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The effect of sounds on enjoyment and perception of varying degrees of realistic environments

A case study in auditory perturbation
Standard project

by

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Acknowledgements

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Abstract

Realism is a poorly defined concept in recent games design research. Not only is the concept poorly defined, but it is disputed if it is even a desirable quality. As tools and technology increasingly allow developers to build near life-like environments, games and animations, the question of whether these increase enjoyment and immersion remains unanswered. Here, we present a small-scale study of 19 participants, investigating the effects of sounds on immersion and enjoyment. Three environments with varying degrees of realism have been created using state of the art tooling and techniques. Participants are exposed to one environment of their choosing where they first play without any sound, followed by playing with realistic sounds. The questionnaire was designed to control for the amount of games the participants play, as well as the type of media the study participant enjoys, while measuring enjoyment and immersion. We note that, as one might expect, realistic sounds increase the perception of realism across the board. In line with recent surveys, results indicate that increased realism (especially in not very interesting environments) is often not-enjoyed. We contest that while a small-scale study, this presents an interesting contribution to the field of games design through the investigation of the effects of auditory changes on realism and enjoyment in games.

Contents

Introduction

Advancements in technology have made games and other forms of computer generated media increasingly more true to life. The advent of photo-realistic games like Unrecord, which achieves such a high level of realism it faced considerable backlash due to allegations of simply being a conventional video, created a new direction of study — is realism always a desired goal and what constitutes realism?

As it is a new concept, realism is still poorly defined in games-design literature [1]. For the sake of simplicity we use the Oxford English Dictionary's definition of realism here as "*close resemblance to what is real; fidelity of representation, rendering the precise details of the real thing or scene*" [2]. Realism in games is undeniably a multi-faceted concept: obviously, the quality of the visual effects make a key component, but one can extend this definition to cover all aspects of the player experience — including auditory effects (sounds), player-movement, realistic physics, realistic environments etc.

While realism is sought by some, it is poorly received by others and has become a controversial topic in the industry. Games like red-dead redemption are accused of being *too realistic*. In cases like these, the over-realistic quality ruins the suspension of disbelief, effectively ruining the enjoyment of the game. The concept of increased realism being a negative can clearly be seen in other forms of media, particularly TV-shows. One can see this also in the growth and sustained enjoyment of animated movies and anime. While originally, the styles of movement and drawing were designed for ease of replication, these have now become a stylistic feature with their own highly developed subcultures. Real-life adaptations which move towards realism have often been exceedingly poorly received (Dragonball-Z, The Sonic movie etc), despite an increase in the perceived realism.

On the other hand, the immersive and realistic nature of first-person shooter games like the Call of Duty Franchise and Fortnite have increased fanbases [3]. Realism has been a long-term goal for games design and for the entertainment industry as a whole. This is rarely questioned and in the words of Lin and Peng, realism is *"deeply rooted in all forms of entertainment… [and is] an essential element of players' arousal and affect"* [5]. Succinctly put,

realism has been a quality which has been both an implicit and explicit goal of the entertainment industry for a considerable period of time. However, various facets of realism have not been extensively explored within games design. One such aspect is that of audio, and how much it affects the perceived realism. This study is particularly interested in to what extent realistic audio has an effect on environments with varying degrees of realism. There have been surprisingly few systematic investigations into how the presence/absence of audio affects users' perceptions, particularly one that compares environments of different degrees of realism.

This work aims to firstly evaluate whether or not realistic sounds have an effect on realism and immersion — with a strong starting hypothesis that the addition of realistic audio increases immersion in a level.

Following that, we evaluate whether increased immersion and enjoyment are correlated by evaluating users' enjoyment. Given the multifaceted nature of realism, and the somewhat unclear relationship between enjoyment and realism, this study presents a novel addition to the literature in pinpointing whether audio-realism is a necessary and crucial component for future games.

Background

This section details the underpinnings and setting for the study detailed in the following section. The first section of this chapter looks at the current state of the art in the literature. Following that we present the motivation of the level design of the realistic environments that were created to be the playground for our study.

Literature Review of realism and enjoyment

Here we briefly discuss the current view of realism in game design, particularly with reference to immersion and the relationship between audio effects and immersion. This section effectively provides the theoretical and high-level motivation for the study.

Realism in the literature

Roger's et al. [1] recently published a literature review of realism in games. A core finding of their research is that realism is not a well defined concept — researchers use the term in connection to immersion, enjoyment and a number of other qualities without a consensus having been reached in the research and development community as to the constituent components of realism. Some go as far as deliberately shying away from defining realism due to its inherent nature as ambiguous. For instance, Denham et al assert *"defining what realism is in virtual space and how it operates to inform and create a sense of the 'real' is unclear"* [5].

They propose a hierarchical taxonomy of components of overall realism, in which realism contains several components, including 1) narrative realism, 2) representational / sensory / perceptual realism and 3) player response realism. Narrative realism refers to high-level aspects of a game, focusing more on the reactions of NPCs, the situations which arise, as well as the setting and immersive aspects (e.g. historical fidelity). Representational and sensory realism is focused more on achieving fidelity to the real-world in terms of visual and auditory effects, and comprises the bulk of existing realism research. Player-response

realism refers to the emotional response a player exhibits in a game, and how that is likely to compare to a real situation (e.g. a bomb explodes nearby — does a player react in a similar way in CoD than they would in reality).

For the purposes of this study, we focus firmly on sensory realism — with a particular focus on player perception and enjoyment.

Realism as a necessity for engagement and immersion

The majority of literature would appear to view realism as a design goal which is crucial to facilitate a positive user experience. McGloinet al [6] describes realism and immersion as intrinsically linked, showing a strong positive correlation between perceived realism and immersion. Bennett and King [7] present supporting evidence that a lack of realism inspired "*frustration*" — which in turn was shown to (predictably) be a negative indication of enjoyment. It seems unsurprising that user immersion, engagement is typically seen to be linked, if somewhat indistinctly, with user engagement. What is perhaps more perplexing is the growing body of literature which suggests that realism is not always a positive addition to a game.

Contra realism: the uncanny valley

It seems counterintuitive that an increase in realism is met with a decreased player experience, however this appears to be a growing body of literature which suggests that realism is not always a positive addition to a game. Often this phenomenon is attributed to the uncanny valley effect.

The uncanny valley as a term was coined in the 1970s to explain the sense of unease humans feel which is shown to grow as a robots' features become increasingly more human-like [9], but fail to attain exact human likeness. There is strong anecdotal evidence for the existence of a seeming revulsion of overly-human characters in film — for example the team behind Shrek [8] have been vocal for making Princess Fiona less lifelike as the original render was deemed too lifelike and unnerving. More systematic analysis have shown that the uncanny valley extends to visual effects and digical characters: Bailey et al show that avatar's displaying human-like emotions were often seen as strange, and factors like gender and positive vs negative emotions were also influential in inducing unease [10].

There is also a growing body of evidence suggesting that this effect extends beyond simply human-like characters, but also into wider domains. Research has recently indicated that increasing fidelity increases cognitive load, and therefore can reduce player engagement. For example, Van der Lard et al. [11] present an interesting study which suggests a mixed response to increased realism in the domain of 3D virtual reality for complex tasks requiring cooperation. They found that realistic virtual settings can improve understanding of complex tasks, but as you move towards increasingly complex (i.e. more immersive tasks), this effect actually reverses, and more realistic environments (in this case a 3D negotiation scenario), it causes things to be less understood and hinders progress — effectively, in some cases an increase in realism causes cognitive overload, and harms the amount of interaction people want to have.

Realism as an objective vs subjective concept

An interesting study by Cheng and Cairns demonstrates that immersion is a highly personal concept, and crucially, that it is not solely dependent on visual graphics quality [12]. In the study they varied graphics quality once a player was suitably immersed within a game, and found that often the degree of realism (i.e. visual graphics quality and coherence) can be reduced, but that it is not noticed by the user if they are sufficiently engaged with the surroundings.

McGloin et al present more evidence that realism is entirely subjective — depending on the user: *"ultimately, perceived video game realism is a user's assessment of how well the game has simulated some event or action based on his or her expectations or mental models"* [13]. This effectively suggests that realism is based on a user's expectations. For example, in an anime-context, what is considered real is based on the realism of previous anime watched. In a very realistic setting which is photo-realistic, or using an engine like Unreal, users are likely to have a well-built mental model of what is to be expected, hence, when the situation diverges from their mental model, a game is likely to be decreed as unreal. Even if the depiction of the environment is something that exists and is generated in a very true to life manner, if it is not well known and/or diverges from the users mental model (example of this later in this study is blue lava) it is likely to be deemed as unrealistic.

Audio experience and Realism

In a recent set of studies, Rogers et al investigated the effect of audio on player experience, with a focus on Virtual Reality (VR). They demonstrate a clear effect of audio as increasing realism and immersion. Crucially, they show that this is a more critical element of realism the more realistic the environment becomes — in their case, audio became an increasingly important factor when the environment was switched from a VR setup to a standard monitor-based form of interaction.

We use this study as the fundamental underpinning for the experimental design detailed in the following section.

Level Design

Here we discuss the design choices for the environments that users interact with in the study. For this study we created three environment maps – a **forest**, a **desert** and a **volcano**. A main objective when doing the environments was to create them with a varying degree of realism and explore how **realistic sound** changes the perceived realism and enjoyment of the environment overall. When discussing the design we start with the first, which is the most realistically designed environment and end with the volcano which is the least realistic. How the varying degree of realism is achieved is further discussed in the implementation section.

The environments are optimised for difference — the biomes are showcasing beautiful and unique properties that could be observed in the real world. However, given the uncanny valley effect (see literature review), we didn't want to make the environments hyper-realistic as to be unentertaining. However, we wanted to explore the effect of sound in realistic environments, so we choose places that will be interesting for a user to see and explore. Some of the environments are also located in far away places which make them unlikely for the participants in the study to have visited in person, which in turn increases the chance that they will find them engaging and interesting to explore.

Forest with Highlands Island

This environment is a combination of types of terrain – highlands and forest. The highlands are inspired by Icelandic sharp cliffs, which stop abruptly and create land "terraces". These spaces are mostly populated by grass and bushes as the strong winds don't allow for other higher vegetation to grow.

Figure 1 A

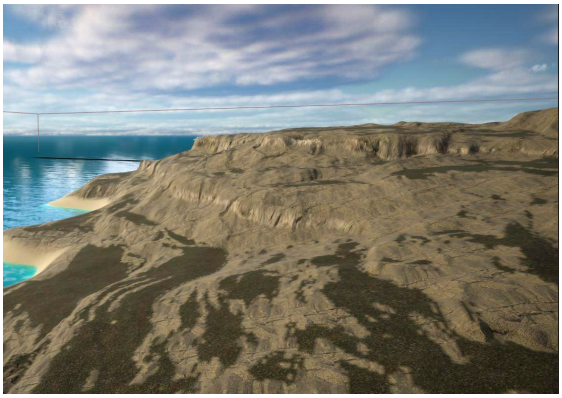


Figure 1B

Figure 1: In Figure 1A we show the mountains by the Giantess's path is a basalt ridge which cuts the hill above Valþjófsstaður and Skriðuklaustur. This photo was found in [14].

Figure 1: In Figure 1B we show the part of the terrain in the Forest with Highlands environment that is inspired by these Icelandic cliffs. This photo is a screenshot from Unreal.

Figure 2 A

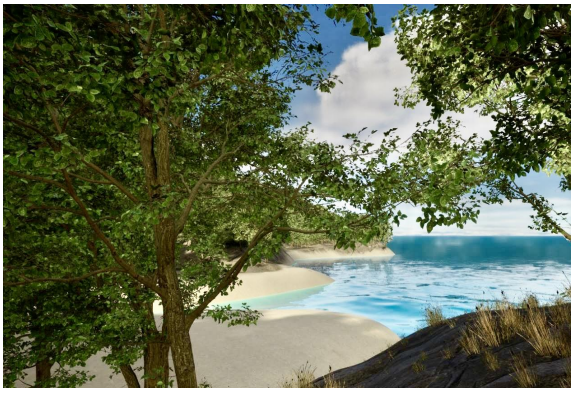


Figure 2 B

Figure 2: In Figure 2A we show a photo of the Chesapeake Bay. This photo was found in [15].
Figure 2: In Figure 2B we show the part of the Forest with Highlands environment that was inspired by this. This photo is a screenshot from Unreal.

The Forest by the beach was inspired by the Chesapeake Bay, which is the largest estuary in the United States. The region has typical big leafed trees, small rocks and dryish grass that are all common around Europe and the East Coast of the United States.

Desert environment

This environment is again a combination of two types of terrain, this time the terrains are rocky and sandy. The inspiration comes from an Island in Yemen called Socotra Island. Socotra Island is a remarkable place, where one can be walking through kilometres of white sands then all of the sudden see a cliff. The described rapid changes in elevation are common on the island and can be seen below in Figure 3A.

Figure 3 A

Figure 3 B

Figure 3: In Figure 3A we show a photo of the rapid changes in elevation seen in Socotra Island. Photo in [17].

Figure 3: In Figure 3B we show the part of the terrain from the Desert environment that is inspired by the rapid change between the sand and the cliff. This photo is a screenshot from Unreal.

What is even more fascinating in Socotra Island is the contrast between the absence of any fauna in the sandy part of the island and the abundance of Dragon blood trees on the cliffs. The Dragon blood tree is well known and one of a kind – it is famous for its crimson red

sap, which makes the tree look like it is bleeding when cut. The rest of the rocky terrain is quite typical for other islands in the Middle East — it consists predominantly of dry vegetation and an abundance of small and big rocks.

Figure 4 A

Figure 4 B

Figure 4: In Figure 4A we show a photo of the dragon blood tree found in Socotra Island. Photo in [16].

Figure 4: In Figure 4B we show the part of the terrain from the Desert environment that is inspired by these Yemen trees. This photo is a screenshot from Unreal.

Volcano environment

The idea for the volcano environment came from an Indonesian volcano called Ijen. The volcano is popular for having an acidic carter lake and blue fire, which are the two features we took for this environment.

The lake in the Ijen volcano (See Figure 5) is one of the most acidic bodies of liquid on the planet. Despite looking like a normal body of water, this lake is actually filled with metals and other earth components making it (0.7pH) more acidic than a car battery (0.5pH). The metals that the lake contains are the reason behind the vivid blue colour it has.

What is even more spectacular about the Ijen volcano is that the lava is blue instead of red/ orange. This spectacular colour comes from a chemical reaction between the magma and

sulphur, which this mountain is particularly rich in. Although that is an incredible phenomena, the height of the volcano and its overall structure isn't as impressive as we desired. That is why the overall terrain design of the volcano was inspired by Fagradalsfjall volcano, which recently erupted in Iceland.

Figure 5 A

Figure 5 B

Figure 5: In Figure 5A we show a photo of the lake at the Ijen volcano. This photo in [18].
Figure 5: In Figure 5B we show the part of the terrain from the Volcano environment that is inspired by this toxic lake. This photo is a screenshot from Unreal.

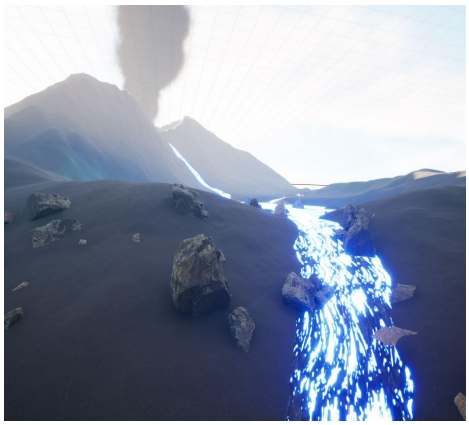


Figure 6 A + Figure 6B = Figure 6C

Figure 6: In Figure 6 A we show a photo of the Fagradalsfjall volcano Photo in [19].
Figure 6 : In Figure 6 B we show a photo of the Ijen volcano lava. Photo in [20]
Figure 6 : In Figure 6 B we show part of the terrain from the Volcano environment that is inspired by these two volcano terrains. This photo is a screenshot from Unreal.

Experimental Objectives and Design

This section describes the methodology of the study from a research perspective: how the environmental design and questionnaire aims to capture certain information.

Introduction to the Study

By way of a brief recap, the study aims to explore how realistic nature sounds can influence the perception of realism in environments. The three environments that the participants will be exploring have been created with varying degrees of realism by design. We have a hypothesis that the addition of sounds in less realistic environments may make a bigger difference in the perception of realism in that environment compared to environments that score highly in terms of visual realism.

Procedure

In this section we describe the way the study was conducted. The study took place in person at a university campus. Upon entering the experimentation room, the participants were given the participant information sheet to familiarise themselves with the purpose of the research and the risks involved. Provided they volunteered to participate they were presented with the participant agreement form, where they agreed to participate in the study by signing the form.

They were then given detailed instructions on how to use the system and asked if they had any questions about the nature of the experiment and their task. At this stage they are asked to fill the first set of questions on the questionnaire form, which determines their level of familiarity with games.

The study then begins with a menu that lets participants choose the environment they want to explore. After clicking on the corresponding button, they are taken into the environment. They first have 5 minutes to explore a portion of the environment without any sound. At this stage they are given the second set of questions which aims to determine how immersed the participants fell into the environment and the level of realism perceived.

Following that the participants were given a headset that plays the added nature sounds that correspond to the area the participant is exploring. Participants are given further 5 minutes to explore the environment before they were given the last set of questions, which aims to determine if they perceived any change in the level of realism of the game with sounds in comparison to the game without sound.

Questionnaire

In this section we describe the questions we asked the participants and then briefly run through the rationale behind each question. The questions can be separated into three categories — one section on participant information and two sections on the enjoyment and realism of the environment, where one batch of questions is without sound and the latter with sound.

Information on the participant

The first part of the questionnaire asks the following questions:

1. Participant Age
2. Participant Gender
3. On a scale of 0-10, with 0 being never having played a digital game before, and 10 playing consistently 6 days a week, how experienced a ``gamer'' are you?
4. How many hours a week do you spend gaming (roughly)?
5. If yes to the above, how visually realistic is the game (1-10, based on accompanying scale provided)
6. Do you often watch animated media (anime/animated movies) --- again 0 being I never watch animated movies/anime, 20 being I exclusively watch animated movies.
7. How many hours a week do you spend consuming media (watching TV-shows and movies) which are not animated (roughly)?

This first set of questions were chosen to establish how familiar participants were with games and animated forms of media. We first asked for their age to determine if different age groups were receiving the realism of the environment differently. This is followed by a number of questions to determine how much time the participants spend consuming

animated media. We ask for this information, as we presume that people that spend a larger portion of their time consuming animated media will be more familiar with environments like the ones created and will therefore be more critical if something is not to the standard of well known realistic games. We also ask for the level of realism the animated media they consume has. This informs us on the level of realism they enjoy the most. If they play less realistic games, it is logical to assume that this is what they enjoy. Not having to ask the participants directly if they enjoy realistic games is useful as it is not a question they would have consciously thought about, so is likely not to get a faithful response to.

Enjoyment and Realism of the Environment without Sound

The second part of the questionnaire asks the following questions:

1. Which environment did you choose to explore?
2. How realistic did you find the environment to be? (1 = Not at all realistic; 10 = Very realistic)
3. How much did you like the atmosphere there? (1 = Not at all; 10 = Very much)
4. How engaged did the surroundings make you feel? (1 = Not at all; 10 = Very much)
5. After playing --- did you enjoy exploring the environment --- what are your thoughts on realism? What elements caught your attention?

This set of questions aims to establish a baseline by exploring the perceived realism of the environment without sounds. The first question is important for us to be able to compare the answers of participants from different environments. Next we want to establish the realism perceived for that environment. We aim to use this to establish if the participants were able to detect that some environments (e.g. the forest) are more visually realistic than others (e.g. volcano). Next we ask if the participants enjoyed the atmosphere. With this question we aim to assess if participants enjoy realistic environments more or less. For this question we will take into account their experience playing games as well and the types of games they enjoy. Following that we wanted to find out how engaged the participants fell in the environment. This is also a baseline question we intend to use for comparison when realistic sound is present. Finally we allow participants to describe in their own words if

anything caught their attention and their general thoughts on the realism of the environment.

Enjoyment and Realism of the Environment with Sound

The final part of the questionnaire asks the following questions:

1. Did the nature sounds make the game feel more realistic (Yes, No)
2. Did you feel more or less immersed in the experience with the addition of sound.
3. How much did the sounds improve your experience as a whole? (1-10)
4. Did you prefer the game with this sound, or prefer without?
5. To what extent did the quality of the sounds in the environment impact your overall perception of the realism of the experience? (0 (small impact) - 10 (big impact))
6. How well did the environment's audio and visual depiction match each other? (0 (not at all) - 10 (very much))
7. How much did you like the atmosphere there?
8. How engaged did the surroundings make you feel ?
9. How much did the sounds around you help you perceive distance and depth?
10. How much did the ambient sounds serve as helpful clues or indicators regarding the surroundings or potential hazards?

This final set of questions is meant to determine how the sound changed the perception of realism (if at all). The majority of those questions are repeated, but reworded versions of the “enjoyment and realism of the environment without sound” set of questions. We also ask if the change (the existence of sound) is appreciated by the participants. Additional questions are also asked to determine if the sounds helped participants orient themselves around the island.

Implementation

In this section we describe in detail the implementational details around the terrain generation.

Terrain Generation

The core feature of all maps is the basic terrain. We opted to create the terrain using Gaea:Indie [21] a node based terrain generator. Each biome is based on an island. The process of developing an island can be divided into two distinct steps: modelling and texturing. Below we detail the workflow for the Forest Island which follows the general principles used for generating terrain. However, this process is roughly mirrored for all three biomes.

Modelling

The modelling component requires elements referred to as nodes. Nodes are visual programming elements supported by Unreal which allow for characteristics and/or functions to be easily “drag and dropped” into a development pipeline. This allows for modular and incremental development of realistic terrains with a large degree of variability. Nodes are a wider concept used for programming in Unreal — one of the key benefits offered by Unreal to allow for realistic environments and games without the typical hours of development. For the remainder of the modelling section, we describe the pipeline with respect to various nodes.

Each island starts with an Island node: this provides a simple 2d mask node (see Figure 7) which allows for swift generation of the coastline. This base can then be fed into both a Distance node (see Figure 8) and a Warp node (see Figure 9). The combination of both of these transforms the mask into the rough shape of a 3-dimensional terrain.

Figure 7

Figure 8

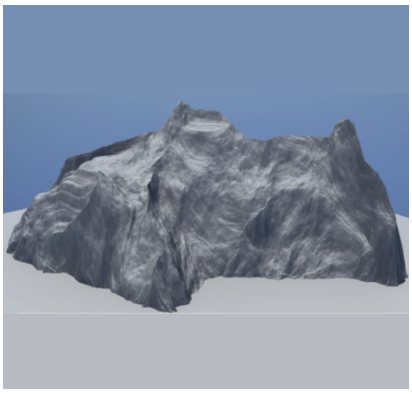


Figure 9

Figure 7: we show a screenshot of Gaea's 2D node from the forest environment.
Figure 8 : we show a screenshot of Gaea's Distance node from the forest Environment — now with added height.
Figure 9 : we show a screenshot of Gaea's Warp node from the forest Environment.

The next step involves using a Ridge node (Figure 10). This has the effect of introducing a number of ridges (as one might expect) into the rough shape, and removing a considerable amount of the terrain, which in turn creates well defined mountains. As displayed in the figure above, prior to the addition of a Ridge node, the height of the terrain is extreme — rendering the terrain unrealistic. Adding a Ridge node resolves this by flattening the terrain considerably while adding realistic-seeming fractures and breaks. This results in the first glance at the basic topology of the island.

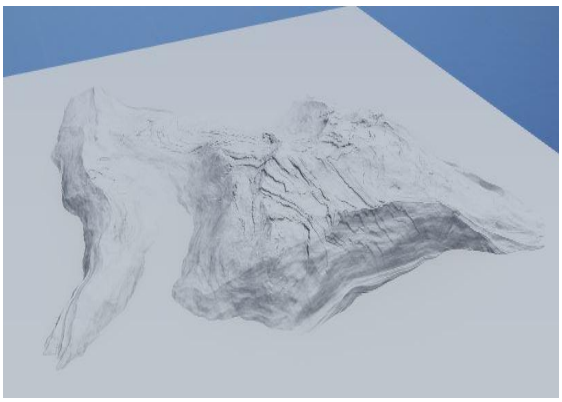


Figure 10

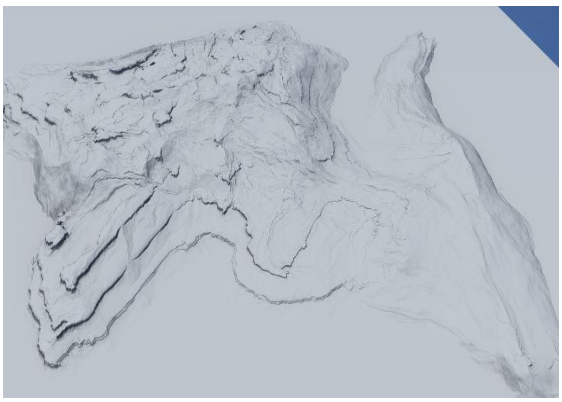


Figure 11

Figure 10: we show a screenshot of Gaea's Ridge node from the forest environment.
Figure 11: we show a screenshot of Gaea's Terrace node from the forest environment.

A crucial feature of the forest island in particular are the sharp cliffs and terraces inspired by the Icelandic highlands (See Section Level Design). To introduce these, we employed a Terrace node, the effect of which is quite stark (see Figure 11). As this environment comprises two types of terrain the sharp cliffs and terraces should be only on one side of the island. We choose for the Terrace node to be applied on the left hand side of the map and therefore have to create a mask to protect the right handside. A mask is a generic way to limit the effect of a node to a smaller area of a terrain). One can clearly see the distinct levels on the left-hand side, and the relatively smooth terrain on the right.

At this point, a Warp node is again introduced to smooth some of the harsher edges. It is pertinent to note that a considerable period of experimentation was undertaken in order to achieve a realistic, yet interesting island.

With the basic topology defined, a Sea node is introduced. This node facilitates the development of textures later in the development process that allow for the creation of a realistic coastline.

The final step in developing the basic model is the development of the sea — i.e. a defining feature of an island is the fact it is surrounded by a body of water. However, at this point of the development process, the sea-level would be at the lowest point of the terrain (i.e. the beach). Effectively, were the ocean to be introduced at this point, it would be exceedingly shallow. Such a shallow ocean would drastically affect any notion of realism, and so the sea floor needed adjustment.

The output of the Sea node results in a mask over the sea-area of the map. To deepen the oceans, we created a simple function where the mask for the Sea was inverted, in order that the mask now covered the land. The output of this inverted mask is then connected into a Constant node (plane) which is then combined with the Sea node with a Combine node (see Figure 12). This has the effect of dropping the level of the ocean, allowing for a far deeper, and therefore more realistic sea surrounding the island.

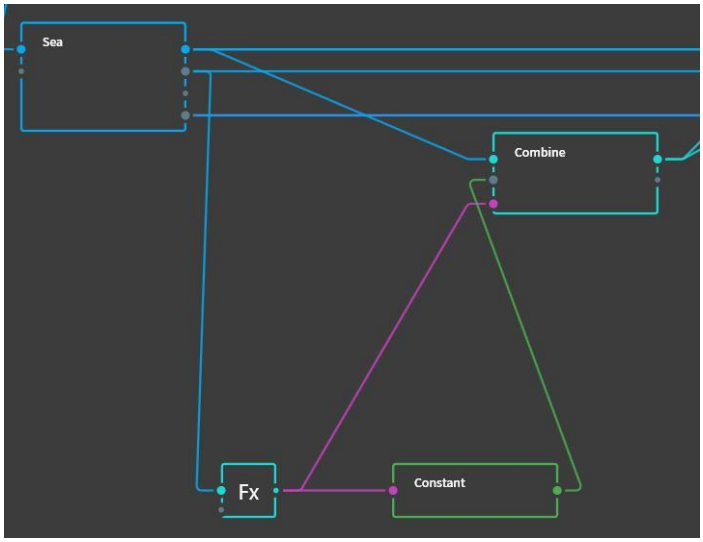


Figure 12

Figure 12: Diagram showing nodes being connected to increase the depth of the ocean floor.

Texturing

Texturing for any island is dependent on how the island was constructed. Texturing in Gaea is predominantly created through masks and SatMap nodes. SatMap nodes are specialised nodes which offer a large number of options of gradients collected from real life environments. These options are separated into Rocky, Sandy, Green, Blue, Colourful and Legacy. This process has the beneficial effect of ensuring designers have the ability to visualise a (sub)project before it reaches the actual texturing stage.

In the context of the forest environment (detailed in the previous section) a total of five gradients and one constant were used, where constants are similar to SatMaps, but instead of a gradient they have a constant colour. The gradients were collected from the SatMap nodes.

As per standard usage, the settings for combine nodes are consistent (despite their inherent versatility — they provide a lot of options with a total of thirteen blending options). By default, they are set with 100% ratio for the second node plugged in. This allows masks

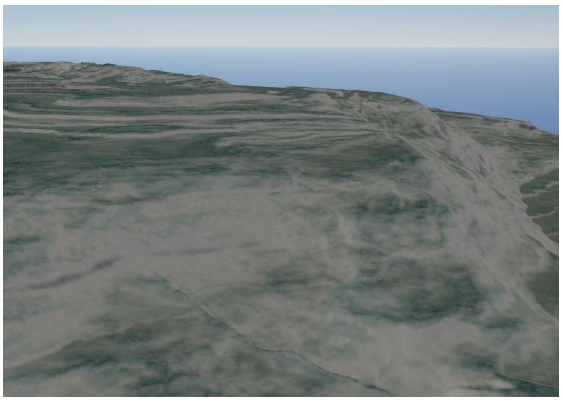


Figure 13

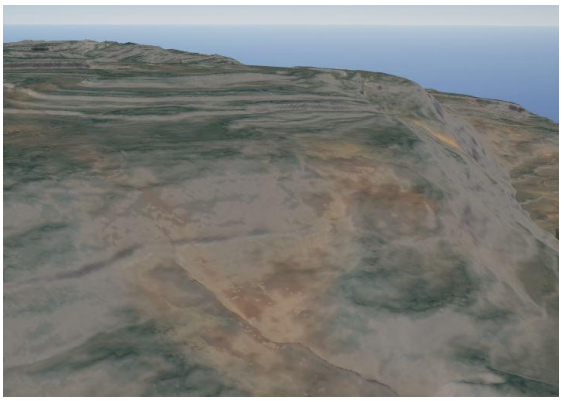


Figure 14

Figure 13: Screenshot of Gaea displaying the initial texturing based on masks.

Figure 14: Screenshot of Gaea displaying the influence of Flow and Shatter nodes.

used as input to any given Combine nodes to define a certain area to be edited with the accompanying texture.

All maps start with a Texture node which creates a mask for the first two materials in any given map. In most cases, these two materials would be rocks and grass (see Figure 13). The mask separates the two materials (e.g. rocks and grass) based on subnodes, which are variables dependent on the environment — for instance the Slope, amount of Soil, and Chaos (some randomness). These masks can then be connected with two Satmaps, allowing for basic early stage colouring and distinctive qualities to be incorporated to the terrain, along with a third mask, which indicates where the textures should not overlap, and leave only rock.

In order to define bare rock in areas which are realistic, we used a Slope node to generate the mask. A slope node calculates the angle of the terrain and isolates areas (i.e. generates a mask) which have a slope above a certain degree.

In an effort to make the topology as real as possible, Flow and Shatter nodes are applied(see Figure 14), which create a difference in the terrain by calculating where water might run and/or collect in the event of rain.

During the development process, layouts change frequently. For realism, the point of the island where the sea meets the land should be fringed by sand (see Figure 15). Given an altering landscape, the exact position of where sand should be can be challenging to calculate. To meet this challenge, sand is set as a sub-output of the Sea node.

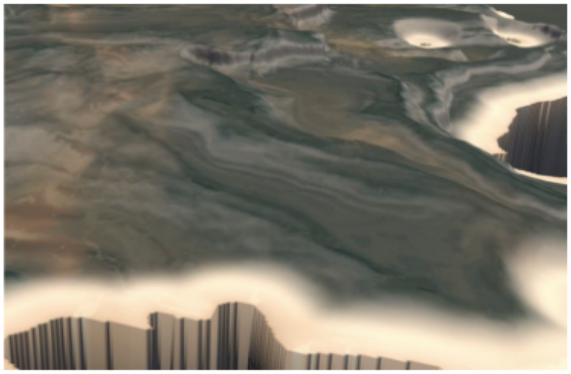


Figure 15

Figure 15: Screenshot displaying the land being fringed by sand.

Finally, we defined a custom mask which indicated the positions of the sea and rivers (despite the fact the rivers were eventually removed from the map. This custom mask is a Combine node set to a blend node of max: Masks work on the same principles as height maps — developing in this way ensures that the rivers do not lose any length and/or width. In practice, the inputs to the final Combine node come from the sub-outputs of River and Sea nodes, called Depth and Sea respectively.

The general techniques used to texture the Forest island (as described here) are nearly identical for the other two biomes (Desert and Volcano). However, it should be noted that the amount of nodes used changes considerably based on the features of the level: for example the Volcano map consists of 79 individual nodes, whereas the Forest and Sandy consist of 45 and 44 nodes respectively.

Exporting

The terrain is generated in Gaea. However, once developed, the terrain must be moved to Unreal. Exporting Gaea is possible through two methods. One can export a terrain either through a height map, or through the use of nodes.

For the heightmap option one needs to connect the main output of the last node, which in most cases would be a Sea node, to an FX node which has been set to mask. This results in a height map which can then be exported.

The other way of exporting is through the use of the node Mesher. In theory, it works in the same way as the FX node. However, instead of producing an image it creates an .fbx file. Upon completion of the mesh/landscape, it's necessary to export all the masks which have been used to visualise your textures. It's also necessary to select their extensions allowing one to use them as an alternative to auto materials. It's crucial to note that each mask must be applied with the same textures, in the same order as in the Gaea project.

Final versions of all Three Gaea levels terrains

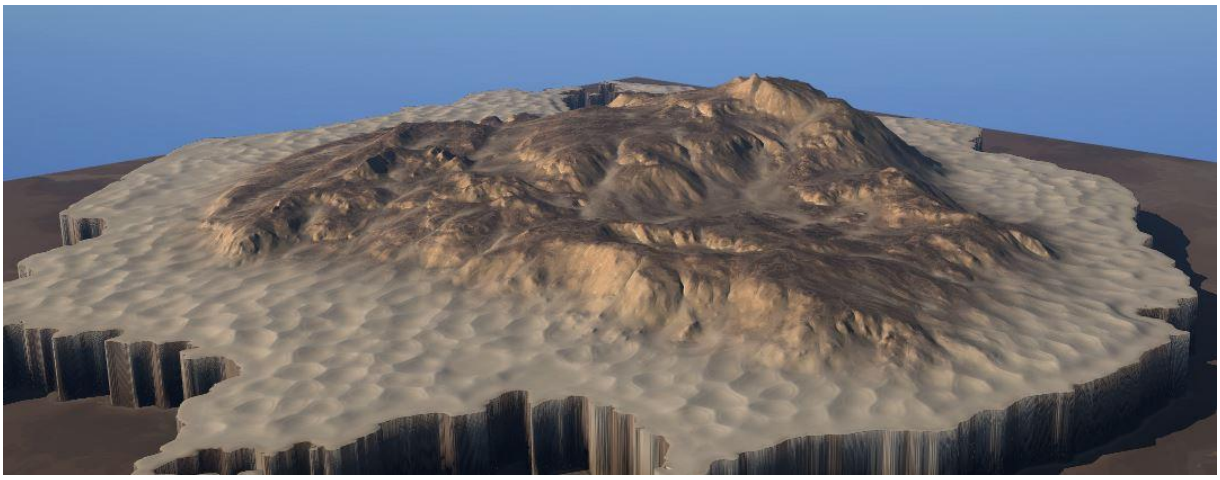


Figure 16 A

Figure 16 A: Screenshot of Gaea displaying the final version of the desert terrain.

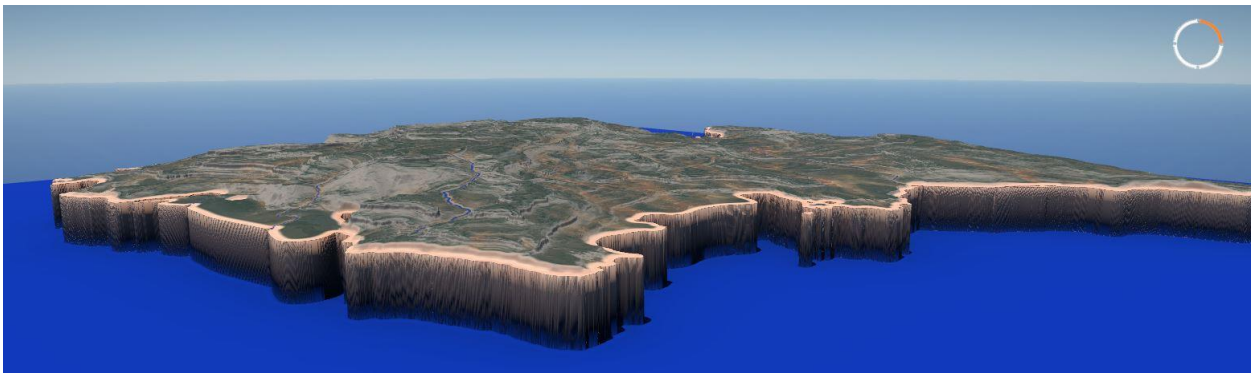


Figure 16 B

Figure 16 B: Screenshot of Gaea displaying the final version of the forest terrain.

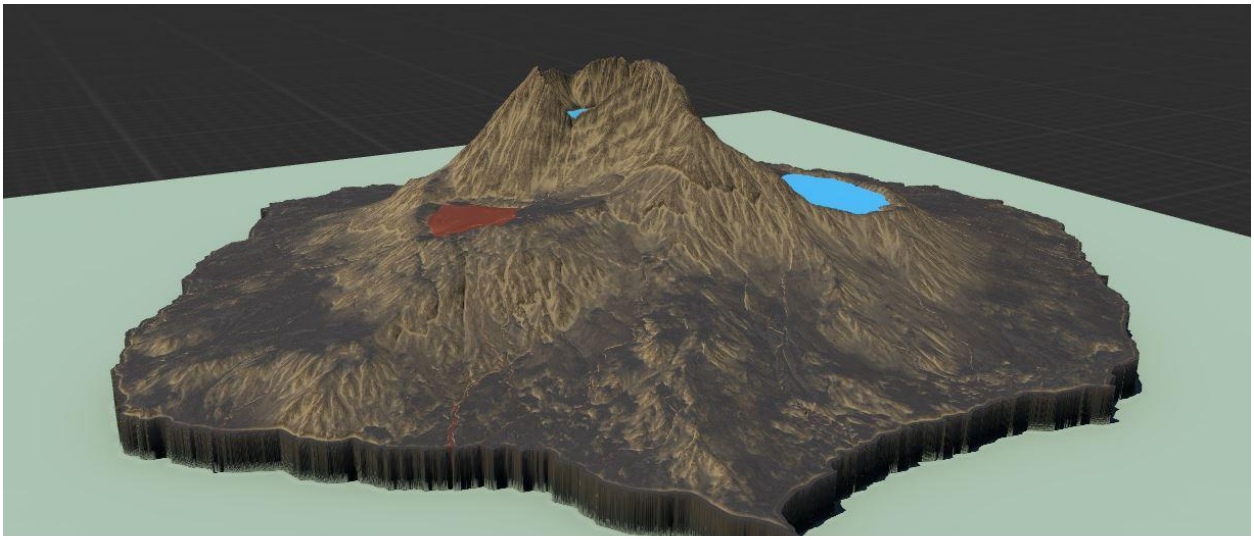


Figure 16 C

Figure 16 C: Screenshot of Gaea displaying the final version of the volcano terrain.

Examples of height maps for texturing

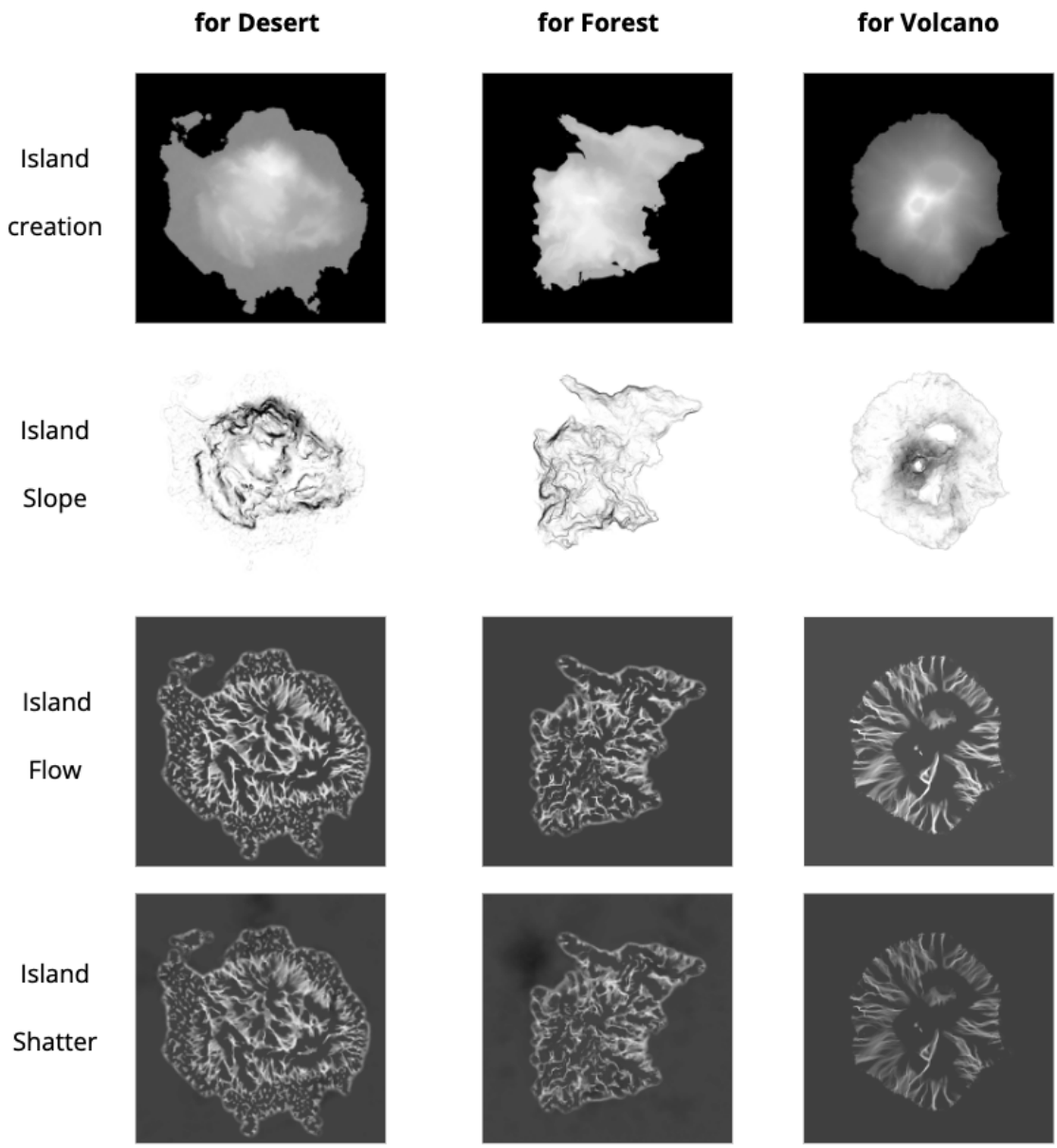


Figure 17

Figure 17: Examples of the various stage height map creation in all three environments

For the textures, a material blend consisting of 5 layers was created.

Each Layer is created as a Material Function. This allows for the function to be changed on demand in the instance settings once applied to a landscape. To work as intended, every distinct material function is separated by their own group.

Additionally in the function there are two sets of tiling parameters defined, as well as two sets of Albedo, Metalnes, AOD, Normal to create the two different texture tilings for the blending. We do this as a method to reduce the amount of memory dedicated to textures. It effectively allows for a reduction in the quality of textures when the player is sufficiently far away, but for the higher-amount of tiling to be used when close. This requires the boundaries to be set for the blend — in this instance, we've employed the Distance blend node in Unreal, and connected it to the alpha of a lerp (below) where the respectful texture would go A (below) as the input for close textures and B (below) for the Far away.

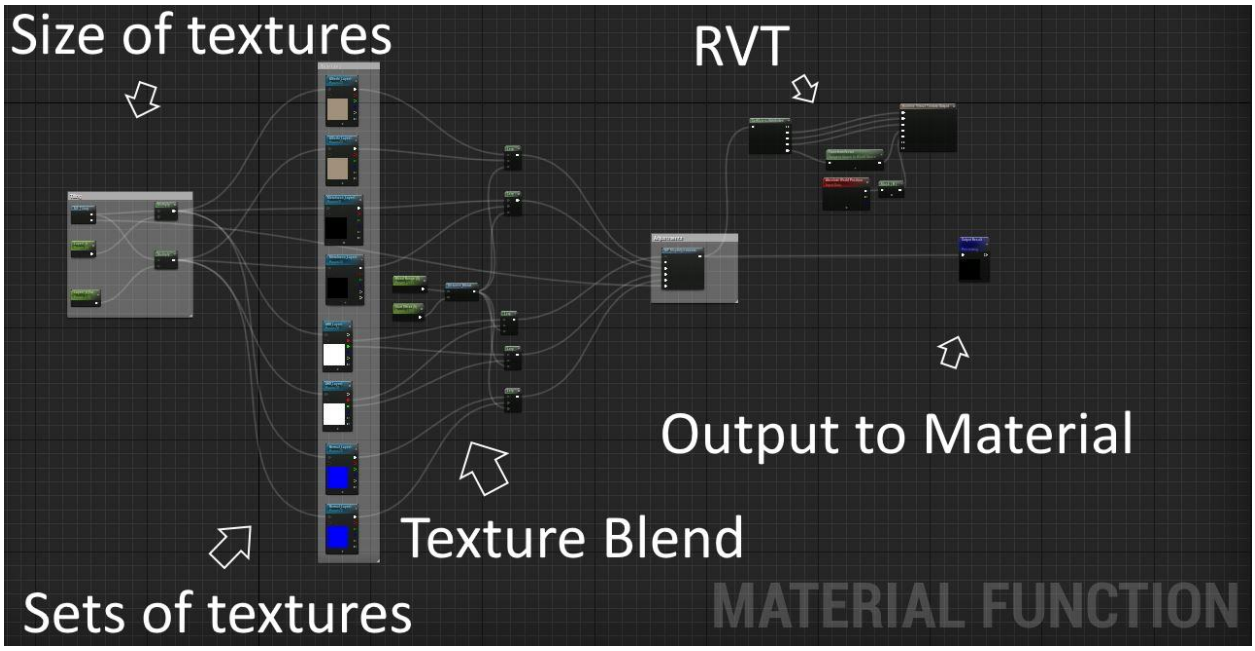


Figure 18

Figure 18: Screenshot of material function pipeline.

Then each material is referenced in the Landscape Material and brought together into a Material Expresion Layer Blend. It is then separated by the next node, BreakMaterialAtributes, to allow access to the different attributes of each Material put into the Landscape instance subsequently.

To add some colour and unpredictability into the material, we've lerp-ed in with the base colour a macro variation graph as well as a runtime virtual texture output. This helps integrate materials into the scene. One can find the specific connections in the basic tiling material and in every Layer (Material Function).

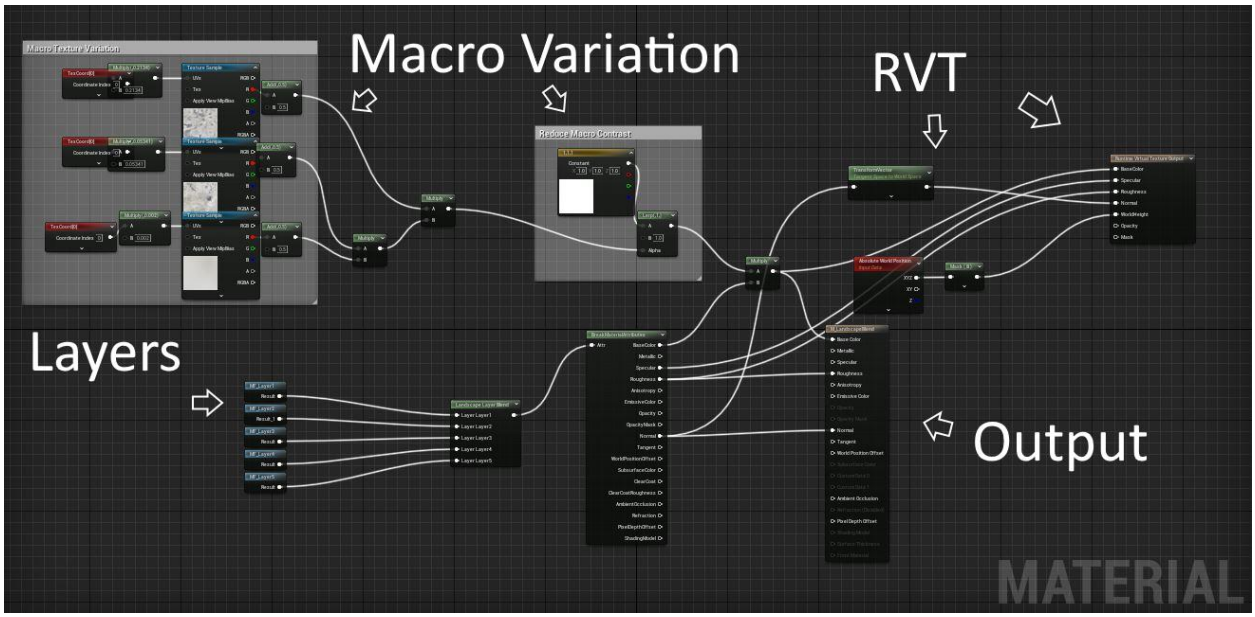


Figure 19

Figure 19: Screenshot of Material Blend pipeline.

Procedural Content Generation (PCG)

The new release in Unreal engines 5.2 version includes support for PCG. Procedural Content Generation is designed to allow users to populate environments quicker and with less chance of error or undesired placements which can be expected using traditional methods like foliage brushes.

Although a lot of the notes for PCG are still under construction/are not available, it is possible to achieve impressive results with it by using options — effectively allowing the user to do almost anything. The only drawback is performance. As of patch 5.2.0, anything consisting of a large number of assets, regardless if broken down, results in a borderline unusable project due to excessively large computational requirements. In practice, a large amount of PCG causes crashes and extended compiling times. This is particularly true when users do not have access to really powerful hardware.

However, despite these performance issues, PCG is functional and effective for a (small) specialised location or low mesh difference and/or density. In this project, PCG is used for the rocks on the volcano island. These rocks were generated, *by design*, to be unrealistic. However, it is feasible to program the PCG to not spawn objects around a spline so as not to have an overlapping effect.

In the special case for the rocks on the Volcano island, only one of the meshes used for rocks had collisions — meaning the user could walk through rocks, proving the desired drop in quality in realism.

PCG was also used in the Desert environment to create the trees, rocks and bushes.

Examples of PCG in the Desert Environment

PCG1: Tree, Grass and Rocks generation

The PCG for the Desert environment involved a 0.002/sq metre density for tree generation. This allowed trees to spawn on slopes with a gradient between 0 and 72 degrees, while making sure they don't overlap with the use of a self pruning node. Trees had free rotation on the y axis and a random offset of up to 10 to -10 on the x and 5 to -5. This rotation allows for the simulation of stronger winds in one direction. Trees have a scale between 0.9 and 2.1.

For the grass, the density values were 0.5/sq metre with 0-72 degrees of spawnable range. Small rocks were allocated a density of 0.7/sq metre with full rotation enabled and spawnable between 0 and 49 degrees. Large Rocks are set to spawn 0.05/sqm and share

their other characteristics with the small rocks, with the exception of scale: big rocks have a scale of 2-4, whereas small rocks only have a scale of 2 to 2.5.

PCG2: Grass and Rocks generation

PCG2 is a component which contains the same components as the big and small rocks (specified above) as well as dead bushes. All have the same characteristics meant for parts of the terrain that require assets but don't need trees.

PCG3: Large and Small Rock generation

We defined a distinct PCG specifically for adding additional rocks. All components remain consistent to the original with the exception that the big rocks now scale between 3.5 and 12.

Figure 20

Figure 20: Screenshot showing PCG3 — a big tree.

Procedural Foliage Volume (PFV)

PFV is a function introduced in the 5.0 version of Unreal designed to allow for realistic and fast generation of trees and foliage. It is comparatively easier to set up, while also providing the user with a lot of options. However, it is more restrictive than PCG.

For natural-looking ('untouched') environments, like the Forest island, PFV provides a near-perfect tool, allowing the user to specify density, rotation, Z offset, maximum and minimum height, and a lot of other functions. One function in particular is layer selection. This involves the PFV to exclude specific layers after a certain amount of percentage overlap between two textures (the textures need to be separated through paint layers — the paint layer allows the PFV to separate them).

Forest environments use PFV to spawn trees in the skirts of the plateaus, with a special grass in the less nutrient-rich areas of the forest (able to be seen on the side of the map).

On the plateaus the main vegetation is grass and bushes, as well as other flowers and berries. Due to the laws of nature, as a lot of smaller species are unable to grow close to trees due to a lack of nutrients — the forest environment realism down to the level of even the smallest elements of foliage.

Lava

Lava is created through the use of splines and a plane with a dynamic texture. The spline stretches the plane between its points. This gives the impression of slow movement, however this can look inconsistent. In theory, this could easily be fixed by creating a new spline when a certain distance is reached. However, the inconsistent stretching reduces the realistic aspects — the Volcano island is meant to provide a lower-level of realism. This is also the reason for the lack of contacts in the lava (allowing users to 'swim' in lava).

Sounds

Sounds are created from a cue which consists of multiple materials which are randomised and put on repeat. This ensures that the player gets a different sound when they enter a sound zone they might have already experienced.

A feature of particular note, sound is attenuated based on the distance and direction of the source of the sound. Effectively this dictates from which direction (i.e. which headphone) and how loudly sound is heard by the user. This is present in the Volcano crater, and with the wind in response to the terrain topology: if the engine cannot create a vector between the middle of the source of the sound and the player, it reduces the volume of the sound to ten percent of the original volume.

While this is sufficient for a game with only a single player, the intention is to develop more complex environments, including animals (e.g. birds). The cue and the attenuation can be mapped into a blueprint which ensures that when more complex moving NPC components are implemented, they will not activate the sound as the blueprint recognises only the first person character — resulting in better performance.

Blockers in development & future/ongoing work

A major reason for stagnated development is driven by the lack of support of Nanite. Nanite is a tool which is crucial for efficient rendering in UE5. It allows for massive amounts of polygons to be displayed for a relatively low performance cost.

As of this point in time Nanite isn't working perfectly with foliage. This introduces a bug where the textures of leaves start to quite literally “float up”. Given the presence of leaves is mostly in the Forest Environment, which is intended to have the highest degree of realism, this is clearly not a bug which can be included in the level. Therefore, the wind function on trees has been disabled until an update is released.

On a personal note, I intend to learn more about blueprints, and how to work better with them. I have spent a considerable amount of time exploring an audio function that would be beneficial for the lava sounds, but I haven’t been able to implement two functions in the same blueprint.

Evaluation of the Study & Reflection on the Participants Answers

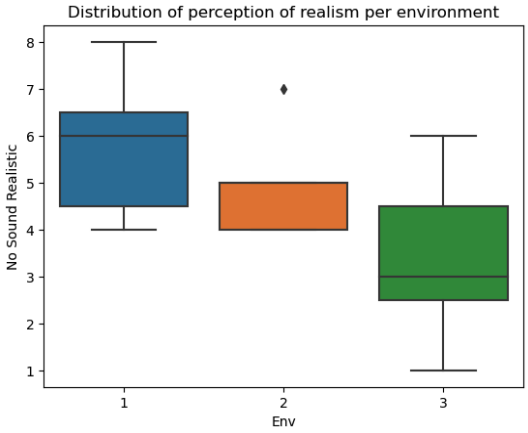
The evaluation section of the study is separated into two main sections — quantitative and qualitative analysis. Quantitative analysis is used to identify trends using statistics. The qualitative analysis section is used to discuss anecdotal findings (comments, suggestions) and outliers — for instance if a participant failed to understand the point of the study, suggestions about

Description of the participants

19 participants volunteered for the study with no inclusion/exclusion criteria – 12 were male and 7 female.

Quantitative Analysis

Participants agreed with realism ranking




```
For all tests, the null hypothesis is that the degree of realism for each environment is statistically the same.
Two sided T-test result that Env 1 is not as realistic as Env 2: Ttest_indResult(statistic=0.9073428958368971, pvalue=0.38618107482748376)
Two sided T-test result that Env 1 is not as realistic as Env 3: Ttest_indResult(statistic=2.498780190217697, pvalue=0.028948801599027477)
Two sided T-test result that Env 2 is not as realistic as Env 3: Ttest_indResult(statistic=1.7385284770782419, pvalue=0.11288836353998943)
```

Figure 21

Figure 21:(Top row) Boxplot displaying relative perceptions of realism, per environment. Legend::1: Forest; 2: Desert, 3: Volcano. Screenshot of t-test showing statistical significance.

There exists a clear indication (without participants having access to more than a single environment) that participants found the Forest environment the most realistic and the Volcano environment the least realistic. Due to the relatively small nature of the study, only the distinction between environment 3 (Volcano) and 1 (Forest) is statistically significant via a two-sided variance adjusted T-test at the 5% significance level (i.e. p-value < 0.05). Test statistics are shown above. However, the figure displaying box-plot clearly shows a trend in realism. For each environment, the mean, spread and range are displayed.

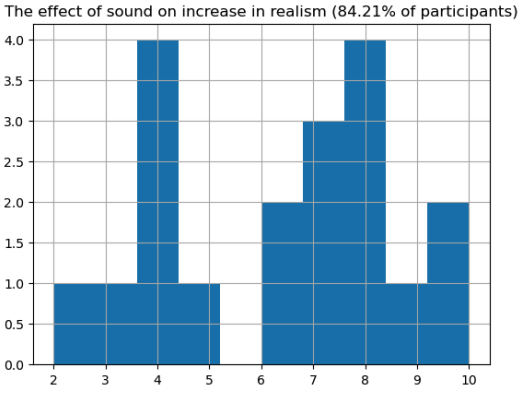


Figure 22

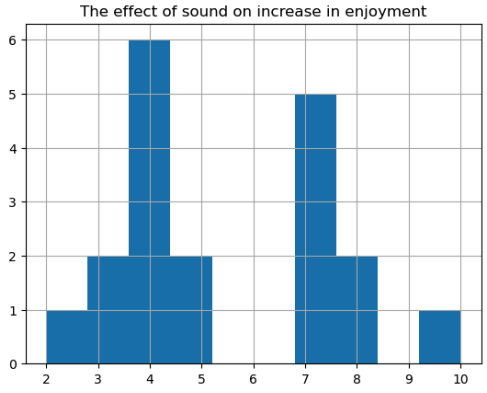


Figure 23

Figure 22: Histogram displaying distribution of the effect of sound increase on realism.

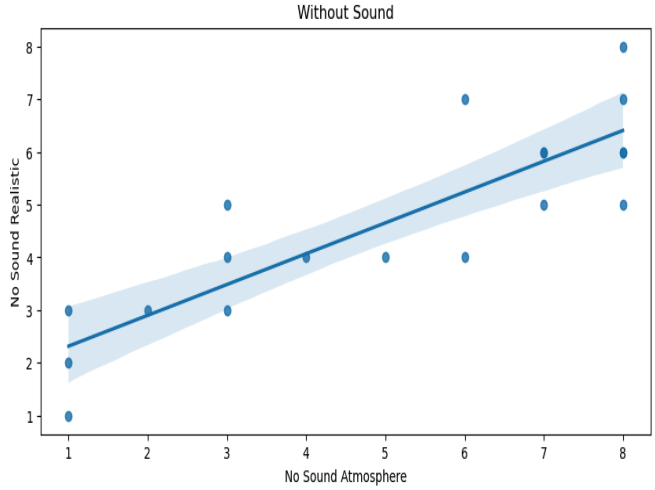
Figure 23: Histogram displaying distribution of the effect of sound increase on enjoyment.

Sound has an impact on realism

Greater than 84% of participants reported a positive impact of sound on realism. The effect was quite varied (shown in the histogram above), but almost universally reported to be positive. As such, we conclude that the addition of sound is definitively a part of (a multimodal concept) of realism in games.

Realism positively correlates with enjoyment and or immersion

Perhaps the most interesting question, one can see that while there was an increase in realism, this did not perfectly correlate to an increase in the enjoyment of the experience.

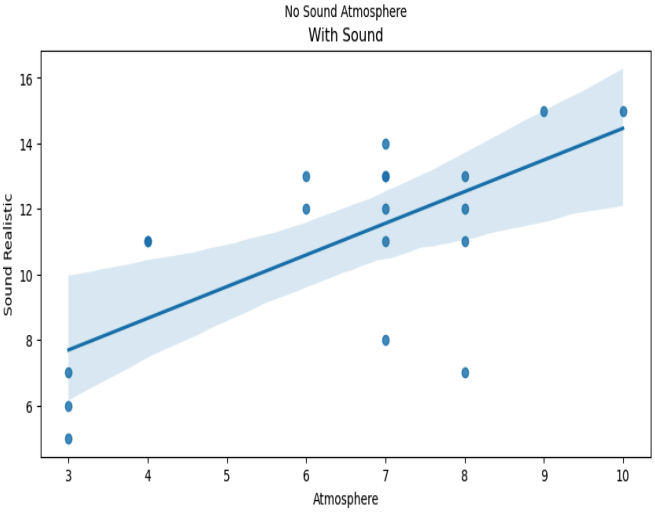


OLS Regression Results

Dep. Variable:	y	R-squared:	0.732
Model:	OLS	Adj. R-squared:	0.716
Method:	Least Squares	F-statistic:	46.41
Date:	Thu, 08 Jun 2023	Prob (F-statistic):	3.02e-06
Time:	00:45:24	Log-Likelihood:	-32.647
No. Observations:	19	AIC:	69.29
Df Residuals:	17	BIC:	71.18
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.8170	0.922	-0.886	0.388	-2.761	1.128
x1	1.2531	0.184	6.812	0.000	0.865	1.641

Omnibus:	0.557	Durbin-Watson:	2.116
Prob(Omnibus):	0.757	Jarque-Bera (JB):	0.589
Skew:	-0.059	Prob(JB):	0.745
Kurtosis:	2.145	Cond. No.	14.6



OLS Regression Results

Dep. Variable:	y	R-squared:	0.453
Model:	OLS	Adj. R-squared:	0.421
Method:	Least Squares	F-statistic:	14.10
Date:	Thu, 08 Jun 2023	Prob (F-statistic):	0.00158
Time:	00:45:51	Log-Likelihood:	-34.714
No. Observations:	19	AIC:	73.43
Df Residuals:	17	BIC:	75.32
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	1.2606	1.422	0.887	0.388	-1.739	4.260
x1	0.4691	0.125	3.755	0.002	0.206	0.733

Omnibus:	0.604	Durbin-Watson:	2.226
Prob(Omnibus):	0.739	Jarque-Bera (JB):	0.503
Skew:	0.352	Prob(JB):	0.778
Kurtosis:	2.625	Cond. No.	44.7

Figure 24

Figure 24:(Top row) Regression Plot (left) displaying correlation between enjoyment and realism, without sound. OLS Regression results (right) displaying regression statistics between enjoyment and realism, without sound.

(Bottom row) Regression Plot (left) displaying correlation between enjoyment and realism, with sound. OLS Regression results (right) displaying regression statistics between enjoyment and realism, with sound.

Above we show the regression results for enjoyment against realism, both before and after sound was added across all environments. While there is a clear correlation between enjoyment and realism before and after the addition of sound, the measures of fit decrease. This suggests that the explanatory power of realism on enjoyment is less important with the introduction of sound — effectively suggesting that when sound is added, things become more real, but that doesn't necessarily get translated one to one to increased enjoyment. This can be seen more clearly by box-plots (below showing increased enjoyment increases to the opposite ordering of realism (and enjoyment) with sound. Effectively, what the data seems to show is that while realism can negatively impact enjoyment, increasing audio can inversely increase the enjoyment. However, this increase in enjoyment is not solely due to the increase in realism.

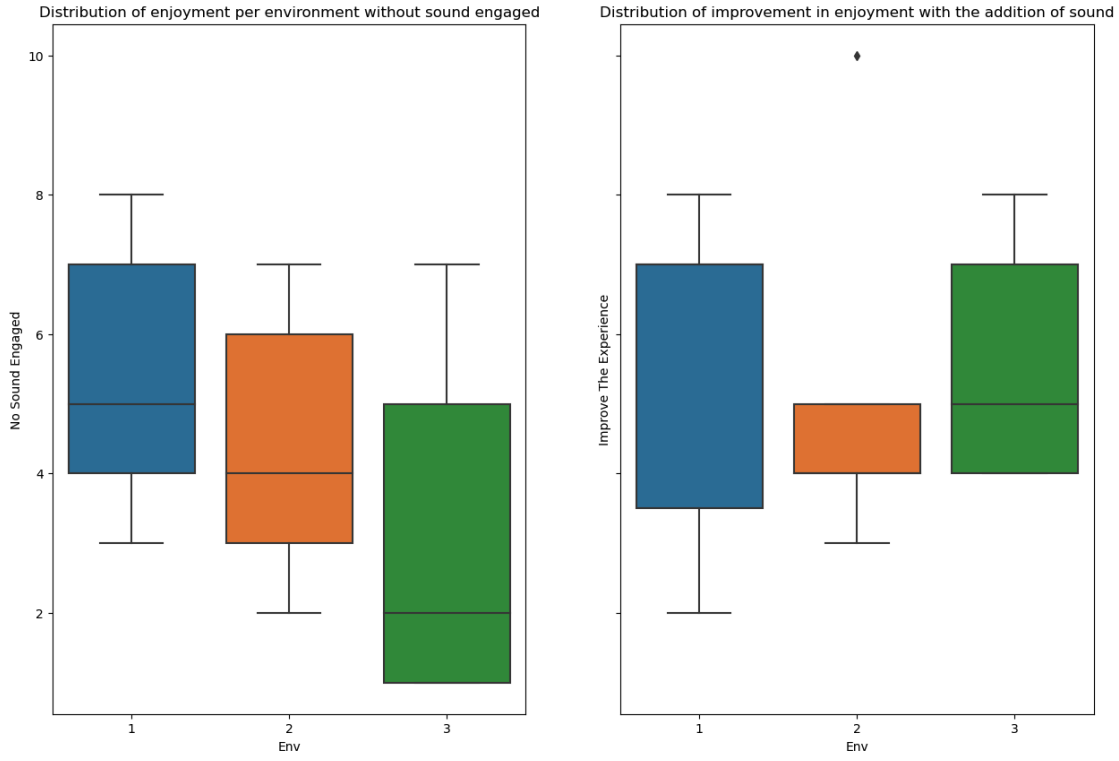


Figure 25

Figure 25:(Left) Boxplot of distribution of enjoyment, separated per environment,pre-sound. (Right) Boxplot of distribution of the change in enjoyment, separated per environment, post-sound. Legend:: 1: Forest; 2: Desert, 3: Volcano.

Qualitative analysis

A qualitative analysis is perhaps more revealing and allows a three themes to be identified.

1) **Realism doesn't necessarily mean interesting — variety seems to be the major driver of enjoyment.**

A core driver of this study is the somewhat murky relationship between realism and enjoyment. While the quantitative components are not entirely conclusive on this point, for a number of participants, it seemed clear that realism was often not the main driver of interest and enjoyment. However, often variety of objects and vivid colours were the aspects users were inclined to comment positively upon.

"*I enjoyed the environment and it looked realistic enough. I don't necessarily consider the most realistic environments to be the most captivating too. I liked the colours a lot, made me want to explore more.*" -- Forest participant

"I did like the exploration " - Forest participant

"I enjoyed exploring the environment - it wasn't repetitive. It was kind of calming. It wasn't hyper-realistic, but felt realistic." -Forest participant

Quite an interesting observation which can be made is that while realism was not consciously attributed as the reason for enjoyment, it was often present and said as an afterthought, rather than specified as a key driver for user engagement. For instance, both of the two quotes specified above were positive comments from the most realistic environment. This suggests that while realism isn't a conscious or primary reason for enjoyment, it is possible that it is a precondition of enjoyment and immersion.

However, other anecdotal evidence contradicts this —- suggesting that even features which are not deemed realistic can inspire enjoyment. For example:

"Exploring it was fun, went up the volcano and down to the seaside. The ground, sea, rocks were realistic. Less realistic: you can run through rocks, lava was blue (not red/orange), no steam when lava was flowing into the ocean." - Volcano participant

Further, a number of participants on the desert map, which is categorically deemed the least interesting (both before and during testing, but more realistic than the volcano map), commented that despite realism, the lack of variety limited interest.

"Environment was quite realistic (ground texture, rocks, shrubs) except for the trees, which looked very machine-like. The map was a little boring and repetitive and there weren't enough different features and colours for it to be engaging to me." - Desert participant

Effectively, what seems common across all maps is that a variety of features and stimuli was deemed engaging, regardless of perceived realism. Curiously, what seemed sufficient to be deemed varied depended considerably on the user, for example:

"I like the varied terrain and surfaces" - Desert participant

This quote is perhaps entirely different to the previous in sentiment — the desert was deemed to be both interesting as it varied, but uninteresting as it was monotonous.

Effectively, what seems to be common is that variety seems to be a key (conscious) driver of interest.

2) **Changes in sounds were often received well, indicating increased interest and enjoyment.**

In line with the previous theme, sounds were often perceived with a degree of interest (at least initially). Perhaps due to the change in stimuli, participants often commented on the sounds initially, but swiftly became used to them. However, some participants felt the sounds worth commenting upon as a topic of variety, which in turn led to more engagement and enjoyment:

"Environment was very barren, without sound I got bored quickly and felt monotonous" - Volcano participant.

Curiously, the Volcano was perhaps one of the more 'interesting' environments —- however, the direct link to sound and interest, and the indication that the addition of sound was the difference between boredom and interest strongly suggest (and is supported roundly by the quantitative analysis) that sensory input beyond simply visual stimuli is a considerably important factor.

It was clear from observing the actions of many players that often without a clear objective players would fixate on various aspects of the game — for instance, a number of players would focus on the visually vivid components (i.e. water/lava) and would continue to interact with this feature. This also became apparent with auditory features. For instance, a number of participants found the change in volume of sounds increasing/decreasing in line with distance from the sounds' source sufficiently interesting to explore, e.g.:

"The sea got louder the closer I got"- Desert participant.

This was also quite often the case when participants became aware of the wind (and the presence of wind-shadows, where the player hides behind an object, resulting in the sound of the wind dropping). Participants would quite often see this as some sort of hidden feature, and continue to experiment with the limits.

This behaviour was not limited simply to sensory components. Often participants would realise some (often unrealistic) component of the game's engine, and would continue to experiment with this — for instance, the lack of a player's ability to die: two participants attempted to kill the player by jumping off high ledges, deliberately trying to drown the character, and in the case of the Volcano, jumping directly into the lava. This is a particularly interesting observation in light of realism — i.e. players found an unrealistic element and focused upon this, despite a number of realistic components: suggesting that often the mixture of a world fitting a pre-existing mental model and a feature in the dynamics which didn't was a source of considerable interest and enjoyment. This directly goes against the general trend observed in the data — that realism roughly correlates with overall enjoyment. One potential way of blending these two conflicting pieces of evidence is that an unrealistic aspect in a (single) different modality can increase enjoyment, however an overall lack of realism in multiple modalities can reduce enjoyment. Further work is needed to explore this particular phenomenon.

3) **Participants often found that sounds helped with orientation.**

Conveying information to the participant via indirect means (i.e. via audio) is an area of interest. In the case of all maps, sounds were designed to provide a rough indication of orientation. A number of participants commented upon this:

"I am not sure about hazards. But I was more aware of where the water is." - forest participant.

"Quite a lot, without sounds sometimes I find it difficult to perceive distance." - desert participant.

"The sound of the sea helped navigate myself and warned me of a cliff" - forest participant.

In particular, the previous quote highlighted the use of sounds to avoid a potential hazard. Participants who commented on the use of sound as a method for conveying the position of an agent on a map tended not to comment on the effect of this on enjoyment. It seems an interesting phenomena that the realisation of the utility of a feature to some extent interferes with potential admiration/enjoyment of it.

"The ambient sounds really helped me in navigating around and exploring the environment. I was missing to explore the sea but the sound helped me by pointing in the right direction " -desert participant.

However, this was not an observation which is strictly supported by all participants, suggesting that this might be a simply a random artefact/feature present in this small dataset which is likely not to be repeated or significant in a larger trial.

Future Work & Conclusion

Future work

There are a number of aspects captured in the data which were not able to be explored sufficiently during this project. For example, one aspect would be to explore the change in engagement induced by a change in sound, as controlled for by environment, age, media-consumption and gender, and the resulting change in perceived realism.

While we are unable to provide evidence, we think that the influence of the type of media usually consumed might have a strong effect on the concept/view of realism. Hence, we believe that participants who typically consume more than the average amount of animated material (i.e. Anime) are likely to have a statistically different viewpoint on what is deemed ‘realistic’ and the knock-on effects on enjoyment and immersion. Future work would involve firstly performing more statistical analysis on the data we have collected. The second step would involve further trials which would explore different aspects of audio-realism — for instance the effect of audio on more and less realistic environments, than those developed for this project (i.e. ranging from 2-dimensional maps) to hyper-realistic environments. Finally, we intend to explore the use of deliberate comedic combinations of realistic/unrealistic features on enjoyment — introducing entirely unrealistic audio for realistic environments. We believe this is likely to paradoxically increase enjoyment, despite the conclusion of this study indicating that realism and enjoyment are positively correlated. The exact limits of this phenomena would be interesting to explore.

Conclusion

This study explores how altering the audio experience of a player affects their perception of realism in realistic environments.

Three realistic environments were created using state of the art tools. Participants were then invited to explore the environment and then provided a detailed description of their thoughts and perceptions via a survey. Through statistical and general forms of evaluation, we have identified a number of major themes which are roughly in line with what one

might expect from a review of the relevant literature. We briefly list the relevant contributions here:

1) The most realistic environment was deemed the one participants were the most familiar with, with reasons for it being unrealistic features which were deemed unrealistic, despite real validity — suggesting realism is subjective.
2) Sound has a positive impact on realism, but a higher increase in environments which are perceived as less realistic. We posit that sound therefore is an important factor in realism, but is particularly pertinent for games which are not hyper-realistic in the middle-end of the scale.
3) As one might expect, realistic environments which are featureless swiftly can lose their interest — further supporting the argument that realism alone is not sufficient for audiences. In contrast, a variety of all aspects of games, including visual, auditory, and even unrealistic physics features can drive interest.

While this study cannot reach a strong conclusion as to the absolute driver of realism, it lends weight to the concept that realism is a subjective and highly personal matter. It further supports the idea that realism is a multifaceted component which applies across a number of dimensions, including auditory, and realism is intrinsically linked to enjoyment. However the relation of enjoyment to realism is far from straightforward.

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Appendix

First Part of Questionnaire Answers

Env	Gender	Age	Gamer	Hours	Realistic-current	Anime	Hours_spend_TV
1	2	23	2	1	6	3	10
1	1	27	10	30	7	5	20
1	2	29	2	1	7	1	7
1	1	25	3	1	8	15	15
1	1	25	7	0	3	5	2
1	2	29	7	2	6	14	30
1	1	26	8	5	4	3	2
2	2	26	1	0	0	2	10
2	1	34	6	19	5	2	1
2	2	28	1	0	0	1	5
2	1	26	8	4	5	5	6
2	1	28	4	0	7	6	21
3	1	24	5	0	0	3	4
3	1	26	9	15	6	14	3
3	2	23	5	5	3	5	10
3	1	26	5	1	6	3	4
3	1	30	7	10	2	2	10
3	1	30	9	5	4	4	5
3	2	30	1	0	0	3	10

Second Part of Questionnaire Answers

No_Sound_realistic	No_Sound_Atmosphere	No_Sound_Engaged
6	8	7
5	3	3
7	8	5
8	8	8
4	6	3
6	7	7
4	5	5
5	8	7
4	4	3
5	7	6
4	3	2
7	6	4
1	1	1
6	7	6
3	1	1
3	2	1
3	3	4
2	1	2
6	8	7

Third Part of Questionnaire Answers

More realistic with sound	More or less immersed	Improve the experience	Prefer with or without sound	Impact of sound	Matching
1	1	7	1	7	8
1	1	7	1	8	9
1	1	7	1	8	10
0	0	4	1	4	7
1	1	2	1	4	9
1	1	8	1	7	7
0	1	3	1	2	4
1	1	10	1	10	10
0	1	4	1	7	5
1	1	4	1	6	7
1	1	3	1	3	6
1	1	5	1	5	6
1	1	4	1	4	4
1	1	7	1	8	9
1	1	4	1	8	5
1	1	5	1	4	7
1	1	7	1	10	8
1	1	8	1	9	9
1	0	4	0	6	8

Atmosphere	With_sound_engaged	Distance and Depth	Sounds as a clue	
6	5	10	10	
7	10	10	10	
10	10	10	7	
8	8	2	2	
7	6	2	2	
8	8	6	7	
3	5	4	6	
9	8	10	10	
4	4	0	0	
7	7	6	6	
3	3	2	10	
6	5	3	3	
3	4	4	4	
7	8	10	8	
4	4	4	3	
8	7	9	6	
7	7	10	10	
8	8	0	8	
7	7	6	8	