Master Degree Project

UNIVERSITY
OF SKÖVDE

A NEW APPROACH AND GUIDLINE FOR LOUDNESS IN GAME AUDIO

Developing Specific Loudness Standards for Each Section of Game Audio

Master Degree Project in Informatics
One year Level 22.5 ECTS
Spring term 2023

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Abstract

Audio plays a crucial role in the immersive and emotional experience of playing video games, and loudness is a key aspect of game audio that can greatly impact player engagement and immersion.

There are existing loudness standards such as AES-EBU R128, which is mostly commonly used by social media platforms such as YouTube and Spotify. Moreover, SONY has developed the Sony Computer Entertainment America (SCEA) Loudness Standard for maintaining consistent and balanced loudness levels in game audio as well.

However, there is a need for more section-specific standards that consider the unique requirements of different genres and elements of game audio.

This thesis is proposing a new approach to loudness standardization for game audio by analyzing existing standards, identifying their limitations, and evaluating the impact of loudness on the gaming experience. The results have implications for game developers and audio designers, potentially enhancing player immersion and engagement.

Keywords: loudness, loudness standard, game audio, immersion, audio design, dynamic range.

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1 Introduction

As we know, game audio is a crucial component of the player's experience, and the loudness of different audio elements in a game can significantly impact the player's emotions, immersion, and engagement with the game.

Sound in digital games is an aspect of game design, with sound effects and music being used to create immersive and engaging game experiences. However, the loudness of game audio has also become a topic of concern, as overly loud or inconsistent sound levels can be jarring and distracting for players. The dynamic nature of game audio, which changes depending on the player's actions, makes it challenging to set consistent loudness levels for different sections of the game audio. To address this issue, various loudness standards have been developed, such as the Sony loudness standard for game audio, which aims to provide a consistent and comfortable listening experience for players.

The existing loudness standard have led a way of how to design game audio into proper loudness generally. One widely used unit of measurement for loudness in digital audio is LUFS (Loudness Units Full Scale), which takes into account the frequency response and duration of the signal. LUFS is based on the ITU-R BS.1770 standard, which specifies a method for measuring loudness in digital audio using a statistical algorithm that models the human perception of loudness (Pestana, P.D., Reiss, J.D. and Barbosa, A., 2013).

However, Game audio is unique because it is interactive and dynamic. Unlike film or music, where the audio is pre-recorded and presented in a fixed format, game audio changes in real-time based on the player's actions and decisions. This means that game audio must be designed and implemented with consideration for player interaction and immersion.

Previous researches and existing loudness standards or guidelines have illuminated a general framework for game audio loudness. Yet, despite these valuable insights, there is still a lack of specific loudness standards for individual sections of game audio, which could lead to inconsistent and unbalanced sound volume levels. The existing loudness standards do not account for the specific needs and characteristics of each section of game audio. This can lead to imbalanced and inconsistent loudness levels, which can negatively impact player immersion and engagement.

Meanwhile, as for the serious game aspect, some instruction on loudness of game audio would also be beneficial for developers when developing serious gams. When it comes to serious research and academic related experiment, on the consideration that the loudness of game audio could have an influence on participants, by referring this article, developers could find an easy way to access to loudness related game audio design, so that it would be more accurate and rigorous for serious games.

Therefore, in this article, the need for a specific loudness standard for each section of game audio will be discussed, along with some suggestions and guidelines to achieve it. It will be explored the existing loudness standards, their limitations, and practical problems faced by game developers when implementing them. There will be also some discussion of the utility of a specific loudness standard in future game development, especially in serious games. By providing a comprehensive analysis of the current state of loudness in game audio and proposing potential solutions for improvement, this thesis aims to contribute to the ongoing development of effective and user-friendly game audio loudness design.

2 Background

Game audio has come a long way since the early days of video gaming. The evolution of gaming technology has resulted in a significant increase in the complexity of game audio. Today's games have great soundscapes that include a wide range of sounds, from background music to dialogue to sound effects. The audio components of a game are an integral part of the player's experience, and they play a significant role in creating a game's mood, atmosphere, and immersion.

Despite the importance of game audio, there has been a lack of specific loudness standards for each section of game audio. This has resulted in inconsistent loudness levels across different sections of game audio, which can lead to an underperforming listening experience for players.

The Audio Engineering Society (AES) and the European Broadcasting Union (EBU) have developed loudness standards for audio in different contexts, such as television and radio. However, these standards are not specifically tailored to the unique demands of game audio.

The lack of specific loudness standards for game audio has been a practical problem that game developers have encountered. It has been challenging to create consistent and high-quality game audio without clear guidelines to follow. Moreover, the absence of specific loudness standards for game audio has limited the utility of game audio in serious games, which have educational or social purposes. A clear set of loudness standards for game audio would enable serious game developers to create immersive and effective audio experiences that contribute to the game's overall impact.

In conclusion, the development of specific loudness standards for each section of game audio is an essential step towards creating consistent and high-quality game audio. By establishing clear guidelines for game audio loudness, developers can create immersive audio experiences that enhance the player's overall game experience. Furthermore, the development of specific loudness standards for game audio has the potential to make game audio more useful in serious games, which have educational or social purposes.

2.1 Loudness in Digital Games

In analogue audio systems, loudness is typically measured using VU meters or peak meters, which provide a visual representation of the relative volume levels of the audio signal. Analog audio signals are continuous waveforms, and their loudness is determined by the electrical signal level that is sent to an amplifier or speaker system.

In contrast of that, digital audio systems measure loudness using digital metering systems, which typically use algorithms based on the ITU-R BS.1770 standard to measure loudness levels. Digital audio signals are represented by a series of discrete samples, and their loudness is determined by the number of bits used to represent each sample and the overall volume of the digital signal (Nielsen, 2016).

2.2 Loudness War and Existing Loudness Standard

The loudness war refers to the practice of increasing the loudness of recorded music to make it stand out more in a competitive market (Vickers, 2010). It often involves the use of

dynamic range compression and limiting techniques to boost the average level of the audio signal, which can result in a loss of sonic quality and musical nuance. The term "loudness war" was coined in the early 2000s, but the practice of pushing loudness levels has been a concern in the music industry for several decades. Critics of the loudness war argue that it sacrifices artistic expression and listener experience in favour of commercial competitiveness.

> While this increase has been facilitated by the use of dynamic range compression, limiting, and clipping, the underlying cause is the belief that louder recordings sell better.
>
> Vickers (2011)

Therefore, loudness standards are necessary to combat the negative effects of the loudness war on audio quality and listener experience. By establishing a standardized loudness level for audio, we can ensure that audio is not overly compressed or distorted, and that the listening experience is consistent across different devices and environments. Additionally, loudness standards can help to prevent hearing damage or fatigue from prolonged exposure to loud audio, which is a concern for both audio professionals and consumers.

2.2.1 AES-EBU R128

AES-EBU R128 is a recommendation from the Audio Engineering Society (AES) and the European Broadcasting Union (EBU) for loudness normalization in audio production and broadcasting. It is a widely used industry standard that measures the perceived loudness of audio using a statistical algorithm that models the human perception of loudness.

The standard uses Loudness Units Full Scale (LUFS) as the measurement unit for loudness, which is a logarithmic scale that represents the average loudness of an audio signal over time. This is different from traditional peak level meters that measure the maximum amplitude of an audio signal, which is not an accurate representation of perceived loudness.

AES-EBU R128 recommends a loudness normalization target of -23 LUFS for broadcast television and -16 LUFS for online content, although different services may have different targets. The standard also recommends a maximum True Peak level of -1 dBFS to avoid distortion and ensure compatibility with various playback systems (European Broadcasting Union, 2020).

Overall, AES-EBU R128 provides a standardized method for loudness normalization that ensures a consistent listening experience across different programs and platforms.

It is widely used by social media platform such as YouTube, Netflix, Spotify and so on.

2.2.2 Sony Computer Entertainment America (SCEA) Loudness Standard

One of the most commonly used standards for game audio is the Sony Computer Entertainment America (SCEA) Loudness Standard, which was developed by Sony Audio Standards Working Group (ASWG) for use in PlayStation games. The Sony loudness standard aims to provide a consistent and comfortable listening experience for players by setting guidelines for the loudness and dynamic range of game audio.

The Sony loudness standard specifies a target loudness level of -23 LUFS (Loudness Units Full Scale) for game audio, with a permissible range of -25 to -20 LUFS. It also recommends

a maximum True Peak level of -2 dBTP (decibels True Peak) to avoid any clipping or distortion in the audio (Audio Standards Working Group,2013).

The Sony loudness standard also includes guidelines for the dynamic range of game audio, with a recommended target of 14 LU (Loudness Units) for the average dialogue level and a maximum range of 20 LU.

While the Sony loudness standard was developed specifically for PlayStation games, it has become a widely recognized industry standard for game audio and is often used as a reference by game developers and sound designers. However, it is important to note that the Sony loudness standard is just one of several loudness standards available, and there is ongoing debate and discussion in the industry about the most effective approach to loudness in game audio.

2.3 Game Audio

Game audio is a multimedia experience that enhances the immersion and realism of the game through sound effects. (Satty & Hashemi, 2022)

Game audio usually uses stereo technology, presenting the sound of different sound sources in different directions, distances, and sound field effects, which can make players feel a more realistic sound environment and spatial sense. Even some games are using Dolby Surround audio system for their audio. In addition, the dynamic range of game audio is large, including bass, treble, and instantaneous burst sound, which can be adjusted according to the needs of the scene and plot to enhance the drama and atmosphere of the game.

Game audio can be divided into several sections, including sound effects, music, ambient sounds, and more. Usually, sound effects include sounds of movements, sounds of visual effects, sounds of feedback to player actions. They can be switched and combined according to different situations and scenes to enhance the realism and emotional expression of the game. The way that each section is mixed and balanced can greatly impact the player's overall experience.

> Game audio can be considered as the art and science of producing and configuring sounds for video game or interactive media. Sound for games is not a single entity, but a combination of entities that all come together to create a complete game audio. Game audio experiences is not just music in video game. There are many different elements which make up game audio. In short, there are three kind of game audio, that is: background music, ambience sounds and sound effects.
>
> Andersen, King & Gunawan (2021, p.222)

2.3.1 Interactivity & Immersion

Game audio has interactivity, which can be rapidly changed and fed back to the audience in real-time based on the player's operation and decision. It can help players better understand the rules and status of the game, improve the playability and challenge of the game. In addition, game audio can be customized and set according to the player's personalized needs, including volume, sound effect type, language selection, etc., to meet the different needs and preferences of players, enhancing the personalization and interaction of the game. (Gallacher, 2013)

2.3.2 Non-linear narrative

Games often feature non-linear narratives, allowing players to make choices and explore different paths. This aspect poses unique challenges for audio design, as the audio must seamlessly adapt to the changing storylines and player decisions, enhancing the immersive experience. (Collins, 2007)

In traditional media, loudness standards are often established to ensure consistent audio levels across different content and platforms. However, game audio requires a more nuanced approach. During such development with non-linear narrative, developers are facing to the process and sections of audio instead of the presented result of it. This makes it more difficult for developers to design the audio into a perfect condition for players.

2.4 Pitch and Volume

It should be mentioned that pitch can affect loudness perception, as higher-pitched sounds are generally perceived as louder than lower-pitched sounds, even if they have the same physical volume (see Figure 1).

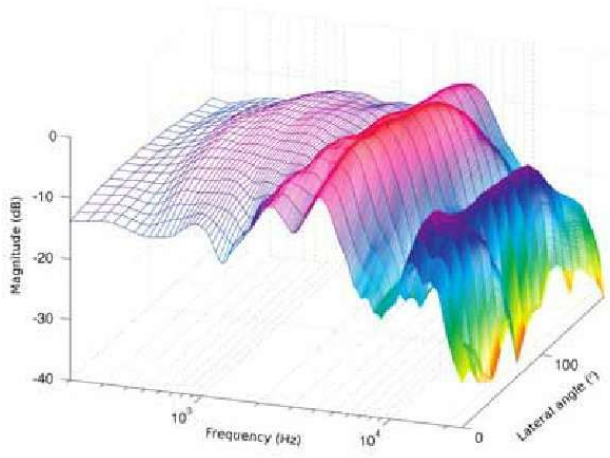


Figure 1 HRTF's of one test subject measured in free field and blocked ear canal with different sound source directions in the horizontal plane. 0 ◦ is in front of the listener.

Measurement Apparatus and Modelling Techniques of Ear Canal Acoustics

Pitch and volume can be considered integral dimensions of sound. Both pitch and volume affect the perceived loudness of sound, and they are important parameters in sound design and mixing. Volume is the physical amplitude of sound waves, and pitch is determined by the frequency of sound waves.

Considering both pitch and volume is crucial in measuring loudness of the sound as well as creating balanced and effective game audio.

3 Problem Statement

The problem with game audio is that it is challenging to set consistent loudness levels for different sections of the game audio. Game audio is a dynamic component reacting to the player's experience, changing depending on the player's actions. This makes it difficult to set specific loudness levels for each section of game audio.

Existing loudness standards, such as the AES-EBU R128 and Sony Computer Entertainment America (SCEA) Loudness Standard, provide a guideline for setting loudness levels in game audio (Audio Standards Working Group,2013). However, they lack specific guidelines for each section of game audio, making it challenging for game developers to ensure that different audio elements in the game are at a consistent loudness level.

According to the research from Schmidt, since interactive audio soundtracks are becoming more and more complex, the mixing of all game audio elements are coming with great unique challenge (2003). Schmidt also mentioned that existing traditional post-productions techniques, such as loudness standards for nowadays media broadcasting, do not necessarily apply to the mixing of interactive audio.

Some books and articles have given advices and instructions on part of mixing audio for games. For example, in *Principles of game audio and sound design: sound design and audio implementation for interactive and immersive media,* it was mentioned that the techniques of using effects and editing via scripting (Sinclair, 2020). Similar contents were also found in book *Audio for Games: Planning, Process, and Production* (Brandon, 2004). However, it is still not easy to find any specific instruction on how loud do each section of game audio should be and any standard suggesting it.

The aim of this article is to find an approach to recommendation of specific loudness standard for each section of in game audio. By studying and analyzing exit games and loudness standards for movies and music, it is hopeful to come to a result of general suggestion towards loudness level for each section of game audio. And by conducting a series of tests, it could be proved to meet the player preference, confirming the suggestion should work well.

Or, in another way to describe it, the research questions of this thesis would be:

> How loud should each section of game audio be?
>
> 1. What kind of recommendation could be extracted from existing games and existing loudness standards?
> 2. How much does it fit the player preference?

In this thesis, a hypothesis according to measurement and statistics of exist games will be drawn, and eventually be confirmed by a series of player preference-based test. At the end of this article, a recommendation of specific loudness standard will be given to instruct further game audio development in both commercial and serious area, especially it is hoped to provide help to studios with small budget who could not afford to hire an experienced sound designer.

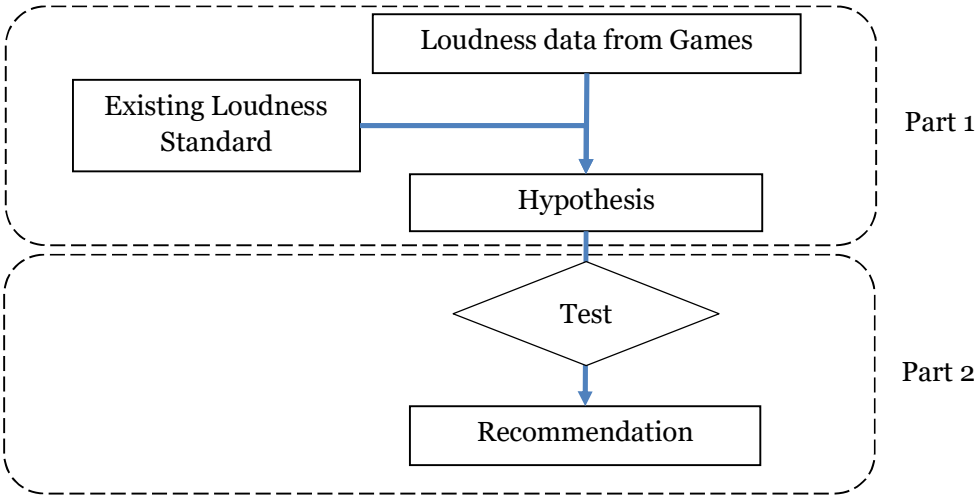
By extracting the hypothesis and doing the validation tests, the researches questions above could be answered progressively, and a recommendation as a final conclusion could be given.

4 Study Method

The study methods contain mainly two parts. One of them is sampling and collecting data from existing games to approach to a hypothesis of target loudness standard for all sections of game audio. Another is a player preference-based test to confirm the hypothesis and provide some correction to the target loudness standard from previous step, which will make it a suggestion of target loudness level for each section of game audio, as conclusion of this thesis.

As showed in Chart 1, the hypothesis will base on the statistics of the loudness data collected from games, and will be adjusted comparing with analyzing of existing loudness standard of movies and games. Then in the next step, this hypothesis will be tested by a series of player preference tests and finally be adjusted and confirmed into a recommendation of specific loudness standard for each section of game audio.

Chart 1. Study method process.



4.1 Sampling Existing Games

One of the main processes in this study is to measure the loudness from the existing games. To analyse the different audio sections in the game, such as background music, sound effects, dialogue, and ambient sounds. Each section has different requirements in terms of loudness levels, and an analysis of these sections can provide insight into the specific loudness levels required for each section.

4.1.1 Data resources

Considering that the data collected should be more general and could be commonly used, 3A games are excellent choices for data collection of this study since they have a reputation for producing high-quality games with impressive sound design.

Additionally, 3A games tend to have larger budgets and experienced development teams (Keogh, 2015). In that case, the sound design and implement in those games shall be better for player experience and more accurate across platforms, which may provide better reference that eventually specific loudness standard could look at.

It should be mentioned that there are many genres of games, each with its unique gameplay mechanics, art style, and audio requirements (Bennett & Bates, 2018). However, in this thesis, a loudness standard for each section of in game audio is being searched in a general and common approach, which means it is designed to be suitable across genres. When developing a game, it should be common that there are some features that games have in general, yet it is crucial to keep in mind that developers should always take the actual situation in to account considering the unique features of the specific game linking to their backgrounds and stories.

Thereby, in this thesis a specific loudness standard for each section of in game audio will be a goal, but developers who could make benefit from it are suggested to use it wisely and selectively as well.

However, games chosen for this thesis is basically based on researcher's personal game library, and it might be not very general. Yet they still meet the requirements of the data resources of this thesis, and are representative as well. For further research, more various and wide selections of games are well recommended.

Games chosen for this thesis will be shown in the list at later section.

4.1.2 Sampling Methods

Sampling loudness data from games can be done through various methods, but one effective way is to record the screen while the game is being played.

> What should be noticed in the consolidation of machinima as an audio-visual genre is the specialization of this aspect of the game as a tool, employed for a sole specific use – that of filmmaking.
>
> Menotti (2014)

This allows for a comprehensive analysis of the game's audio levels and dynamics, and can provide a clear picture of how the game's audio is being perceived by players. Once it has been collected by recording and capturing, the data can then be stored and analysed using various software tools, such as loudness meter. The stored data can be used as a reference for future researches and studies as well.

To record each section of game audio separately, it may be necessary to modify the sound options in the game to isolate specific audio elements. This can be done by adjusting the volume levels of individual audio tracks or by muting certain tracks altogether. For example, to record the sound effects in a game, the music and dialogue tracks may need to be muted or lowered in volume. Similarly, to record the dialogue in a game, the music and sound effects tracks may need to be muted or lowered in volume. By modifying the sound options in this way, it is possible to capture each section of the game audio separately, allowing for a more targeted analysis of the loudness levels and dynamics of each section.

However, modifying the sound options in this way could potentially affect the dynamic range and loudness of the audio in the game, particularly in cases where ducking is used to lower the volume of one audio element in favour of another (Wilhelmsson & Wallén, 2011). Considering that it could have less influence on loudness measuring but more related with audio system design, it is recommended that in research a global audio clip could be captured as a comparable sample towards all isolated tracks, but not be used to analysing

data. And loudness standard for each section could give no instruction on dynamic relationship between tracks.

4.1.3 Tools

Measuring loudness can be done through a process called Loudness Metering, which uses different algorithms to measure the perceived loudness of an audio signal.

To fight against loudness war, standards for broadcast audio associated with video were usually set to limit the level of audio across an entire program, both shows and advertisements (Vickers, 2010). This measure of level across a full program is called integrated loudness. Integrated loudness is a measure of the perceived loudness of an entire audio program, calculated over its entire duration.

It is good to focus on integrated loudness when comparing different audio clips between genres or platforms (Brown & Banzon, 2019). The integrated loudness level provides an overall measure of the program's loudness, taking into account the dynamic range and any changes in level over time. It is widely used in loudness normalization for broadcast and streaming services.

In the thesis, iZotope Insight 2[1] was used as a loudness meter for measurement. And it is also highly recommended to use loudness measuring tools such as that to process the data of experiment materials in the further study.

4.2 Analysing Existing Standards

The loudness standards for games can borrow a lot from the loudness standards for movies and music (Vickers, 2010). While game audio requires consideration of interactive and environmental aspects, among others, which differ from movies and music, game loudness standards can learn from movie and music standards, particularly in terms of loudness range and measurement methods.

On the other hand, as games, like other media, are typically experienced by players on devices such as computers or home theatre systems, game loudness standards should also consider the balance between game loudness and other media. This means that when developing game loudness standards, they should be compared and aligned with the loudness standards of other media, to ensure that the loudness of games is consistent with that of other media when played on the same device (Fletcher & Munson, 1933). This can help avoid jarring or muted game audio, and improve the listenability and user experience of the game. Additionally, the different platforms and devices on which games are played should also be taken into consideration, and game loudness standards may need to be adjusted to suit the different platforms and devices (Fletcher & Munson, 1933).

4.3 Hypothesis

After collecting data from sample games, a hypothesis for each section of game audio will be drawn to cover all data collected.

[1] Developed by iZotope Inc., 2018.

The loudness levels of different game genres and sections, such as cutscenes, gameplay, and menus, can be analysed and compared to existing loudness standards in movies and music. Additionally, the loudness data collected from sampling can be stored and utilized to inform future game audio design and production.

According to the previous text, the analysis will consider the loudness levels of various game genres, including action, adventure, sports, role-playing, and more. Additionally, existing loudness standards in the film and music industries will be examined to provide a reference point for establishing game audio loudness standards. The data collected from various games will be recorded and stored for future reference, allowing for ongoing analysis and refinement of the suggested standards.

However, it should be mentioned that the final conclusion in this article should be commonly useful and effective, but flexible when it comes to specific game. Developers could follow the suggestion given by the recommendation, but need to improvise according to the fact of actual development.

4.4 Validation Test

It is crucial to test the given conclusion afterwards in order to demonstrate it could be useful to game developments.

In this article, some validation tests towards loudness preference were conducted to test if the prospected loudness standard based on data from the game could be suitable for player.

Due to the time limit, it was impossible to test all result generated from data collected, yet it is still suggested that further test could be done by other researchers in the future.

The forthcoming section will provide a detailed overview of the validation tests.

5 Data Sampling & Hypothesis

5.1 Experimental Data

In the following table, many games' loudness data were showed in each section (see Table 1).

Table 1. Loudness data of games.

	Main Dialogue	Weapon or Attack Sound Effects	Background Music (Combat)	Background Music (Exploring)
Assassin's Creed Odyssey[2]	-23	-25	-35	-38
Assassin's Creed Syndicate[3]	-23	-26	-35	-37
Cyberpunk 2077[4]	-20	-24	-26	-30
Final Fantasy 7 Remake[5]	-20	-21	-25	-30
Ghost of Tsushima[6]	-21	-20	-26	-30
Hogwarts Legacy[7]	-20	-21	-23	-30
The Last of Us 2[8]	-20	-20	-30	-38
The Witcher 3 Wild Hunt[9]	-23	-25	-30	-35
Uncharted 4: A Thief's End[10]	-20	-20	-35	-40

It is important to note that each piece of data must be measured for a sufficient amount of time throughout the experiment.

According to ASWG, the audio content to be measured for integrated loudness data should be measured for as long as is practical and for a minimum of 30 minutes, and that those sections of any title that are measured should be a representative cross section of all different parts of any title, in terms of game-play. However, in this experiment it is impossible for all games and all audio clips to be measured in such time. Besides, as for dialogue and sound effects, they could be only measured in short term or momentarily. Thus, suggestions given by following could be useful in sampling loudness data of game audio:

1. Dialogue and weapon or attack sound effects should be measured in short term (3 seconds), which is shown as Short-Term Loudness in iZotope Insight 2. And the momentary loudness of it could be considered as a reference to the data collected;
2. Music should be measured in long term as long as possible and for a minimum of 30 seconds, which is shown as Integrated Loudness in iZotope Insight 2;
3. For each data, an average should be calculated by at least 3 samples;
4. The collected or calculated data should be rounded to approximate integer.

[2] Developed by Ubisoft, 2018.
[3] Developed by Ubisoft, 2015.
[4] Developed by CD Projekt Red, 2020.
[5] Developed by Square Enix, 2022.
[6] Developed by Sucker Punch Productions, 2020.
[7] Developed by Avalanche Software, 2022.
[8] Developed by Naughty Dog, 2020.
[9] Developed by CD Projekt, 2015.
[10] Developed by Naughty Dog, 2016.

It is clear to see that most games keep the loudness of the dialogue around -20 LUFS to -23Lufs, which is slightly similar to the loudness of dialogue in movies. According to Brown and Banzon, movie dialogue typically measures around -24 to -18 LUFS in loudness (Brown & Banzon, 2019).

As for the weapon's sounds or the attack sound effects, data measured from different games are slightly distinctive and it might be considered as the genres differs. However, the loudness of sound effects generally remains -20 LUFS to –26 LUFS. It should be mentioned that during the entire sampling process, the dynamic range of this part of sound is fairly wide as it gives player most of feedbacks from actions and attacks.

The sampled games vary in volume of background music, which ranges from -23 LUFS to -40 LUFS. Thereby it is suggested to take actual game design into consideration when design music for those part in games, instead of put referring loudness standard recommendation into first step. In this thesis, the recommendation of loudness of background music was calculated to a certain level covering all games sampled and averaged from data collected. Yet it should be mentioned that separate test towards background music for combat and for exploring would be more beneficial for verification and correction.

5.2 Hypothesis

After sampling and calculating the data collected from those games, data in each column were calculated into an average for the following research.

For each section, the target loudness level given in the table was calculated to cover all the loudness data previously collected from games. Though it was originally calculated as an average (see Table 2), yet adjustments were made to make the coverage easier.

Table 2. Average Calculation

	Main Dialogue	Weapon or Attack Sound Effects	Background Music (Combat)	Background Music (Exploring)
Assassin's Creed Odyssey	-23	-25	-35	-38
Assassin's Creed Syndicate	-23	-26	-35	-37
Cyberpunk 2077	-20	-24	-26	-30
Final Fantasy 7 Remake	-20	-21	-25	-30
Ghost of Tsushima	-21	-20	-26	-30
Hogwarts Legacy	-20	-21	-23	-30
The Last of Us 2	-20	-20	-30	-38
The Witcher 3 Wild Hunt	-23	-25	-30	-35
Uncharted 4: A Thief's End	-20	-20	-35	-40
Average	**-21.1**	**-22.4**	**-29.4**	**-34.2**

From which, A hypothesis of suggested loudness level for each section of game audio was drawn as shown in the following table (see Table 3).

Table 3. Hypothesis of Suggested Loudness Level for each section of game audio.

	Suggested Loudness Level (LUFS)	Allowance
Main Dialogue	-21	±3
Sound Effects	-23	±3
Background Music (Combat)	-29	±6
Background Music (Exploring)	-35	±6

For now, the expected target loudness level of each section of game audio were drawn into a hypothesis. In the next chapter, it will be tested be the validation tests to confirm the accuracy and validity.

6 Validation Tests

For each section of game audio, a validation test is necessary to prove that the result as a hypothesis matches the player preference well and could be useful.

In a study by Xu, Fang, Chen, Ohno and Paliyawan (2021), an experiment was conducted to find out player's preferences concerning pitch and loudness levels of commentators in games. In the study, they showed examples of testing player preferabilities.

In this thesis, several validation tests were done inspired by their study.

The tests were based on re-made gameplay video, with generally the same sound tracks but only the volume of one section of game audio was different from the others. For example, when testing the player preferability on loudness of background music, the other section of audio in all videos in this part of test were the same, but the music tracks were edited into different loudness.

6.1 Research Ethics

For test part of this thesis, it involves a number of participants. It is crucial to make sure all participants were well informed how their experimental data would be used in the study, and how their confidentiality and privacy would be protected.

In the tests, all participants were assured that their personal information would be treated with the utmost confidentiality and that their data would be reported in aggregate form to maintain anonymity.

Before the test, participants were told that their answer would be used as data of the thesis, and further research if needed. The participants were also asked before starting if they had any hearing impairment, which none of them had. If they have had any impairment, they would not be allowed to participate, both because we didn't want to risk any further harm, and because the data collected might not have been relevant in that case.

Data collected from them includes all the answer in the survey, but without their personal information such as names, genders, ages, etc. At the end of the survey, the participants could also find contact information if they ever wanted to ask any questions, or if they wanted to cease their participation.

6.2 Test on Loudness of Background Music (Combat)

6.2.1 Methods and Process

As a material of the test, a recording of gameplay video from Hogwarts Legacy was made with the music turned off, while the sound effects and voices were remained. The background music of combat scenes for testing purpose were attached to these with two settings of different levels of volume afterwards (see Table 4).

The volume setting for the voice track was edited to -21 LUFS according to previous chapter. The default volume setting for the soundtrack in the game is at -29 LUFS (Loudness Units Full Scale), which was due to the hypothesis, and was used in one of the videos as a default as well. Two of the videos used louder levels of volume and two used quieter volume levels,

each one with a difference of 3 loudness unit. The default video was the first video that the participants watched, so that they could turn their listening device to a comfortable volume level. After this part, the participants were not allowed to change the volume during the rest of the test.

According to the human ear's sensitivity, this difference should be distinguishable for the participants. Generally, the smallest perceivable difference in loudness is about 1 dB (decibel) for pure tones in the mid-frequency range (around 1,000 Hz) (Middlebrooks, 1989). In other words, loudness difference at 1 loudness unit should be distinguishable for the participants.

Table 4. Two settings of soundtrack volume for the different videos (BGM = background music, LUFS = Loudness Units Full Scale).

Setting 1			Setting 2		
Case	Voice	BGM	Case	Voice	BGM
Example	-21 lufs	-	Example	-21 lufs	-
A	-21 lufs	-23 lufs	A	-21 lufs	-35 lufs
B	-21 lufs	-35 lufs	B	-21 lufs	-32lufs
C	-21 lufs	-32 lufs	C	-21 lufs	-26 lufs
D	-21 lufs	-29 lufs	D	-21 lufs	-23 lufs
E	-21 lufs	-26 lufs	E	-21 lufs	-29 lufs

The participants first watched the default video, where they could alter the volume to a comfortable level. After this, they continued on with the rest of the gameplay videos. They were not allowed to alter the volume at this stage. The participants were divided into two groups; setting 1 and setting 2 (see Table 4). For each setting group, the participants were led to watch the video in order and allowed to replay it themselves. In this way we will know if the order has an influence on the participants' judgment. If it doesn't affect the results, we should get similar data from the different groups.

The participants were allowed to re-watch each video several times if needed. Their task was to figure out the right order regarding the loudness level of the background music, e. g. sort the videos from the lowest volume to the highest. This was to find out if the 3 loudness unit's differences were distinguishable enough for the participants. They were also supposed to figure out which gameplay video they preferred, e. g. which video had the best sounding audio according to them.

The hypothesis, which drawn afterwards the statistic of loudness data collected form games, is that the participants should clearly distinguish the loudness levels in the different videos, and they should be able to sort the videos in order from low to high. The default volume of the background music should be the most preferable one (see Table 5), and there should not be a large difference in both order and preferred choice between the results of two groups.

Table 5. Prospections of videos with preferred loudness of music (highlighted in red).

1	Prospection	B	C	D	E	A	D
2	Prospection	A	B	E	C	D	E

6.2.2 Result

There were ten participants in total, which were divided evenly into the two settings. The results from the online survey were put into a spreadsheet (see Table 6).

In Table 6, the red highlights are the participants most preferred videos, where the video orders that the participants sorted are listed. The information about what kind of devices they used and the type of player they used to watch the videos are also shown in the table.

Table 6. Survey results with favourite sample chosen highlighted in red.

Setting	Device	Equipment	Player	Order (low to high)					
1	PC	Headphone	Google	B	C	D	E	A	D
1	PC	Headphone	PotPlayer	BC		D	E	A	BC
1	PC	Speaker	Windows Player	B	C	D	E	A	E
1	PC	Earphones	Google	B	CD		E	A	CD
1	PC	Speaker	Windows Player	B	C	DE		A	C
2	PC	Headphone	WeTV	A	B	E	CD		E
2	PC	Headphone	Google	AB		E	CD		E
2	iPhone	Earphones	Safari	A	B	EC		D	B
2	PC	Headphone	PotPlayer	A	B	E	C	D	B
2	PC	Headphone	Clipchamp	A	B	E	C	D	E

Almost all of the participants could sort the right order of loudness levels from lowest to highest. This could indicate that the 3 loudness units is enough to distinguish the volume levels from each other. But since a couple of participants sorted the videos in the wrong order, the difference in loudness units could be increased 4 or 5 to ensure that it is distinguishable. The wrong order could indicate that these participants have a different hearing sensitivity.

However, the preferred video chosen by participants were quite different from the hypothesis. Less than half of participants have chosen the default video (which is recommended by previous chapter as a hypothesis) as their favourite loudness level of combat music, while the others chose either louder one or less loud one.

6.3 Test on Loudness of Sound Effects

6.3.1 Methods and Process

As for the sound effects section, a very similar test was conducted as well with the same recording methods but different tracks.

The main methods and process of this test were basically the same with the previous one on loudness of music. The setting of test materials and the prospections are shown as following tables (see Table 7 & Table 8).

Table 7. Two settings of soundtrack volume for the different videos (SE = Sound Effects, LUFS = Loudness Units Full Scale).

Setting 1			Setting 2		
Case	Voice	SE	Case	Voice	SE
Example	-21 lufs	-	Example	-21 lufs	-
A	-21 lufs	-23 lufs	A	-21 lufs	-20 lufs
B	-21 lufs	-17 lufs	B	-21 lufs	-17lufs
C	-21 lufs	-20 lufs	C	-21 lufs	-26 lufs
D	-21 lufs	-29 lufs	D	-21 lufs	-23 lufs
E	-21 lufs	-26 lufs	E	-21 lufs	-29 lufs

Table 8. Prospections of videos with preferred loudness of sound effects (highlighted in red).

1	Prospection	D	E	A	C	B	A
2	Prospection	E	C	D	A	B	D

6.3.2 Result

Table 8. Survey results with favourite sample chosen highlighted in red.

Setting	Device	Equipment	Player	Order (low to high)					
1	PC	Headphone	PotPlayer	D	E	A	C	B	A
1	PC	Headphone	Google	DE		A	C	B	A
1	PC	Headphone	Windows Player	D	EA		C	B	EA
1	PC	Earphones	Google	D	E	A	C	B	A
1	PC	Speaker	Google	D	E	A	C	B	A
2	PC	Headphone	PotPlayer	E	CD		A	B	D
2	PC	Headphone	Google	E	C	D	A	B	D
2	PC	Headphone	WeTV	E	C	D	A	B	C
2	PC	Earphones	PotPlayer	E	CD		A	B	CD
2	PC	Earphones	Windows Player	E	C	D	A	B	D

Comparing with Test in 6.2, participants still mostly be able to distinguish the differences between each segment, and tended to be more likely to choose the expected one sample to match the hypothesis.

6.4 Discussion

6.4.1 Game Chosen as Material

In the tests, Hogwarts Legacy was chosen as an experimental material only because it is easy to get access for the researcher of this thesis. This is the weakest point of the test.

It would be strongly recommended to have more games in comparation, or to have a test-purposed developed small game clip to ensure the functionality of the test.

6.4.2 Segment Difference within Groups

The segment difference setting in the test were 3 loudness units, which should be distinguishable for the participants according to the human ear's sensitivity. Still, it should be discussed if the segment difference could be set smaller to let participants choose more

freely. It is clear that smaller segment could lead to more accurate of the result, while on the other hand it means longer time the test would take. Therefore, it is not easy to us to spend such long time doing the test.

However, in the future study, it is highly recommended to test that if the smaller segment difference setting could lead to more accurate result, and meanwhile it would make no much concentration decreasing to participants.

6.4.3 Experimental Environment Difference

In the test, online survey was chosen as a sampling method so that the participants could easily get access to and they could give feedback data by sending the document as well. However, by doing that we could not require the participants do the test with same experiment environment, which could possibly be considered as a source of bias in this study.

For example, the video player software that participants used are various according to the table. In the instruction document for the test, we pointed out that some software like PotPlayer[11] would have volume normalization function, which could lead to inaccuracy when test the loudness preferabilities. Furthermore, we inform the participants to disable volume normalization if they use PotPlayer, otherwise we would recommend they used other kind of video player in order to finish the test correctly. However, we did not compare the difference between software, which means that the audio played by one video player, its frequency response or dynamic response might be slightly different from it played by another. In that case, the experimental data would not be comparable since the variables are not strictly controlled between participants in the experiment.

For another example, most of the participants tend to use personal computer doing the test, yet there is one participant used mobile phone with earphones as the experimental device.

In further study, it would be recommended that researchers could do the experiment in a fully controllable environment. The aspect should be considered for the test include if the participants could be distracted by environmental noise, if all participants could use the same device, if the condition of the environment which participant were at before the test should have an impact on the test.

6.4.4 Other Experiment on Demand & Relativity of Them

In this section, only two validation tests were conducted, meanwhile there is no test showcases the accuracy of suggestion on loudness level of voice section of game audio and the background music when exploring in game.

However, it is meaningless to conduct another test to confirm the preference, since the experiments only showcase the relation of loudness within each section of game audio. If, in the test, the voice track and the other tracks were increased by a certain loudness level at the same time, it is easy to find a same result as the original test, which means that it only indicates how loud the tracks should differ relative to the voice track, and does not indicate the absolute value that each track should have.

[11] Developed by Kakao (formerly Daum Communications), newest stable release version 2023.

As for background music for exploring, considering that the genre of them could be vary, as well as the demand of player experience, the loudness of background music for exploring could have a wider scope.

Generally speaking, it would be helpful to have further test towards the loudness preferabilities of voice and so on. But it should be mentioned that this series of experiments is relative in nature and does not give the exact absolute correct values to each section. The final result of recommendation should be based on other data collected from games as well.

7 Conclusions & Prospects

7.1 Results of Data Sampling

The hypothesis extracted from analysing loudness data of games did gave a general conclusion of how loud currently existing games are, and it refers to nowadays gaming audio sound volume levels.

7.2 Results of Validation Tests

Generally speaking, the results from the validation tests matched the hypothesis well when it comes to the suggested target loudness level for each section of game audio.

As for the fact that in the test on loudness of background music, participants tend to prefer a wider range of loudness level of background music, in the conclusion part it will be adjusted with a wider allowance.

7.3 Suggested Recommendation of Loudness Standard

By sampling and collecting those loudness data from games, and doing the tests to confirm the player preferabilities, a relative conclusion of loudness standard suggestion for each section of game audio was approached (see Table 9).

Table 9. Suggesting loudness standard for each section of game audio.

	Suggested Loudness Level (LUFS)	Allowance
Main Dialogue	-21	±3
Sound Effects	-23	±3
Background Music (Combat)	-29	±9
Background Music (Exploring)	-35	±9

At the loudness level suggested by the table, in-game audio should be relevantly balanced and be suitable for general game design.

It is thereby suggested:

1. To have dialogue audios at a loudness level of -21 LUFS, with 3 LUFS unit allowance plus or minus;
2. To have sound effects audios at a loudness level of -23 LUFS, with 3 LUFS unit allowance plus or minus;
3. To have background music for combat scenes at a loudness level of -29 LUFS, with 9 LUFS unit allowance plus or minus;
4. To have background music for exploration at a loudness level of -35 LUFS, with 9 LUFS unit allowance plus or minus.

Game sound developers are highly recommended to follow this suggestion to create balanced and immersive sound design for games. However, developers should not stick to the standard rigidly but improvise with actual situation to provide the best for player experience.

7.4 Future Work

7.4.1 More Experiment towards Player Preferability

According to the test, it is useful to have such preferability test for each part of game audio. Thus, it is hopeful to see more survey could be conducted related to sound effects, music and other game audio sections. In this way it could be proved the suggested loudness level should be suitable for players' comfort level or not.

7.4.2 Dynamic Range

Additionally, future research could investigate the use of dynamic range compression and other audio processing techniques to further optimize game audio loudness and clarity, while also maintaining a balanced and immersive audio experience for the player.

A number of games allow players to choose the device they use for game, such as headphones or home theatre. The main difference between those option is the dynamic range of game audio, which usually reflected in amplitude or compression in each section of game audio.

In future, some measurement and research could be done towards the dynamic range design of each part of game audio, so that more analysis and suggestion on it could be conducted.

7.4.3 Special Tools or Software

According to the data and result given in this article, as well as further potential studies, some special tools might be possible to be developed for assisting game sound designer and programmer to monitor and control audio levels in development.

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