5.6.1 Door Audio Module

The Door Audio module tracks the relative position of the door through the Door Mechanism Module, and if that position comes within range of a set of positions it has calculated it will play and audio effect. The door module creates as many audio sources as it requires to play overlapping sound effects. This works really well with the sliding doors.

5.6.2 Hand Poses Module

This optional module is used to deactivate the hands of the player, and activates a hand model on the interactor at a predetermined position closest to the player's hand. This gives the illusion that the hand is attached to the interaction point.

This has the benefit of looking more natural to the player, but has the downside that it means the player's hands in game don't match the position of their hands in real space. This is demonstrated in the this video and ties into the discussion of the Uncanny Valley of Virtual Reality Interactions.