Aural Architects: Exploring Professional Practice in Videogame Audio

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ABSTRACT

The videogame medium is young and rapidly evolving, and many areas of videogame audio practice are under explored. This project utilises qualitative semi-structured interviews with current industry professionals as a means of uncovering and comparing approaches to the creation of immersive videogame audio, with a focus on game mixing approaches, compositional approaches, and the effect of middleware and game audio creation tools on audio outcomes. The findings from this research contribute to understanding the creative processes used in the creation of videogame audio and identify implications for practitioners. The interviews highlighted many trends in game audio, including the increasing multi-disciplinary nature of the industry, the pervasiveness of audio middleware, the broadening of the game composer role, how audio mixing techniques differ from other mediums, practitioner perspectives on immersion in videogames, and the influence that game audio tools have on audio outcomes.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**;; • **Social and professional topics**; • **Professional topics**;; • **Applied computing**; • **Arts and humanities**; • **Sound and music computing**;

KEYWORDS

Game audio, audio middleware, sound design, composition, immersive audio, game mixing

1 INTRODUCTION

Divergent from cinema and other fixed playback media, the videogame medium comes with a unique layer of complexity: interactivity. Where the playback of a film is predetermined and playback is identical each time, every playthrough of a videogame will be unique. To capitalise on the interactive nature of the medium, a composer or sound designer should be familiar with techniques

and approaches that function effectively in a reciprocal environment. Additionally, with immersion being a core concept of the medium, compositional and sound design approaches that create or further player senses of immersion are of particular value. This research project investigates current approaches and techniques used by game audio professionals in the creation of audio content for immersive sonic environments in games.

2 GAME AUDIO PRACTICES

2.1 Composition

Considered an important ingredient in the recipe for a successful videogame [1], music is incredibly prevalent in modern videogames. Winifred Phillips, highly acclaimed game composer and author on the topic of game audio, poses the simple yet obvious question: "why do video games have music?" In answering this question, she writes about the importance of music as a contributor to state of mind, or the zone, where "...games require a specific mindset to play them effectively." According to Phillips, the zone is where a gamer is experiencing a "... sensation of perfect focus..." and is experiencing a state of total immersion in the game. This experience is a large part of what makes videogames so enjoyable to play, and music plays a crucial role in making this sensation more accessible to the player by contributing to the environment in an inviting way.

To ensure that the music created can be as adaptable as the medium requires, game composers employ a range of techniques to help them accomplish this including:

- Vertical layering: a technique that shares similarities with mixing music, where the music is kept as a collection of recordings that make up the different layers of the piece. Instruments and layers can be brought in and out in real time in response to information received from the game engine [2].
- Horizontal Resequencing: where a piece of music is constructed as a collection of segments that each represent discrete chunks of a composition in the time domain [3]. These chunks can then be arranged in real-time by the game's audio engine to adapt to what is happening in game [4].
- Imbricate Audio: where very short chunks of music, e.g, 2 second phrases played on a piano, can be pre-rendered with reverb tails included that "results in a densely modular matrix of musical 'chunks' which can change states quickly while still preserving the integrity of the instrument sounds used" [5].

2.2 Sound Design

In the videogame medium sound design is multifaceted, fulfilling both a functional gameplay role and an immersive role [2]. Functionally, sound design provides the player with cues for in-game actions and events so that they may better respond to what is happening in game.

Sound design also fulfils an immersive role, fleshing out and bringing to life the world around the player. Sound design of this nature furthers the cohesiveness of the in-game world by ensuring that there are appropriate auditory responses to in game events [6].

2.3 Immersion

Immersion is integral to the videogame medium and is considered to be a main contributing factor to their entertainment value [7]. Audio plays an important role as a contributor to state of mind, helping to get the player into the right headspace to engage with the content [1]. Immersion is a complex mental and emotional state which is difficult to measure, although there have been attempts to do so [8]. Lee [9] breaks immersion down into three parts:

- Physical Presence, being disassociated from the physical world and having a sense of being in the presented world.
- Social Presence, defined as the sense of being together and interacting with another intelligence.
- Involvement, a mental and/or physical engagement in a task or an activity.

2.4 Implementation

2.4.1 In Engine. In engine implementation refers to a game's audio being implemented in the game engine itself. Before the advent of middleware, this was the only way of integrating audio into a game, making audio programmers a requirement for game production. The specific methods of implementation vary depending on the engine, but in a basic engine, significant programming knowledge would be required to implement audio in a way that meets the expectations of a game in 2024. Some engines are more comprehensive and already have capacity to handle audio built in.

2.4.2 Middleware. In game audio, the term middleware refers to software that communicates with, and sits adjacent to, a videogame's engine, and handles tasks from a specific area such as the physics, graphics, networking, or audio [10]. Audio middleware aids game makers in implementing their music and sound effects into a game, allowing the audio team to attach sound files to a game environment and to be able to determine the interaction of those files with other elements of the game environment. Some of the functionality that middleware provides includes easier access to pitch variation, sample granitization, beat syncing, and transition implementation. Middleware's primary value is that it enables developers to make games more quickly and easily, enabling designers, who tend to not have high levels of programming knowledge, to do more of the audio implementation themselves. To facilitate this, audio middleware has a visual interface so designers can interact directly with the game world without needing to use a programming language.

2.5 Mixing

Audio mixing is an iterative process where sounds are shaped, placed, processed, and balanced to build a sonic experience that best represents the artistic vision of the creator [11]. Videogame mixing and music mixing share a similar objective: balancing the audio palette in a way that allows each sonic element to shine without overcrowding any frequency band. However, outside of this common goal and conceptual similarities, there are quite a few differences in the mixing practices for each medium [1]. Given the dynamic nature of the videogame medium, mixes for games need to be active structures that can adapt to the player's actions and adjust the mix to be appropriate for the current game state. Middleware such as Wwise can be helpful for building these structures and relationships, but it is not a strict requirement for game mixing.

3 METHOD

This project involves conducting qualitative semi-structured interviews with industry professionals to gather information on their practice and work in the industry. Compared to similar entertainment mediums like film, the field of videogame audio is young and quickly evolving, leading to a gap in knowledge of current practices. To address this gap, this project employs qualitative semi-structured interviews to gather up-to-date and industry relevant first-hand information. Going to the source with interviews with a broad spectrum of practitioners allows the project to capture a snapshot of the current state of the industry.

This project utilises Thematic Analysis (TA) as outlined by Braun and Clarke [12]. For this research project, TA provides several benefits, namely its flexibility and applicability to diverse data sources. As the direction of the project will be shaped by the outcomes of the interviews, flexibility and applicability to diverse data sources are of particular value. Additionally, as the interviews and analysis are conducted by the same individual, the role of reflexivity in TA is of particular value.

Thematic Analysis is an iterative process involving initial data familiarisation, coding, and the identification and review of core themes related to the research focus. The qualitative analysis software package NVivo 12 was used to aid the process. After the transcription of the interview recordings was complete, the analysis began using the following 6 step method for Thematic Analysis:

- 1. Familiarising oneself with the data
- Immersing oneself with the transcripts to ensure a thorough understanding of the data and make initial observations.
- 2. Generating initial codes
- Systematically identifying and labelling meaningful sections of the data to break it up into more manageable parts.
- 3. Searching for themes
- Examining the codes and grouping them into themes that reflect commonalities or patterns in the data.
- 4. Reviewing themes
- Refining and consolidating the themes, to ensure that they are relevant, distinct and meaningful.
- 5. Defining and naming themes
- Developing clear names that accurately represent the relationships that they contain.
- 6. Producing the report

- Writing up the analysis findings and presenting them in a clear and engaging way.

The research questions pursued in this project are:

- 1. How do the tools used in the creation and implementation of immersive game audio influence the creative process?
- 1.1. What influence has audio middleware had on the production of videogames?
- 1.2. What are the limitations of current immersive game audio tools?
- 2. What are the emerging professional approaches to mixing in game audio?
- 3. How do game audio professionals define and measure 'immersion' in video games, and how are they using audio (especially spatial audio) to enhance this immersion?

The interviewees in this project are a selection of professionals involved in videogame audio from a wide variety of roles, including game composers, sound designers, audio programmers, audio leads, game mixers, etc, and have been chosen to represent different parts of the widely varying industry. In addition to individuals spanning many roles, the interviewees have been picked to represent three basic categories of the industry:

- Indie, games of a smaller scope usually made by a handful of individuals with little funding or as a passion project
- III, games made by a small game studio with a moderate amount of people and resources involved
- AAA, higher profile games made by large teams from major game studios with significant funding and resources.

The interviewee pool also contains practitioners who work predominantly in specific roles as well as those who work across a variety of roles depending on the project. This research project aims to capture a global perspective, having already had interviewee candidates from Australia, USA, Canada, France, and the UK, and has (as of 2024) accumulated around 13 hours of interview data with 11 participants. The following sections outline the key themes identified through the interview analysis process.

4 FINDINGS

4.1 General

Most of the game audio practitioners interviewed in this project had worked in several different roles in the industry, and crossover between roles was quite common. Practitioners many times got into the field by combining a passion for music with a passion for videogames, often starting with aspirations for writing music for games, before diversifying into other areas of game audio. The generalisation of practitioner's work seems to lead to breadth and familiarity with a wide range of roles, which appears to be quite beneficial to the practice of game making.

The game audio field often includes work that is both very technical and very creative. Generally, practitioners who are able to bridge technical and creative work are highly sought after, yet relatively uncommon. Established composers with advanced implementation skills were particularly referenced as being in demand. Interviewees with industry experience dating back decades were able to provide insight that, in the earlier days, this was not the case, and composers tended to stick to writing musical assets, and tended

to be less involved in the implementation than they are today. As the games industry has developed over time, so too has the depth of the games produced, leading to a more complex environment in which previously established roles may no longer best address the requirements of game making. This blending of roles is often beneficial, particularly when bridging a creative environment like musical composition with a technical one like audio programming. Practitioners with these skills will have a better understanding of the practices and limitations of a technical environment, and therefore be able to ingrain their compositions more deeply in a game.

4.2 Middleware

Generally considered ubiquitous in the modern game audio industry, middleware tools are very commonly used. 9 out of 11 interviewees reported having used either Wwise or Fmod on a project, and even the two participants who hadn't used it in a work project still had a basic understanding of how to use it and what it does.

In the current videogame audio landscape, it appears that familiarity with audio middleware is a very commonly expected skill among practitioners, although the extent of this requirement appears to vary across different positions. For certain roles, such as sound design and roles that came with a greater technical workload, middleware knowledge appears to be a more critical requirement, as indicated by one participant involved in hiring: "When I've interviewed in the past, we would pretty well dismiss someone who didn't have any experience at all [with middleware]." Other commonly expressed sentiments include "It's been a long time since we worked on a project that does not use middleware…", and "…I think you can't really work in game audio and not have an awareness of game audio middleware." These statements reflect both the frequency with which audio middleware is used in game making, as well as its perceived necessity.

While success can be found in composing music for videogames without middleware knowledge, such instances seem to be diminishing in frequency. The trend towards a demand for composers who are proficient in middleware usage suggests a shift in the industry towards a more integrated approach to game audio production.

Given the widespread nature of its usage, middleware skills likely enhance employability, especially for those new to the game audio industry. Fortunately, middleware knowledge is readily accessible, with tools like Wwise being free for use in smaller-scale projects, allowing individuals to develop their skills in practice projects. Additionally, courses and tutorials to extend one's skills are readily available. These sentiments were best put by one practitioner, "It's not hard to get experience, even if it's just work you've done. But if you've shown no effort…" This quote highlights an expectation for proactive engagement in the development of middleware skills.

When it comes to audio implementation, middleware is not a technical requirement. Middleware does not allow for anything to be done that couldn't otherwise be done given enough time, resources, and programming knowledge. The value of middleware comes from its ability to provide an improved audio workflow experience for game engines. Middleware primarily provides

convenience, making many facets of game audio implementation smoother, quicker and easier.

One area of significant value that middleware provides is its ability to make advanced audio implementation more accessible and less time consuming to achieve. Out of the box it provides an extensive set of tools to allow a practitioner to use in their practice. This saves time and resources that would otherwise be spent designing and creating a bespoke set of tools or code needed to fulfil the same functions. Manipulating audio playback to create a complex and game state influenced sonic environment is therefore much more achievable for a small or medium sized team, who likely wouldn't have the resources to create a system to handle it on their own.

While audio middleware can save time and resources in the development stage of a game project, its vast functionality results in it being a deep and complex software package. While professionals that regularly engage in implementation work tend to have a good grasp on its functionality, mastering the software can require considerable use.

Continuity between consumer game platforms is valuable, as many teams work on games intended to ship to multiple platforms. Wwise's object-based audio system aids multiplatform development and allows for a uniform approach to handling audio across the many platforms it supports, improving the multi-platform shipping experience. However, while Wwise offers a consistent audio processing framework, adapting audio projects from more powerful platforms, such as PCs, to less powerful ones like the Nintendo Switch, often requires modifications. These alterations can be substantial, with one interviewee sharing an experience where they had to cut the sample rate from 48KHz down to 24KHz, along with a complete re-mix, to save enough CPU usage for the game to run as intended.

While this project primarily deals with Wwise, the emergence of the audio middleware software Elias is an interesting development. Aimed at offering a new approach to implementing audio, Elias is designed to handle the processes involved in a way that leverages creative practice. Audio implementation in videogames can be quite technical in nature, which can pose a challenge when trying to stay in a creative headspace for a project. Elias attempts to address this by providing a set of tools that change the way a game audio person interacts with the implementation of music and sound in the game, incorporating some of the technical parts in a way that involves them in the creative process.

4.3 Tools

The practitioners interviewed firmly felt that tools used on a game audio project play a considerable role in shaping the final audio outcomes. This research project aims to provide insights into how these tools facilitate and guide the creative processes involved in game audio development.

Tools appear to provide a framework of creative limitations, shaping the direction and possibilities of the audio outcomes by imposing a set of boundaries. Often, there can be an initial lack of concrete ideas about what can and should be achieved in terms of audio. In such situations, the tools available to the audio team become influential in guiding the creative process, ultimately influencing the direction of the audio design.

Similarly, the tools available for a project set the parameters for what can and can't be achieved, to a degree. Teams that work with proprietary engines, generally AAA teams, exhibit a higher degree of flexibility in this context, as they can often tailor and expand their tools to align with their vision for the creative goals of the project. In contrast, teams that rely on established middleware can face more constraints due to the predefined nature of these tool sets. However, two interviewees noted that AudioKinetic, who develop Wwise, are receptive to feature requests, and have worked with teams in the past when features weren't working as intended, or extension was requested.

The usability and approachability of game audio tools was an area of note for many participants as well. Many practitioners perceived the audio tools in game engines as being more programmer-centric, rather than audio-centric, in their design and functionality. One practitioner said the Unreal engine used terminology that was not consistent with other areas of audio and game audio practice, leading to experiences where things were not working as they had intended.

Several interviewees said that the increase in quality of consumer audio playback devices, especially in console gaming, influenced their practice. A shift from built-in TV speaker audio to the use of headphones, which on modern consoles can be directly connected to the controller, has led to a change in priority for the game mixers interviewed. The interviewees involved in game mixing shared that, like for PC games, they now mix console games primarily for headphones, and secondarily for TV speakers. The audio professionals also expressed appreciation that the improved systems will allow their mixes to be appreciated in greater detail.

4.4 DSP

When asked about the issue of processing headroom, practitioners described varying levels of concern, depending on factors such as the target platform and the scope of the project. For game development on platforms like PC or 5th gen consoles, where processing capabilities are typically higher, concerns about processing budget were less prevalent. Conversely, those working on games for platforms with more limited processing power, such as the Nintendo Switch, were more likely to require a careful approach to audio production and implementation to ensure efficient use of available resources.

The other main factor influencing the practitioners' consideration of processing headroom usage was the scope of the project. In smaller or indie game projects, there was often less concern about exceeding the processing budget. In contrast, projects made by AAA studios tended to be larger in scope and therefore require practitioners to be more mindful of DSP usage. In these projects CPU usage was more likely to be a limiting factor.

Interestingly, even in cases where low CPU usage was important, higher CPU average usage was still preferred over higher peak CPU usage. One participant explained that it is better to have your audio processes set up in a way that avoids sudden spikes in usage, as spikes can lead to stuttering and other issues when playing the game.

Regardless of whether processing headroom was regularly a limiting factor for practitioners, effective management of resources is an important part of good practice. Being involved in decisions regarding resource allocation likely helps to provide a better understanding of the project's constraints and allows for advocating for the audio department's needs, aligning it more closely with the project's overall vision.

There is always DSP happening at runtime and most commonly it is used to create artificial space in the game audio that represents the physical characteristics of the game space. In practice, this means applying delay and reverb effects to elements of the sound design. When CPU budget is of a premium, delay was favoured by practitioners, as it can achieve similar results without taking as much processing power. Practitioners also described using lower fidelity DSP for less important sounds, like those that are further back in the mix, to save budget for sounds that are at the centre of the player's attention.

4.5 Mixing

In game audio production, the practices and methodologies differ substantially from those of traditional music production. The process of game mixing is less about the conventional approach of balancing audio tracks and more about creating complex hierarchies and bussing structures. These structures are designed to dynamically interact with the game's parameters, such as volume, spatialization, and effects processing, allowing audio elements to respond to the game environment and player actions, effectively creating a mix that adjusts to the game state.

High dynamic range (HDR) audio is an approach used in videogame mixing to increase the perception of the dynamic range available. As a game's mix gets busier, volume becomes a premium as more sounds fight for space to playback at the same time. This can result in an audio experience that can fluctuate between being too quiet and too loud. With an HDR mixing approach, louder or higher priority sounds will duck the volume of quieter or less important sounds to fake the experience of hearing more dynamic range than is available, being capable of compressing approximately 190 dB, into 96 dB.

HDR audio systems have often been designed by audio implementers in-engine, often proprietary. AudioKinetic have their own implementation of this available in Wwise, however it had not been used extensively by any of the interviewees in this project. The interviewees that had tried it characterised it as analogous to a "secondary set of controls," which some found difficult to work with. The system imposes a layer of dynamic processing that can affect the overall mix in a way that is not always predictable or desirable for the audio designer. One compared it to "mixing music with heavy compression on the mix bus." Due to these considerations, some practitioners advocate for manually building dynamic audio hierarchies, rather than relying on the Wwise HDR system, offering more granular control over the audio mix.

4.6 Immersion

The concept of immersion in video game audio, as described by the interviewees, typically encompassed three key components: suspension of disbelief, flow state, and emotional engagement. Media that possesses all three components seems to lead to maximising the immersive experience of the player. The three components that came up in the interviews were similar to the three components described by Lee in A Conceptual Model of Immersive Experience in Extended Reality [9].

Practitioners generally described Suspension of disbelief as the plausibility of the game world, enhanced by environment accurate details such as having forest foley in a woodland area. Flow state was generally described in line with the concept of flow as described by Mihaly Csikszentmihalyi, "a state of concentration so focused that it amounts to absolute absorption in an activity" [13]. Flow is often tied to engagement in an activity, and practitioners felt that audio can aid in increasing the accessibility of flow state for a player by making the game experience more cohesive, accessible, and engaging. Interviewees described emotional engagement as resonating with the game content on an emotional level, encouraging the player to be invested in the outcome of the game they are playing, and is often supported by the game music itself.

Interestingly, few participants articulated all three components when describing immersion. Most participants described two of these components in detail when discussing immersion, possibly influenced by the nature of the games each individual tended to work on. This variance points both to the multifaceted nature of immersion in gaming, and to the lack of a universal definition among practitioners. Most know what it is like to experience immersion in a game, but few have a deeper understanding of its components.

One practitioner viewed immersion as an outcome-driven concept, closely tied to the objectives of the project, suggesting that the facets of immersion that are prioritised can differ depending on the goals of the project. This variability in approach to immersion could be likened to the difference in auditory experiences between a high-octane action movie and a subdued and serious war documentary. While both may strive for an immersive experience, the former often emphasises sensory impact, whereas the latter might focus on authenticity to the source. Similarly, in the gaming context, the type of immersion sought in an arcade-style racing game like Mario Kart and a simulation-focused driving game like iRacing differs.

In the discourse surrounding immersion, there is a notable distinction between audio that is characterised as "realistic" and audio deemed "believable." These terms, while frequently used interchangeably in discussions about game audio by consumers, encapsulate distinctly different concepts for game audio. "Realistic" audio refers to sound that faithfully replicates real-world acoustics, adhering to the physical properties and behaviours of sound. Naturally, this style is often pursued in simulation games that aim to closely mimic reality. Conversely, "believable" audio may not necessarily conform to the exacting standards of realism but instead seeks to create a sound environment that is congruent with the game's setting and narrative. Given that videogames are almost always intended to be fun to play, this is a worthwhile distinction, as game features that are realistic aren't always fun to play. One notable example of this is the volume of footstep audio in First Person Shooter games, which is often comparatively louder and more perceptible than in real life. Without this change players could struggle to perceive their enemies, leading to less engaging and enjoyable gameplay. Regardless, sound design in games is typically

employed to fulfil player expectations. When a player interacts with the game world, they expect there to be a consequence to their action, and audio has a primary role in communicating this.

4.7 Composition

The interviewees suggest that the scope of work subsumed under the title of game composer is so varied that it can lead to significantly different professional perspectives on what it means to be a game composer. One interviewee, who is actively engaged in this line of work, even remarked that, "we're not doing the same job" when comparing his practice to the practice of others. This statement was not intended as a critique of the work performed by others, but rather as an observation of the diverse nature of the role.

"Game composer" appears to function as an umbrella term used to represent work in composition, sound design, and implementation. The diversity within the role reflects the multifaceted demands of audio in game development, acknowledging that the skill set and creative output required of composers can vary widely based on the needs of the project. One interviewee suggested the term "Music Design" as what they felt was a more accurate representation of their role, which included implementation, adding more specificity to differentiate from Game Composer.

Many interviewees felt that game audio implementation should be seen as an extension of the composition process. This view advocates for a holistic approach to creating game music, where the embedding of music into the game's mechanics is seen as part of the creative composition. Recognizing implementation as part of composition encourages a design thinking that further considers music's interaction with game dynamics from the beginning, likely leading to better outcomes. This holistic approach requires composers to be familiar with both the creative and technical aspects of game audio production.

Similarly, over the past two decades the relationship between game developers and game composers appears to have become transactional. Developers appear to be increasingly favouring "music designers" or game composers who play a more involved role in the development process, as opposed to simply handing over their audio assets. Creating music systems that are relevant to and involved in gameplay was a recurring theme.

5 CONCLUSION

5.1 General

Interviews with game audio practitioners highlight a trend towards multi-disciplinarity in the industry, with many entering through a combination of musical interest and gaming passion, eventually broadening their skill set beyond just composition. The industry values versatility and a blend of technical and creative abilities, with a growing preference for professionals proficient in both composition and audio implementation. This marks a shift from earlier practices, reflecting the increasing complexity of video games that demand a more integrated audio approach. Skills in both music creation and technical implementation are now essential for embedding audio effectively within the game's interactive framework.

5.2 Middleware

Audio middleware has become a staple in modern game audio production, with industry practitioners emphasising its ubiquity. Middleware is not a strict requirement for a game project, but it is likely to increase the speed and ease of which audio can be implemented. Wwise was by far the most used middleware by practitioners, and middleware knowledge also appears to boost employability. Familiarity with middleware appears to be increasingly prevalent and regarded as an important skill in the videogame audio industry, with some variation in its perceived importance based on the role of the practitioner. This trend reflects a growing emphasis on technical capabilities alongside traditional musical skills in the field. The industry appears to be moving towards a paradigm where a combination of musical talent and technical proficiency in middleware is highly valued. Audio middleware democratises access to advanced audio implementation techniques, making sophisticated audio design possible even for smaller teams.

5.3 Tools

This research explores the impact of production tools on game audio outcomes, emphasising that the choice of tools significantly shapes the creative process and final audio design. Practitioners highlight how tools not only guide initial creative decisions but also define the possibilities and limitations of what can be achieved in game audio. The distinction between proprietary engines and established middleware also impacts audio development, with proprietary tools generally offering greater customization for a project. Some practitioners noted that the design of game audio tools can be programmer-centric, which can complicate audio-centric work. Technological advancements, such as improved data streaming, have helped ease some historical limitations faced by practitioners, like storage constraints, reflecting the industry's ongoing evolution. Additionally, the improvement in consumer audio playback devices, especially controller-headphone compatibility for consoles, appears to have shifted mixing priorities towards a headphones-first approach.

5.4 DSP

Practitioners in game audio production noted that considerations of DSP and processing headroom vary with the target platform and project scope. Higher processing capabilities on platforms like PC allow for expansive DSP use, whereas platforms with limited processing, such as the Nintendo Switch, necessitate cautious DSP application to manage resources effectively. The scope of the project also influences DSP management. Smaller indie projects are less likely to worry about processing constraints, whereas AAA projects were more careful with DSP usage to prevent CPU overload. Techniques that lead to stable CPU usage were prioritised, as CPU usage peaks can cause gameplay issues like stuttering. Active involvement in resource allocation decisions enables audio teams to align closely with the project's vision and ensure the audio department's needs are met. At runtime, DSP usage varies, primarily enhancing the game world through spatial effects like delay and reverb. Delay is valued for its lower CPU impact than reverb, and applying lower fidelity processing to background sounds can help optimise DSP within processing limits.

5.5 Mixing

Video game audio mixing significantly departs from music and film mixing approaches, emphasising the use of adaptive hierarchies and bussing structures to control playback, instead of manual track balancing. This method allows sound elements to interact with the game world dynamically, responding to player actions and environmental changes, and offering an evolving audio experience unique to gameplay. High dynamic range mixing, employed to manage competing sounds in complex audio environments, dynamically prioritises sounds to maintain clarity in the mix. It is a useful technique when employed, and to some degree a consequence of a dynamic game mix. Despite its effectiveness, the implementation of HDR in middleware Wwise received mixed feedback, with some practitioners finding it difficult to use, and preferring to manually manage its implementation for better control over the mix.

5.6 Immersion

The concept of immersion was described by practitioners as having three components: suspension of disbelief, flow state, and emotional engagement. Interestingly, these components are very similar to the three mentioned in Lee's immersive experience model [9]. Practitioners tended to place unequal emphasis on these components, possibly a reflection of the type of projects they work on frequently, as different types of games lean more on some components than others. Experienced practitioners differentiated between "realistic" and "believable" audio, with the latter often prioritised for enhancing gameplay. Realistic audio aims to replicate real-world sounds precisely, while believable audio supports the game's narrative and setting, sometimes amplifying certain sounds to improve the gameplay experience. Audio typically plays a supportive role in games, focusing on fulfilling player expectations and reinforcing gameplay actions with appropriate sound feedback. This leads audio to complement, rather than dominate, the gaming experience, highlighting its role in crafting immersive and engaging game environments.

5.7 Composition

The work of a "Game Composer" in video game audio spans a broad range of responsibilities, leading to diverse professional experiences and interpretations of the role. This variability prompted the suggestion of "Music Design" as a term that more accurately captures the blend of creative and technical tasks involved. Interviews indicate a shift towards integrating audio implementation into the composition process, suggesting a more holistic approach to game music that considers its interaction with gameplay from the start. Composers are increasingly expected to engage in various aspects of game development, highlighting the importance of versatility and a deep understanding of game audio's technical and creative facets, and transactional relationships between composers and game makers have become less common.

ACKNOWLEDGMENTS

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