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Auditory and Visual feedback: Impact on player performance and comprehension in First Person Shooters

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ABSTRACT

The video game industry has grown rapidly over the past decades, with games in the First Person Shooter genre, such as the *Call Of Duty* or *Battlefield* series, usually topping the sales charts every year. However, the current user interface design principles within First Person Shooters has been shown to have problems related to "clutter", and players have expressed their discontent with overcrowded heads up displays. This study hopes to shed light on how different interface design principles affect both the player's objective performance and subjective experience. In this study, participants were asked to play a custom made game with three different "feedback configurations". One based on visual elements, one based on auditory elements and one that mixed both elements. Quantitative measurements such as level completion time and the number of collected pickups were tracked in order to observe how or if they were impacted by the feedback configuration. The participants were also asked to reflect on their experience playing with the different configurations, and there was a large consensus among the participants that a feedback configuration based on visual elements was not preferable. Overall the feedback configurations did not have any significant impact on the player performance, however all of the 12 participants preferred either the Mixed or Auditory configuration.

SAMMANFATTNING

Under de senaste decennierna har spelindustrin växt snabbt, där bland annat spel inom First Person Shooter genren såsom *Call of Duty* och *Battlefield* serierna ligger högt upp på topplistorna varje år. Men de nuvarande designprinciperna för användargränssnitt inom "First Person Shooters" har visat sig ha problem relaterade till "clutter", och spelare har uttryckt sitt missnöje med överflödiga heads-up-displayer. Denna studie syftar till att belysa hur olika designprinciper för användargränssnitt påverkar spelarens prestanda och spelupplevelse. I studien spelade deltagarna samma spel med tre olika "feedback-konfigurationer". En baserad på visuella element, en baserad på auditiva element och en som blandade båda elementen. Kvantitativa mätningar såsom speltid och antalet samlade "pickups" utfördes för att se hur och om dessa påverkades av feedback-konfigurationen. Deltagarna ombads också reflektera över sin upplevelse av att spela med de olika konfigurationerna, och det fanns en stor konsensus bland deltagarna att en feedback-konfiguration främst baserad på visuella element inte var att föredra. Övergripande sett hade feedback-konfigurationerna ingen signifikant påverkan på spelprestandan, men alla de 12 deltagarna föredrog antingen den blandade eller auditiva konfigurationen.

NYCKELORD

Heads up Display ; User Interface ; User Experience ; Feedback ; Performance ; Auditory ; Visual

1. INTRODUCTION

The video game Industry is a constantly growing market. According to the Entertainment Software Association (ESA), there are billions of people playing video games every day [1]. Furthermore, people turn to video games for various different reasons such as community, stress relief and entertainment. According to ESA the video game industry grossed a total of $43.2 billion in 2019, $56.1 billion in 2020 and $60.4 billion in 2021 [2].

When scanning different video-game forums across the internet, one may come across varying threads where players discuss and point out both subjective and objective problems with "cluttered" user interfaces. For example, at the gaming forum of ResetEra, a user expressed their discontent with the current state of many video game user interfaces stating:

> *"[...] I'm talking about extraneous visual clutter in games. Stuff like objective markers, oxygen meters, and worst of all, health bars that float over the heads of enemies. I guess the thought is that all this information is vital, but in practice it just clutters up the screen and takes away from the artwork and animation."* [3]

In a short article published on the website fandom it is also mentioned how poorly thought-out UI design can be detrimental to the player experience. Two examples, such as the video games *NBA 2K13* and *Battleborn*, are mentioned as suboptimal UI designs that limit the player experience [4]. An example of the *Battleborn* UI can be seen in *Figure 1*.

Figure 1: Example of Battleborn (2015) UI during regular gameplay

However, players' subjective opinions are not the only thing indicating that there is a problem here. It is also becoming a prominent issue in the development world as well. The treatment of Quality Assurance (QA) workers within the gaming industry is steadily becoming a focal point for concern and outrage within the development space. This is especially true for game studios with the largest budgets, most commonly referred to as “AAA” studios [5]. QA testers are some of the first people that provide feedback on UI/UX, and sadly, usually the first ones laid off [6]. They are also often regarded as “non-developers", despite their importance to the final product. This is one of the main reasons that QA testers became one of the first and largest unions within the game development industry [7].

With this in mind, this study's primary objective is to address both the subjective and objective issue. This will be done by navigating and researching the intersection of auditory and visual elements in First Person Shooter (FPS) video games, to unearth how a blend of these two components can not only streamline the gaming interface, but also if it can impact player performance. More specifically, the study aims to explore the synergy between auditory and visual feedback within the realms of user interfaces and user experience. It will delve into the modification of the Heads-Up Display (HUD) and the incorporation of complementary auditory cues to augment the gaming experience. By providing data from our study and discussions surrounding it we plan to shed light on alternative methods for optimizing HUDs and game UIs.

1.1 Hypothesis

The hypothesis for this study is that the feedback configuration has a noticeable impact on the level completion time. More specifically, we hypothesize that the playtime difference between the best performing configuration and the worst performing configuration might be as large as 10-20 seconds. Playtime regards the time it takes for the player to complete the level. This hypothesis stems from the fact that an interface containing a lot of overwhelming information might negatively impact the players ability to focus on finishing the main task. The study will include three feedback configurations, which provide the player with varying UI elements. Our hypothesis is that the Visual feedback configuration will perform the worst, which entails the longest playtime, and that the Mixed configuration will perform the best, which entails the shortest playtime.

2. BACKGROUND

2.1 What are games?

Games can in many cases be quite complex, but games can also be broken down into a couple of basic principles and parts. Mifrah Ahmad’s paper on game design principles features the concept of games broken down into four core elements [8]. The four basic elements are Mechanics, Aesthetics, Story and Technology and they all play a vital role in the game. The first and one of the more vital elements is Mechanics which is stated to encompass all boundaries and different procedures that regulates the players and their performance when working towards the goal of the game. Aesthetics refer to the look and feel of the game and it is also considered a very important factor of game design because of its close correlation to the player’s experience. The story refers to all the in game events: how they are constructed and how they come to unfold in the game. The last element, Technology, essentially refers to the tools and expertise needed to develop the game and bring it to life.

2.2 User interface

A user interface is the access point where users are able to interact with a device or a technical system. It can include many different components such as screens, graphical elements, auditory elements and more. As a result, there are multiple different types of user interfaces such as graphical user interfaces, command line interfaces, touch user interfaces and voice interfaces, among others [9]. However, Leonel Vinicio Morales Díaz states in his paper that this tends to be a quite thin definition of the term [10]. Díaz collected a wide range of available definitions to come up with a new, more robust, of the concept. His new definition is as follows:

> *“A user interface is an artifact, meaning that it has to be designed and built with a purpose, that connects a computational device and a human user, enabling the effective coupling of the motor, sensitive, perceptive, cognitive and volitional faculties of the human with the input, storage, processing, and output capacities of the device, for the set of tasks that are related to a particular set of objects.”* [10] (page 6)

In the context of video games this means that the UI is the component in the game that supports interaction between the player and the game.

UX is another term that usually is seen in conjunction with UI. These terms are often confused with each other but deal with different aspects of the user interaction with an application or device. UI can be seen as a subset of UX where UI deals with the specific interactions, feels and surface of a design. UX concerns all aspects of the experience when using the products and/or application. An effective analogy for distinguishing between these two concepts is to consider UX design as an entire car, where UI design corresponds to the specialized driving console [11].

2.2.1 Audio in user interface design

Communicating with the user through visual means is not the only way to effectively provide vital information to the user. Research in the field has previously explored design principles concerning auditory elements in user interface design. A study conducted by Michel Beaudoin-Lafon and Stéphane Conversy, delved into the utilization of non-speech auditory elements for conveying information and offering feedback to users. [12]. In this study they successfully implemented non-speech auditory cues to make the use of scrollbars more effective. They also concluded their study by stating that computer objects should produce some sort of sound since real-world objects do so. We as humans are used to manipulating objects in the real world, and the sounds they make help us in perceiving the world. Thus, sounds added to computer objects can also assist us in perceiving the virtual world. It is also mentioned that the sounds used in the auditory feedback do not have to be natural, granted that they still provide useful information to the users.

In another study conducted by Maury et. al, sounds and rhythm were implemented into traditional drop-down menus in order to try and improve the menu selection experience [13]. In this study the selection of items in the drop down menus were not implemented using the traditional point and click selection, but instead through a continuous automatic cycling through the options by the system where the users could select an option by clicking anywhere on the screen when their desired option was highlighted.

Brewster conducted a study where buttons, one of the most common elements in graphical user interfaces, were improved using non-speech auditory cues [14]. It is mentioned in the study that buttons are in some ways quite problematic, primarily because users might think that they have pressed the button even when it was not successfully pressed. This problem is usually caused by the user moving the cursor off the virtual button before the mouse button is released, in combination with lacking feedback from the interaction with the button. Brewster successfully improved the buttons by adding non-speech sound effects in order to provide more informative feedback to the user. The auditory feedback was implemented using three different sound effects, corresponding to three different stages of interaction with the button. The first sound, which was a constant tone at a pitch of 130 Hz, was played as long as the mouse was over the button. The next sound, a constant tone at a pitch of 261 Hz, was played when the mouse button was pressed down while hovering over the graphical button. The last sound bite, two short consecutive tones at a pitch of 1046Hz, were played when the mouse was released over the graphical button in order to signify that the user had successfully pressed the button. In this case the higher pitched sound effects were used to represent “success”. This implementation was then tested in order to evaluate its performance. Overall the study concludes that sonically enhancing graphical widgets is an approach that yields positive results. In the case of the buttons, the overall preference rating of the buttons by the users saw a significant increase after being modified using the sonic elements.

A survey on common design practice for audio in user interfaces was done Frauenberger et. al. found that most of the 86 participants in their study believed that audio can be used to improve human-computer interaction [15]. More specifically all participants except one expressed that they thought audio could improve the field to some extent. There seems to be a large consensus among users that audio is a good complement to visual elements in human-computer interaction design.

2.3 Heads-up display

The heads-up display, often abbreviated as simply “HUD”, is an integral part of a video games user interface (UI). A game's UI provides the player with important game state information through various methods. Some of the most prominent include meta-representations and diegetic methods. Meta-representations are described as fictional and non-spatial elements that belong to the fiction of the game but are represented outside the fictional world space. Diegetic means elements that are occurring within the context of the story and able to be heard by the characters [16]. A common example of diegetic UI within FPS games is an in-world ammo counter. A diegetic ammo counter from the game *Call of Duty: Advanced Warfare* can be seen in *Figure 2*.

Figure 2: Diegetic ammo counter in *Call of Duty: Advanced Warfare*

Despite the vast amount of methods, most video game HUDs rely mainly on non diegetic, “flat” visualizations to convey information to the player. A common philosophy in HUD design is to make it accessible but virtually unnoticed [17]. There have been a handful of similar studies done in the past exploring different specific parts of the HUD and its implications. In a study conducted by L. Caroux, M. Delmas, M. Cahuzac, M. Ader, B. Gazagne, and A. Ravassa titled *Heads-up displays in action video games: the effects of physical and semantic characteristics on player performance and experience,* it was found that the player experience and performance was affected when semantic characteristics of HUD elements related to the main task were changed [18].

At York University in Toronto, Canada a study comparing different ways of displaying the ammunition count to the player was conducted by M. Peacocke et al [19]. The study found that a diegetic information display was best suited in this case since this placed the information closer to the players line of sight. Hence, an important takeaway from this study is to try and place important information close to the players direct line of sight.

2.4 Audio in video games

In popular gaming genres such as FPS and Real Time Strategy (RTS) games, sound design often serves as a critical information source. The soundscape of a game, which is a work that combines sounds in order to create a particular effect, serves to provide players with relevant information about their current situation in real time.

According to the study titled *Informative sound design in video games* conducted by Patrick Ng and Keith Nesbitt at the University of Newcastle, there are two main approaches to designing and implementing auditory cues to a game UI [20]. One of these approaches focuses on enhancing the player's enjoyment and satisfaction, while the other aims to use audio to help users perform their actions and tasks in the game. The latter puts emphasis on providing the player with information through auditory cues. A general assumption is mentioned: As a larger number of senses are utilized in an interaction, the amount of information presented to and processed by the player increases.

According to a report by Holloway et al. [21] most in-game sounds in FPS games can be divided into three categories: reactionary sounds, pre-emptive sounds and feedback sounds. Pre-emptive sounds tell the player where the enemies are located before they can strike. Examples of this would be enemy footsteps, sounds of jumping, etc. Reactionary sounds indicate the location of an enemy after the enemy has attacked, such as gunshots or explosions. Lastly, feedback sounds indicate immediate changes to the player, such as a grunt when taking damage, or a soundbite connected to healing the player.

In more recent years another field of in-game audio has been popularized, that of spatial sound. Spatial audio refers to the process of replicating the experience of being surrounded by multiple audio sources [22]. This can create a more immersive sound experience than traditional two-dimensional (2D) audio.

2.5 Sonification

In a paper by Kramer, G. et al., it is said that sonification is the use of sound to transmit information and more specifically it is conveying information with the use of non-speech audio [23]. Furthermore they argue that to successfully implement sonification one needs to amalgamate multiple different disciplines from various fields such as acoustics, human perception and engineering among others. The following subsection will cover possible ways of mapping physical quantities to sound.

2.5.1 Mapping of physical quantities

There have been numerous studies done within the field of sonification. A study conducted by G. Dubus and R. Bresin performed a systematic review of previous studies within the field to draw conclusions on how to represent physical quantities within the realm of sonification [24]. This study found that a majority of common associations between the auditory and physical realm involve pitch as an auditory property. Furthermore, it is mentioned that associations between the physical and auditory dimension that don’t rely on pitch instead utilize natural perceptual impressions from the real world. Examples of physical quantities that are most often associated with the auditory property of pitch are size, velocity and orientation. Contrarily, examples of physical properties that most often are not associated with pitch are distance, energy and location. In this case, distance is often mapped to loudness. This is also usually the case for energy. Location however, is often mapped to the auditory property of spatialization. In an auditory context, spatialization refers to the representation of a sound source in 3D space.

Furthermore, in an article by D. Geere and M. Quick it is stated that musical pitch is commonly used in data sonification to signify a sense of quantity [25]. In this context, a note of increased pitch usually signifies a greater quantity of a certain unit.

2.6 Levels in video games

The term “Level” in a video game refers to either a section or the entirety of the environment in the game world as stated by Tobias Karlsson et. al [26]. Furthermore it is stated that level creation consists of two main stages: White boxing (sometimes also called gray boxing) and Set dressing. White boxing is the stage in the level creation process where the outline of the level without any art is created. This is also typically used for quick prototyping purposes. The second part, Set dressing, refers to decorating the White box version of the level with the art assets.

Level layouts can be designed according to two main design principles, linear design or a non-linear design. Carlo Fabricatore et al. states that, when a game has multiple stages or objectives, they can be organized in a more or less linear way [27]. It is also stated that the relation between these stages or goals is defined as linear if it only makes unidirectional, one-to-one traversal between the different stages possible. The design is however considered non-linear if it is possible to transition between stages in a one-to-many fashion. In level design, this would mean that if in every part of the level, it is only possible to traverse to one other part, it is considered linear. However, if there are parts of the level that allows the player to go into multiple different parts of the level, it is considered to be designed in a non-linear fashion.

2.7 Monte Carlo simulations

According to IBM a Monte Carlo simulation is a type of forecasting simulation or model that can be used to predict a set of outcomes by utilizing a probability distribution for any variable that has uncertainty [28]. In a paper on monte carlo simulations by Samik Raychaudhuri it is also stated that these types of simulations utilize continuous random sampling as well as statistical analysis to create potential outcomes [29].

Raychaudhuri further simplifies the explanation by stating that the simulation contains three main parts, the input data, the mathematical model, and the output analysis. In other words, the mathematical model receives input data and computes the output data.

Conducting a Monte Carlo simulation typically involves a couple of important steps. According to Raychaudhuri the initial step before conducting the simulation is to develop a deterministic mathematical model that accurately mirrors the real-world scenario [29]. This step also involves identifying the input parameters and applying mathematical relationships that transform the input variables to the output variables. Furthermore Raychaudhuri states that the next crucial step is to identify the distribution of the input variables. This step consists of analyzing the nature of the input variables and trying to identify, if any, underlying distributions in the nature of the variables. The last step is introducing random variable generation. This step involves generating random numbers from the identified distributions. These random numbers will then be used in the deterministic mathematical model to generate different potential output data. This is the step that is then repeated continuously to create a wide range of different possible outcomes.

3. METHOD

3.1 Introduction

The foundation for the study was creating and refining multiple UI configurations in a small-scale, simple FPS game for the study subjects to play. The main idea was for subjects to play different custom-made levels using the varied UI configurations to measure different variables connected to the gameplay.

The base game was rather basic, allowing the player to move and look around in a 3D space. However, more complicated gameplay mechanics were included, such as picking up gold coins, shooting and destroying different types of enemies. Three different "feedback configurations", which altered gameplay elements such as audio and visual feedback directed towards the player, were also created. Since the study aimed to investigate audio and visual feedback's impact on player performance and comprehension, these feedback configurations were the basis for the study.

Creating a custom game facilitated the curation of game mechanics, which allowed for an increased focus towards specific variables such as level completion time and gameplay information comprehension, which were the dependent variables for this study. Additionally, it helped to eliminate extraneous independent variables that could influence the dependent variables, such as those mentioned previously.

3.2 Game Design

The game was constructed using the Unity game engine's "FPS Micro-Game" template [30]. The template is used for teaching beginners the ins-and-outs of the Unity game engine. Due to the modular nature of the template, implementation of basic gameplay features and HUD elements became much simpler. Unity is also one of the simpler game engines available, which made it easier to learn any new skills required for the creation of the game.

For the game, three small-scale white box levels were created using varying prefabricated structures from the micro-game template. The levels were also designed in a non-linear fashion, allowing for more open-ended exploration of the various parts of the level. Examples of these structures were ramps, walls, floors and other decorative tiles. Each level was created to be as different as possible, with different sized rooms with varying layouts, hallways and open areas, all specific to their own level. However, the objective "length" of each level, as in the time needed to complete the level, was equalized/normalized to focus on the feedback configurations effect on level completion time. The aim was to have the test subjects playing each level for around 2-3 minutes.

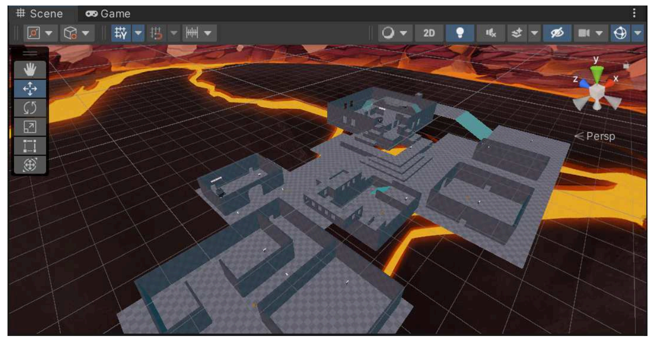

Figure 3: Example of level layout ("Level 1")

As was mentioned in the method introduction, three feedback configurations were created, each focusing on a certain method of giving feedback to the player. The Auditory configuration was focused almost solely on auditory feedback. The Visual configuration was focused on visual feedback, with the final Mixed configuration being centered around a balanced mix of both visual and auditory elements. The Mixed configuration was included to mimic the "standard" amount of visual and auditory elements in game UI, specifically those games outside the realm of cluttered UI that we are researching. For the game, most HUD elements that were deemed necessary to complete the level remained constant through each configuration, as to not hamper performance outside of the chosen metrics, as well as to make sure subjects could complete the levels consistently. Those elements deemed necessary include a health bar, a compass to show the direction of enemies, weapon information and pause menu information.

Figure 4: Visual feedback configuration UI

Depending on the configuration, sound effects were either removed or changed to add pitch increases based on certain factors. For the Auditory and Mixed feedback configurations, a metallic "pling" sound effect would play upon picking up a gold coin. This sound effect was chosen because of its frequent application in comparable scenarios across various games. Specifically for the Auditory configuration, the coin sound effect would increase in pitch for each pickup collected, using a constant increase value. The pitch increase was done to give players passive feedback that the pickup count was increasing without showing a number value increase. This was a crucial aspect in our study of whether auditory or visual feedback is more effective for player gamestate comprehension, which was in this case the amount of pickups they have acquired. In the Visual feedback configuration, the pickup sound effect for pickups was completely removed, and instead replaced with a popup at the bottom of the screen that informed the player that they had picked up a coin.

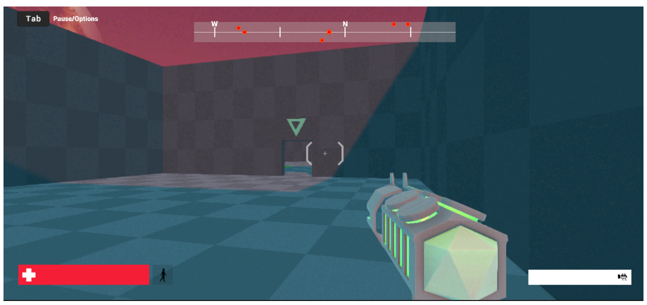

Figure 5: Auditory feedback configuration UI

The present elements in each feedback configuration: Visual, Auditory and Mixed, can be seen in *Figure 6* and *Figure 8*.

3.2.1 Visual Items

	Visual	Mixed	Auditory
Compass	X	X	X
Health Bar	X	X	X
Weapon Info	X	X	X
Kill Counter	X	X	
Pickup Counter	X	X	
Controls	X		
Flash upon taking damage	X	X	
Timer	X	X	
Pause menu information	X	X	X
Pop Ups (Enemy Killed & On Pickup)	X		
Fixed Objective	X	X	
Information			
Initial Objective Pop-up	X		

Figure 6: Table illustrating which visual components of the user interface that are present in each configuration.

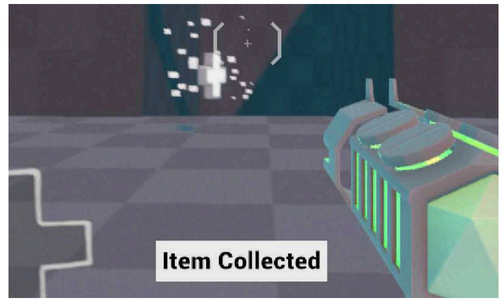

Figure 7: Example of Visual feedback configuration popups

3.2.2 Auditory Elements

Almost all sound effects used for the test game were from the Unity FPS template. The most commonly used sound effects from the template were sounds for enemy movement, enemy detection, health pickup and for when the player takes damage. These sounds were chosen mostly to save time, as the effects were quite well suited for the gameplay situations that would transpire when playing the game, and were already included in the template. The only sound effect that was imported was the metallic "pling" effect. The reason this sound effect was chosen, as previously explained in section 3.2, was due to similar effects being used frequently throughout various different games. The effect was downloaded from a royalty free sound effect site [31], to avoid potential legality issues that could stem from using a sound effect in a study without consent.

	Visual	Balanced	Auditory
Coin Pickup Sound effect		X	pitch increase with amount
Enemy Movement sounds		X	X
Enemy Detection Sound		X	X
Health Pickup Sound Effect		X	X
Enemy Taking Damage Sound effect		X	X

Figure 8: Table illustrating which auditory elements that are present in the different configurations.

3.3 Simulation

Before beginning the user testing, a basic Monte Carlo simulation was done to simulate quantitative data points based on our hypothesis. This was done in order to get a better understanding of the possible outcomes of the user testing as well as gaining understanding of how many participants would be needed in order to draw statistical conclusions from the test data. This meant that the independent variables, also known as the input variables, were based on our hypothesis. Possible outcomes of the test subjects' playtime were then simulated. The simulation program, developed by the researchers in python, and the full program code can be found in APPENDIX A.

The simulated playtimes for a configuration were calculated based on three main factors. These factors were: “expected playtime for the configuration”, “player deviation” and “level deviation”. The factor “expected playtime for config” is a value unique to each configuration that is closely related to the expected playtime per level. In other words, this value is based on the expected level playtime of 120 seconds as well as if the configuration is expected to cause a faster or slower playtime. The expected playtime per level was based on internal testing and a pilot test prior to the user tests. Furthermore, the specific value of “expected playtime for the configuration” is based on our hypothesis regarding the different configurations play times. For example, the expected playtime for the Mixed configuration is set to a lower value than the expected playtime for the Visual configuration as per our hypothesis. The factor “player deviation” is randomized based on a normal distribution with a standard deviation of 9 seconds, and the “level deviation” factor is a randomized float value between -10 to 10 seconds. The resulting simulated test data underwent analysis via a T-test, providing an estimate of the necessary number of test participants required for the data to achieve statistical significance.

Two sets of simulations were run in total. The difference between these two sets of simulations were in the expected playtime of the different configurations. The first simulation assumed a 20 second difference in playtime between the fastest and slowest configuration while the second assumed a 10 second difference in playtime between the fastest and slowest configuration. Two sets of simulations were run in order to encapsulate the lower and higher bounds of the expected configuration playtimes according to our hypothesis.

3.4 User Testing

The foundation for this study was based on both quantitative and qualitative methods. By creating a custom game, the quantitative variables were able to be measured automatically, through custom scripts written within Unity. The quantitative measurements included time to completion, enemies destroyed, and coins picked up. The idea was to use these measurements to find a potential link between different feedback configurations and player performance.

The qualitative data came from questionnaires answered by the subjects throughout the test. Prior to the test, subjects were asked to answer a short questionnaire, which covered topics related to previous experience with FPS games and usage of common gaming peripherals such as keyboard and mouse. This would hopefully reveal a connection between feedback configuration preferences, performance and the subject's prior experience with the genre and hardware used for the study, once the testing was complete and the subjects data had been analyzed. Since a keyboard and mouse were used as the input methods for the test, asking for their experience prior to testing also seemed worth tracking and analyzing.

During the test, subjects were asked to play the game through three different levels, with each level having one feedback configuration activated; either Visual, Auditory or Mixed. The order of both levels and which configuration was used was different for each participant. However, it was made sure that the number of times each configuration was played on each level was even across the entire study to avoid it affecting the results.. As mentioned in section 3.2, each configuration included and excluded different feedback elements, such as sounds when picking up coins, pickup counters and red flashes when taking damage. The match of level and feedback configuration was chosen before each test to have an even amount of configurations per level. This was done to avoid level bias in the data, as one level may be easier or more well suited to a configuration compared to another. During the tests a few pieces of basic equipment were used, namely, over-ear headphones (Sony WH1000XM4), a mouse and a computer (Lenovo Yoga 7 laptop) to run the game. These were constant throughout the entirety of testing to ensure that all participants played the test game in the same conditions.

Each level was created to take around 2-3 minutes to complete. This “testing time” stems from wanting a relatively comfortable total test time for students, so as to not disrupt their studies, as they would have to play 3 levels as well as answer questions. Having shorter levels meant that it would be more difficult to measure the impact of each feedback configuration. This meant a total game time of approximately 10 minutes and an approximate testing time of 20 minutes per subject.

After each completed level, another questionnaire was provided to the subject. This was done to gain a better understanding of their subjective experience with each feedback configuration, which would later be compared to the objective impact of the feedback configurations on the player. The questions on this questionnaire were formed so as to allow the subject to openly voice their opinions on the configuration and their preferences regarding FPS UI. The questions were:

- How many pickups do you think you acquired?
- What did you think about the visual elements in the game?
- What did you think about the auditory elements in the game?

Follow up questions were sometimes given to gain a more specific opinion on the configuration, if the subject was too ambiguous with their answer. An example of a followup question would be “Was there anything on the HUD you would remove, and why?”.

Once all the levels were completed, subjects were asked to answer a final questionnaire, which was also focused on the subject's subjective opinions and experience of the entire game.

Questions asked after the entire test were:

- Was it easy to understand the main objective of the game?
- Which of the configurations would you prefer and why?

The final question was asked to gain a subjective preference from the subject, on top of the objective optimal feedback configuration for the subject.

The qualitative data from the tests underwent a thematic analysis by organizing the answers to each question into three groups, one for each configuration. The answers to the questions for each configuration were then analyzed to find recurring themes and patterns in the answers.

3.5 Participants

Most participants that were asked to take part in this study were gathered from around the campus of the Royal Institute of Technology in Stockholm, Sweden, mainly focusing on the areas where students in the Media Technology program usually reside. Therefore most of the participants were Media Technology students, varying between ages 20 to 24. As to not have too large of a spectrum of results, subjects with previous gaming experience were prioritized, as this study mainly aims to provide information for experienced gamers. This was also a way to limit the scope of the study since previous experience might have an effect on how the players perceive the feedback configurations and this study does not seek to provide insight into the relations between previous experience and the perception of the game.

4. Results

The results for this study consists of several parts. The following subsections will present the results for the Monte-Carlo simulations and the user testing. The results from the user testing covers the recorded playtimes, collected pickups as well as a thematic analysis of qualitative statements from the participants.

4.1 Monte-Carlo simulations

Prior to testing, multiple Monte Carlo simulations were conducted, each varying solely in the expected deviation setting between the different configurations. The simulations were done in order to get a rough indication of how many test participants that would be needed to show statistical significance between the configuration playtimes. Each simulation was run multiple times, with the same settings, but with a varying number of players. A paired t-test was then conducted with a chosen significance level of 0.05. In other words, if the result from the t-test is less than 0.05 then it is said to be statistically significant. All simulations took “player randomness” into consideration, since factors like prior experience within the genre may affect the level completion time.

4.1.1 First simulation

This initial simulation assumed a significant difference in playtime between the configurations, specifically 20 seconds, between the fastest and slowest configuration.

After simulating the playtimes with these settings, a paired t-test was conducted in order to test statistical significance of the acquired simulation data. A full list of the obtained simulated playtimes can be found in APPENDIX B..

5 Players		
P-value (Visual/Mixed)	P-value (Visual/Auditory)	P-value (Mixed/Auditory)
0,0389	0,1233	0,1473

Figure 9: Table illustrating obtained p-values from t-test conducted on the playtimes generated by the simulation.

Furthermore, a simulation with 10 participants was run, and a corresponding paired T-test was done. The results of the t-test can be seen in *Figure 10* below.

10 Players		
P-value (Visual/Mixed)	P-value (Visual/Auditory)	P-value (Mixed/Auditory)
0,0012	0,1033	0,0044

Figure 10: Table with results from simulation 1. Data points from 10 players.

As can be seen in *Figure 10*, two of the obtained p-values were less than the chosen significance level of 0.05. This suggests that if there is a significant difference in playtime between the configurations, it would be advisable to aim for a minimum of 10 participants.

4.1.2 Second simulation

The second simulation assumed a less significant difference, namely 10 seconds, between the expected playtime for the fastest and slowest configuration. The full list of simulated playtimes can be found in APPENDIX C.

10 Players		
P-value (Visual/Mixed)	P-value (Visual/Auditory)	P-value (Mixed/Auditory)
0,0054	0,7568	0,0106

Figure 11: Table showing obtained p-values from the simulation with 10 players

15 Players		
P-value (Visual/Mixed)	P-value (Visual/Auditory)	P-value (Mixed/Auditory)
0,0485	0,4128	0,1643

Figure 12: Table showing obtained p-values from the simulation with 15 players

20 Players		
P-value (Visual/Mixed)	P-value (Visual/Auditory)	P-value (Mixed/Auditory)
0,0002	0,1457	0,009

Figure 13: Table showing obtained p-values from the simulation with 20 players

This simulation concluded that demonstrating statistical significance between all the different configurations becomes particularly challenging when the expected playtime differences among them are minimal. However, statistical significance was demonstrated by only 10 participants in this simulation. Thought to reliably indicate statistical significance across multiple configurations, it appears that at least 20 participants would be necessary in this scenario.

4.1.3 Conclusion of simulations

The simulations indicate that it would be beneficial to aim for around 10-20 participants to increase the chances of being able to show statistical significance between the configurations. However, pursuing a larger participant pool was not feasible due to the time constraints of this study.

4.2 User Testing

A total of 12 subjects participated in the study, all Media Technology students. In terms of prior relevant experience for the study, 9/12 participants described themselves as having a high amount of prior FPS experience, while 10/12 participants stated having high levels of M&K (mouse and keyboard) experience. Although many of them showed similarly high levels of skill, their completion times throughout each test varied rather drastically, mainly due to each user's unique playstyle. Some focused solely on the main objective, which was getting kills, while others opted to explore the map more, trying to make difficult jumps as if it were the objective of the game to get across the map efficiently. Other participants focused mainly on pickups despite them not being the main objective.

4.2.1 Level completion time

Quantitative measurements of level completion time were made and organized into a table for analysis. See *Figure 14* below:

Level completion times (seconds)		
Level 1	Level 2	Level 3
241	143	150
250	150	187
110	95	121
162	146	212
172	119	115
143	105	160
131	162	135
146	124	110
200	137	127
168	130	176
240	243	264
162	104	77

Figure 14: Table of recorded completion times for each level. Each row in the table corresponds to a participant in the test and each column corresponds to a level in the game. Measurements are in seconds

It can be observed in *Figure 15* that Level 1 turned out to have slightly higher completion times on average.

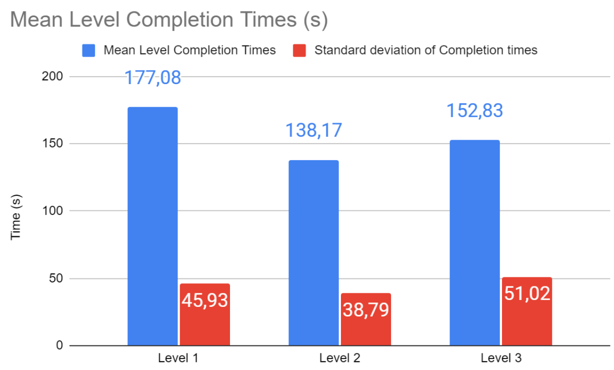

Figure 15: Diagram illustrating average completion times per level and the corresponding standard deviation

4.2.2 Configuration completion times

The recorded completion times were organized into tables, with completion times mapped to their corresponding feedback configurations.

Configuration completion times (seconds)		
Visual Configuration	Mixed Configuration	Auditory Configuration
143	241	150
250	150	187
121	110	95
146	212	162
172	115	119
160	105	143
131	162	135
110	146	124
137	127	200
176	168	130
240	243	264
104	77	162

Figure 16: Table of recorded completion times for each feedback configuration. Each row in the table corresponds to a participant in the test and each column corresponds to a feedback configuration in the game. Measurements are in seconds.

The average completion times along with their standard deviation in *Figure 16* show a slight, if not negligible, difference between completion times in regards to the auditory configuration compared to the other two.

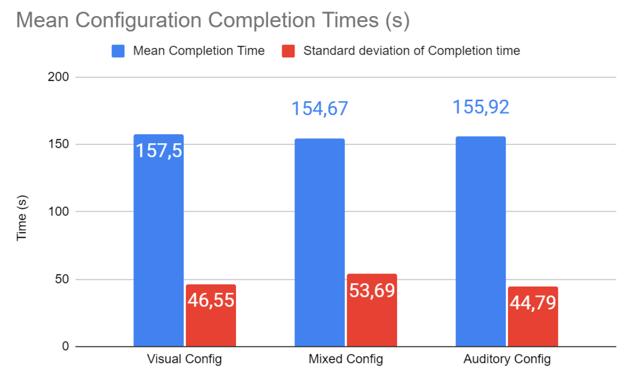

Figure 17: Diagram illustrating average completion times along with standard deviation for each configuration. Measurements in seconds.

From *Figure 17* it can be observed that there is little to no difference in the playtime between the different configurations. Before conducting the test, we had planned to perform a t-test on the gathered data. However, we ultimately opted against this as the mean values were sufficiently close, indicating a lack of statistical significance between the various configurations.

4.2.3 Coin pickups

Quantitative measurements of the number of coin pickups collected by the participants during their tests were made. These measurements were organized into a table alongside the participants' perceived number of pickups they had collected, which was gathered in a post-test questionnaire.

Number of Coin pickups collected (Actual vs Perceived)					
Visual Configuration		Mixed Configuration		Auditory Configuration	
Actual	Perceived	Actual	Perceived	Actual	Perceived
8	6	6	8	7	6
7	6	8	8	6	9
4	4	4	5	5	7
6	?	5	6	7	7
7	6	6	6	7	6
7	4	7	7	7	5
4	4	8	8	9	7
5	5	6	6	7	5
6	8	7	5	7	7
7	5	7	6	8	4
7	8	7	9	7	6
8	3	6	6	7	7

Figure 18: Table containing actual and perceived values of player obtained coin pickups. Each row in the table corresponds to a participant in the test. The columns labeled as "A" are the number of collected pickups and the columns labeled as "P" are the number of perceived collected pickups. The columns are color-coded such that yellow columns are the Visual configuration, orange columns are the Mixed configuration and blue columns are the Auditory configuration. Table cells marked with "?" indicates that the participant could not recall any specific number of pickups.

As seen in *Figure 18* above, one of the participants didn't dare to guess the number of pickups collected on the Visual configuration due to them being very unsure of whether they noticed anything or not. In the analysis of this data the "?" in the table was regarded as if the participant perceived 0 collected pickups. These values were then added and compared to each other below in *Figure 19*, *Figure 20* and *Figure 21*.

Sum of actual/perceived values (Visual)	
A - Visual	P - Visual
76	59
Summative deviation (A - P)	
17	

Figure 19: Table showing the added perceived/actual values of collected pickups compared to each other. The columns labeled as "A" are the number of collected pickups and the columns labeled as "P" are the number of perceived collected pickups.

Sum of actual/perceived values (Mixed)	
A - Mixed	P - Mixed
77	80
Summative deviation (A - P)	
−3	

Figure 20: Table showing the added perceived/actual values of collected pickups compared to each other. The columns labeled as "A" are the number of collected pickups and the columns labeled as "P" are the number of perceived collected pickups.

Sum of actual/perceived values (Auditory)	
A - Auditory	P - Auditory
84	76
Summative deviation (A - P)	
8	

Figure 21: Table showing the added perceived/actual values of collected pickups compared to each other. The columns labeled as "A" are the number of collected pickups and the columns labeled as "P" are the number of perceived collected pickups.

Furthermore, the relative deviations between the actual and perceived number of pickups were calculated. In this context, "relative deviations" quantify the numerical deviation from the correct answer relative to the actual number of pickups collected. For instance, if a participant gathered 8 coins in a level but estimated they only picked up 4, this would result in a relative deviation of -50%, indicating their guess was 50% lower than the accurate count. The relative deviations were calculated for each player across all three configurations and then the mean relative deviation for each configuration was calculated.

Mean Relative Deviations		
Visual Configuration	Mixed Configuration	Auditory Configuration
−19,99%	5,34%	−6,85%

Figure 22: Table showing mean relative deviations in actual vs perceived number of pickups collected.

It can be observed in *Figure 22* that the visual configuration saw the largest mean relative deviation of -19,99% indicating that on average 20% of the collected pickups were not noticed. The total number of times that the participants correctly guessed the number of collected pickups was also recorded which can be seen in *Figure 23* below:

Number of correct guesses on number of pickups		
Total Correct Visual Configuration	Total Correct Mixed Configuration	Total Correct Auditory Configuration
3	6	3
25%	50%	25%

Figure 23: The frequency of correctly guessed number of pickups by participants.

Overall it can be observed that the Mixed configuration had the highest rate of correctly recalled number of pickups. *Figure 23* also indicates that the Visual and Auditory configuration performed similarly in this regard.

The number of times that each configuration had the highest number of collected pickups was also tracked. In this scenario, it is important to distinguish between a configuration achieving a "max" number of pickups and one achieving a "true max." To qualify as a "true max," the collected coins in a configuration must exceed the number of coins collected in all other configurations. On the other hand, for a configuration to be labeled as a "max," it simply needs to have a number of collected coins greater than or equal to those in all other configurations. The labeling of the different configurations was added up for all players and are presented in *Figure* 24 and *Figure* 25.

Number of times labeled as "Max"		
Visual Configuration	Mixed Configuration	Auditory Configuration
5	4	9

Figure 24: Table showing how many times each configuration was labeled as “Max”

Number of times labeled as "True Max"		
Visual Configuration	Mixed Configuration	Auditory Configuration
2	1	5

Figure 25: Number of times each configuration was labeled as “True Max”

These tables show that it was most common that the players collected the most number of pickups on the Auditory configuration.

4.2.4 Qualitative Data

During the test, qualitative data was also gathered through questionnaires and interviews with the subjects. The questionnaires were answered by the subjects pre-test, as well as after each completed level. The qualitative data allowed us to garner a greater understanding of the subjects' subjective experience with the feedback configurations using thematic analysis. The most important identified themes was visual clutter, a preference for auditory cues rather than visual cues such as “pop-ups” and that the game's objective is best clarified via visual elements. As the participants were asked to reflect on their experience with the configuration after each played configuration, a thematic analysis was conducted for each configuration. The thematic analysis was done in order to efficiently highlight any discovered patterns in the three configurations as well as distinguish any recurring themes across them.

4.2.4.1 Visual Configuration

Overall, the feedback from the users regarding the Visual configuration emphasized the importance of minimizing visual clutter, reducing the frequency of pop-up notifications, as well as balancing visual and auditory feedback to create a more streamlined and immersive experience. The most common theme identified with the Visual configuration was “visual clutter”, with 8 out of 12 participants expressing their discontent with the layout of the configuration in some way. Notably there was a moderately strong consensus among participants regarding the frequency and the intrusive nature of pop-up notifications, with 6 subjects finding them to noticeably interfere with the gameplay loop and to be generally distracting. These participants also suggested removing unnecessary notifications, such as those for kills, pickups and time to enhance the experience and reduce visual “noise”.

4 participants specifically acknowledged the persistent display of the controls-tutorial and found it to be unnecessary and distracting as well. This was the most common example of inconvenient visual clutter that was brought up by the participants. However, 2 participants appreciated certain visual cues such as notifications regarding the main objective of the game.

Conversely, 9 out of 12 participants expressed a preference for auditory feedback in regards to enemy kills and pickup collections rather than having the feedback be visual. The participants expressed their discontent with the absence of auditory feedback when picking up items during their time with the Visual feedback configuration. They emphasized the importance of auditory cues in alerting them to certain in-game events. For example, one participant stated that:

“*I had to turn back in order to see if I actually picked up the coin*”.

Another common theme that was identified was the notable preference for auditory cues over visual ones among the subjects. 5 participants explicitly expressed that the visual feedback was hard to notice or even register for a majority of their game time, as well as feeling more intrusive than what they perceived the auditory cues to be. Two participants also explicitly stated that the visual elements require more "active reading" from the player in contrast to the auditory cues, which they felt could convey the same information more passively.

2 out of 12 participants felt that the introduction of visual elements did not significantly impact the gameplay due to their strong focus on playing the game and completing the objective, over giving feedback on the UI design and its impact on their performance.

4.2.4.2 Mixed Configuration

In general, the Mixed configuration produced the same themes and patterns as the Visual configuration, however, the participants seemed more satisfied with the balance between visual and auditory elements. While 4 participants expressed that certain visual elements were somewhat redundant, they also acknowledged that some elements also provide clarification in terms of the game's objective. For example one participant stated that:

"*I like that the objective is shown visually*".

Most notably, 5 participants recognized an improvement in the overall experience, particularly appreciating the reduced visual clutter and the absence of persistent control tutorials on the screen. Even though many found the reduction in visual elements to be an improvement, 3 subjects suggested that certain visual cues still visible lacked impact, particularly when it came to indicating low player health and weapon ammunition levels.

11 out of 12 subjects expressed appreciation for the helpful sound effects and auditory cues introduced in the Mixed configuration compared to the Visual configuration, most notably how they provided clarity on certain in-game actions. The consensus among the participants regarding the audio elements was that they felt crucial in alerting them to important events such as picking up coins and other items. One participant also found the sound effects for the coins to feel "rewarding" and immersive, making the overall gameplay experience more engaging. Overall, participants favored auditory feedback to convey simple yet important, in-game information, with 7 out of 12 participants specifically stating it in their questionnaire answers.

4.2.4.3 Auditory Configuration

The overall theme identified for the Auditory configuration was that participants seemed to appreciate the minimalist design of the game when using that configuration. 3 participants specifically mentioned preferring minimalist design, stating that they found the approach to be effective and non-intrusive, allowing them to focus on the gameplay and objectives without unnecessary distractions. 5 others mentioned preferring the Auditory config's UI over other configs, yet were not able to put specifically state why. However, 4 participants disliked the absence of certain visual cues, such as where to go and a visual representation of the main objective. 3 participants stated that they would not have recognized the main objective in this auditory configuration if they hadn't been instructed on it prior to starting the game. Generally the participants felt that the visual feedback provided in this configuration was sufficient, with no elements being intrusive or distracting, with 4 participants specifically stating that they did not feel the configuration was missing any crucial visual elements.

Overall, participants found the auditory cues in the game to be effective feedback tools when using this feedback configuration, particularly in the context of pickups, with 4 participants stating that the audio was more helpful than popups. They felt the simplicity and clarity of the sound effects were effective in helping them recognize and distinguish pickups and enemies. However, only 2 participants explicitly stated that they were able to perceive additional information from the subtle variations in pitch of the pickup sound effect.

4.2.4.4 Configuration preferences

Generally participants favored the configurations with minimalist design, and most notably, no participant chose the visual feedback configuration as their preferred way of getting feedback. More specifically 5 out of 12 subjects preferred the auditory configuration while 7 out of 12 preferred the Mixed configuration.

5. DISCUSSION

Overall the results from this study indicate that there are a few notable differences between the chosen ways of giving the player information from the game. Most notably it seems to have a significant impact on the players subjective experience with the game, rather than an objective effect on player performance. In the following subsections we will be discussing the different aspects of the study and their implications.

5.1 Simulations

The goal of the simulations was to give an estimation on how many participants would be needed to show statistical significance between the different configurations. Following our participant testing and thorough analysis of completion times, it became evident that our initial hypothesis regarding the influence of feedback configurations on completion time was incorrect. The simulations were based on a hypothesis where the different configurations would cause some differences in level completion time. However, the disparity between the user testing data and this hypothesis rendered the conclusions drawn from the simulations regarding the number of required participants obsolete. This is most likely due to the fact that other factors impact the completion time more than the feedback configuration.

5.2 Levels in the game

One of the first issues that we noticed when beginning our testing was the disparity in level completion time between Level 1 and the other two levels. According to the test subjects, Level 1 was more confusing compared to the other levels due to a variety of factors, with level design and enemy placement being the main focal points for the complaints. From our observations of the participants playing, these factors were also seemingly the ones affecting the level completion and confusion the most. Some participants noted doors not being large enough to see, certain platforms being unnecessary and that would lead to lost time if used, and confusing verticality in the enemy placement. Compared to Level 2 and 3, Level 1 had more structures and platforms, most likely due to it being the first level that was worked on. This issue could have been avoided through more extensive and thorough internal testing before commencing the user testing. It is also worth noting that this issue most likely did not have any significant impact on the overall conclusions of this study, since we made sure that each configuration was played an equal number of times on each level.

5.3 Feedback configurations

In terms of the different feedback configurations that were tested, our initial hypothesis regarding player performance seems to have been disproved. No significant disparity in game completion time has been observed between the different feedback configurations. However, the qualitative data indicates some interesting patterns. The players' ability to correctly recall the number of collected pickups, and their subjective preferences of the different configurations showed that the cluttered Visual configuration was the worst performing. The Mixed configuration on the other hand seemed to perform very well among the participants and this is also reflected in that 7 out of 12 participants chose this one as their preferred configuration.

From both our own personal experience in gaming, and from what we gathered from observing the test subjects, it seems that the more experienced one is with gaming and the FPS genre, the more one tends to prefer a minimalistic UI design framework. This could stem from a variety of factors. The main assumption is that having knowledge of the norms of game UI and how to extract information from it efficiently means that an experienced player doesn't require constant reminders of gameplay elements, such as kills or pickups. An experienced FPS player or gamer might already be taking active gameplay elements and passively memorizing them through muscle memory, or they just know what to look or listen for, compared to a less experienced FPS player.

For the Visual and Mixed configurations, 5 participants explicitly noted that counters for gameplay elements such as coins and kills didn't feel necessary. It was mentioned that outside of keeping track of how many enemies you had left to destroy, knowing the amount of kills you had as the player felt relatively unnecessary. From the qualitative data, it appears that players prefer to visually perceive essential information directly associated with the primary task or objective. However, extraneous visual elements on the screen, which do not aid in the main task, are seen as unnecessary or even distracting. This could be due to the fact that having extra visual elements, especially ones that change constantly, tends to distract and reduce focus on a singular objective. However, as seen in the mean configuration completion time in *Figure 17*, this perceived reduction in focus seems to be mainly subjective and not actually impact performance.

Those same participants also noted that they preferred a more passive comprehension method for the pickups, such as the sound bites that played on pickup, compared to a more active method, such as the pop up notifications that informed the player that they had picked up a coin or killed an enemy. However, having a visual counter seemed to give the player a higher precision in their comprehension, as can be seen by the quantitative results from the Mixed configuration in *Figure 23*, which included a pickup counter. This could go to show that players are more susceptible to comprehending gameplay elements that require instantaneous feedback, such as pickups or killing an enemy, when said feedback is given passively, for example through auditory cues. On the other hand, gameplay elements where feedback is not required in the moment, such as the exact number of pickups or kills, is better communicated through visual means rather than communicated passively to the player through audio.

5.4 Coin pickups

Looking at and analyzing the data of the number of pickups collected by each player across different configurations along with their estimations of acquired pickups, interesting patterns can be observed.

Generally speaking participants seemed to find it significantly harder to estimate the number of collected pickups when playing the Visual configuration. In the Visual configuration, both the highest summative deviation (*Figure 19*) and the highest average relative deviation (*Figure 22*) were observed, with participants failing to notice 20% of the pickups collected on average. The qualitative data from the questionnaires also suggests something similar, where participants expressed how they preferred the collection of coins to be indicated by an auditory cue rather than a visual element. This could stem from the player needing to actively redirect their focus or read in order to register the visual feedback, which means that, for a short time period, they stop focusing on the main task. Since the coin pickups were not a part of the "main" objective, players might have been less likely to stop and acknowledge the visual feedback regarding the pickups. However, the passive registration of the auditory feedback cues when picking up coins might have allowed the player to continuously focus on the main task while also subconsciously noticing when they acquired a pickup.

Another interesting pattern that can be observed from the data is that the Auditory configuration was the configuration most frequently labeled as "max" and "true max", respectively. This means that the Auditory configuration most frequently saw the highest number of collected pickups by players. This, in some capacity, indicates that players might have been able to focus more on side-tasks (i.e tasks that are not directly related to the main objective) when less visual clutter was present on the screen. We have also mentioned how participants expressed that they preferred the collection of coins to be conveyed through auditory cues rather than visual effects. Perhaps players are more inclined to focus on collecting coins in the configurations where they find the feedback from the action to be more satisfactory.

However, it's worth considering that, while playing with the Auditory configuration, players may have directed less attention towards the main objective and instead prioritized collecting more coins. This shift could be attributed to the main objective being communicated less explicitly compared to the other configurations.

5.5 Sound effects

In the game we used a short high-pitched "pling" sound effect for the coin pickups. This sound effect was chosen for a couple of reasons, the main reason stemming from previous successful research on the topic of designing non-speech auditory cues for human-computer interaction. An example is how Brester effectively improved the interaction with graphical buttons using sounds of varying pitch, with the higher pitch sounds signifying a successful action [14].

The second reason behind choosing this type of sound was its close relation to the real world sound of coins. Beaudoin-Lafon and Conversy spoke on how the sound made from real-world objects assist us in perceiving the world [12], however, they also stated that the sound effects do not necessarily have to be "natural". Nevertheless, it's a common practice in games to tie gold or coins to a sound that is similar to a coin being dropped, or audio associated with a "shiny" feel, so it felt natural to choose such a closely associated sound bite.

Generally speaking, this sound effect performed well during the test and effectively conveyed to the players that they picked up a coin. The participants also expressed their appreciation for the coin sound effect and also conversely expressed their discontent when the sound effect was absent.

5.6 Method discussion

There are some areas of the methodology that could have been improved to varying degrees. Starting off, the test game could have been done with a few more days of framework programming. A large amount of time and effort was spent just to understand the framework that the template was built on, and how modular it was. This meant that the programming of relevant game mechanics was done with quite a strict time constraint. Due to this, many systems for testing purposes were not fault-proof or bug free. Bugs such as enemies being spawned within walls or ceilings, falling through terrain, or certain tracked data points not being printed in Unity's terminal. This meant that during testing, certain elements had to be manually double checked, or that we sometimes had to manually time the level completion time. In hindsight, this could have affected player completion times. However, when looking at the quantitative data, an extra half second on each level from the human reaction time that comes from starting the timer, wouldn't have affected the end result or conclusion of this study. For further study, one would of course make sure that these times are logged and output.

Another element of our methodology that both we and the subjects had issues with was level design. We the authors are both very inexperienced with not only level design in general, but level design for FPS games as well. This meant that not only were the levels not particularly interesting to look at or explore, as they were quite bland in layout and color. They were also filled with extra structures, holes in the terrain and other unnecessary obstacles that hindered subjects' completion time. If given more time, additional internal testing on each level could have given more conclusive measurements, both qualitative and quantitative.

As mentioned previously, both our qualitative and quantitative measurements required multiple reworks. For example, our initial qualitative measurement was kills, then both kills and pickups, then those as well as level completion time. In hindsight, having a more streamlined focus on either qualitative or quantitative measures, or even simulations, could have led to more conclusive results. Our initial thought was to focus solely on qualitative measurements and the players subjective opinions on UI and their experience, however this was unrealistic for our study. Solely researching qualitative data is outside of the scope of a study of this size, and would require much more time and increased resources than those available to us. Having quantitative data alongside less broad qualitative data allows us instead to find more specific patterns, and draw conclusions based on objective data, instead of purely subjective. If given another chance, we could have given more time to create a more realistic and streamlined methodology that focused on either qualitative or quantitative measurements whose results satisfied our hypothesis.

The levels in our test game were designed in a non-linear and open-ended way which gave the player an opportunity to explore the different sections of the level in any order they wanted. However, this facilitated the players own playstyle to impact their playtime, and might have had a noticeable impact on the overall result as well. This could have been avoided by simply designing the levels in a more linear manner, instead of the segmented areas with open spaces connecting them.

It is also worth mentioning that having 3 levels and 3 configurations forced us to limit the number of tests. This was due to the fact that the number of played levels and feedback configurations had to be equal to avoid unbalanced results, which meant that the test amount had to always be divisible by 3. This was unavoidable due to the structure of our tests. This shouldn't have impacted our end result, since we had 12 participants.

5.7 Further research

Our study was rather broad in terms of researching the impact of audio and visual elements on performance and comprehension, as we did not specify any UI elements or frameworks, and instead adopted the norms of game UI design from our own experience as a base. If we had more time or if someone wanted to continue the study, one could reasonably argue that a good starting off point would be researching the impact of auditory and visual feedback on specific UI elements, or for specific gameplay loops, both within and outside the genre of FPS.

Another area that warrants further research is whether or not the visual elements, which we have shown to be less favored by players for certain in-game elements and events, can be fully or semi-replaced by audio. Such a study would have to be rather large, or focus specifically on certain elements, genres or gameplay scenarios. It is also worth mentioning that such a study should change the method to avoid having to have a participant quantity that must be divisible by 3, as it's unnecessary and an obstacle to limit participant quantity in such a way.

When it comes to the visual elements in this study, the primary focus has been visual elements of quite simple nature, more specifically text-based elements. Conducting a study to evaluate how the implementation of icons impact the players perception of the visual feedback could be very interesting and shed further light on the subject. Also studying how UI designers can use colors in their visual feedback to further optimize UI design could be interesting and worth further research.

In terms of auditory elements this study has focused on very simple sound effects and cues, however further research could perhaps focus on evaluating the effects of music and various musical attributes and how they impact player performance. Further studies could also aim to evaluate alternate sonification strategies such as testing other ways to map physical quantities to auditory cues. Another interesting topic is also if the visual text-based elements can effectively be replaced by “spoken” auditory elements.

In terms of the potential usage for the results of this study, we hope that our results have shown how both visual and auditory elements are best used to efficiently provide feedback to the player. From our results one can see that UI elements tied to the main objective of the game are preferably visual, while instantaneous feedback is preferably auditory. We hope that these results show UI designers the quantitative facts regarding visual and auditory elements’ impact on players, and hopefully shift the paradigm more towards less cluttered or even minimalistic UI designs.

6. CONCLUSION

The different feedback configurations have not been shown to have any significant impact on player performance in regards to level or game completion time. However, the configurations have been shown to have a more notable impact on the players experience with the game as well as their ability to comprehend information about certain in-game events. The results of the study seems to indicate a preference amongst the participants towards a minimalist design approach in terms of the visual elements. This study has also indicated that most, if not all, information not directly related to the main task can efficiently be conveyed through auditory elements to give the players a more streamlined satisfactory gaming experience.

Additionally, our research has revealed that visual feedback elements typically demand more active attention from players, actively diverting their focus from the game and its primary objectives. In contrast, auditory feedback elements enable players to passively register information without needing to shift their focus away from the game.

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APPENDIX A - Simulation program

```python
import random
import statistics
from scipy import stats

def run_simulation(num_simulations = 10, filename = "Simulation.txt"):
    config_level_counter = [
                            [0, 0, 0],
                            [0, 0, 0],
                            [0, 0, 0]
                            ]

    with open(filename, "w") as output_file:
        # Parameters
        level_playtime_seconds = 120  # seconds (2 minutes in seconds)


        player_deviation_factor = 27

        config_1_deviation = 5 # Visual
        config_2_deviation = -5 # Middle
        config_3_deviation = 0 # Auditory
        # Mean playtime for each configuration
        expected_playtime_config_1 = level_playtime_seconds + config_1_deviation  # Configuration 1 takes a bit longer (30 seconds more)
        expected_playtime_config_2 = level_playtime_seconds + config_2_deviation  # Configuration 2 is a middle ground (12 seconds more)
        expected_playtime_config_3 = level_playtime_seconds + config_3_deviation  # Configuration 3 is faster (18 seconds less)


        playtimes_config_1 = {'level_1': [], 'level_2': [], 'level_3': []}
        playtimes_config_2 = {'level_1': [], 'level_2': [], 'level_3': []}
        playtimes_config_3 = {'level_1': [], 'level_2': [], 'level_3': []}
        print("________________________________________________________________________________\n", file=output_file)
        print("Simulation settings: ", file=output_file)
        print(f"There are {num_simulations} players in this simulation", file=output_file)
        print(f"Time may vary between different players by  up to {2*player_deviation_factor}s [Player Deviation factor is normaldistributed with mean 0 and std-dev "
              f"{player_deviation_factor/3}](This is due to varying previous experience in first person shooter games)", file=output_file)
        print(f"Expected playtime per level: {level_playtime_seconds}s ", file=output_file)
        print(f"Config 1 (Visual) deviation: {config_1_deviation}s ; Config 2 (Mix) deviation: {config_2_deviation}s ; Config 3 (Auditory) deviation "
              f"{config_3_deviation}s ", file=output_file)
        print("\n________________________________________________________________________________ \n", file=output_file)
```

```python
        for _ in range(num_simulations):
            player_deviation = random.normalvariate(0, player_deviation_factor/3)
            print(f"Player {_ + 1}:", file=output_file)

            # region SELECT CONFIGS
            config_for_level = {1: None, 2: None, 3: None}
            available_configs = [1, 2, 3]

            for level in range(1, 4):
                config_choice = random.choice(available_configs)
                config_for_level[level] = config_choice
                available_configs.remove(config_for_level[level])
                config_level_counter[level-1][config_choice-1] += 1
            #endregion

            #region PLAY
            for level in range(1, 4):
                level_deviation = random.uniform(-10,10)
                configuration = config_for_level[level]
                # Assign mean and standard deviation based on configuration
                if configuration == 1:
                    playtime = expected_playtime_config_1 + player_deviation + level_deviation
                    playtimes_config_1[f'level_{level}'].append(playtime)
                elif configuration == 2:
                    playtime = expected_playtime_config_2 + player_deviation + level_deviation
                    playtimes_config_2[f'level_{level}'].append(playtime)
                else:
                    playtime = expected_playtime_config_3 + player_deviation + level_deviation
                    playtimes_config_3[f'level_{level}'].append(playtime)

                # Print or store the results as needed
                print(f"Level {level} - Configuration {configuration} - Playtime: {playtime:.2f} seconds", file=output_file)

            print("\n", file=output_file)
            #endregion
```

```python
#region Calculate overall mean and standard deviation for each configuration and level
mean_config_1 = statistics.mean([item for sublist in playtimes_config_1.values() for item in sublist]) if any(playtimes_config_1.values()) else 0
mean_config_2 = statistics.mean([item for sublist in playtimes_config_2.values() for item in sublist]) if any(playtimes_config_2.values()) else 0
mean_config_3 = statistics.mean([item for sublist in playtimes_config_3.values() for item in sublist]) if any(playtimes_config_3.values()) else 0

std_dev_config_1 = statistics.stdev([item for sublist in playtimes_config_1.values() for item in sublist]) if len([item for sublist in playtimes_config_1.values() for item in sublist]) > 1 else 0
std_dev_config_2 = statistics.stdev([item for sublist in playtimes_config_2.values() for item in sublist]) if len([item for sublist in playtimes_config_2.values() for item in sublist]) > 1 else 0
std_dev_config_3 = statistics.stdev([item for sublist in playtimes_config_3.values() for item in sublist]) if len([item for sublist in playtimes_config_3.values() for item in sublist]) > 1 else 0
#endregion
#region Print overall mean and standard deviation for each configuration and level
print("______________________________________________________________________________________\n", file=output_file)

print("Config 1 (Visual) - Mean:", mean_config_1, file=output_file)
print("Config 2 (Middle) - Mean:", mean_config_2, file=output_file)
print("Config 3 (Auditory) - Mean:", mean_config_3, file=output_file)
print("\n", file=output_file)

print("Config 1 (Visual) - STD:", std_dev_config_1, file=output_file)
print("Config 2 (Middle) - STD:", std_dev_config_2, file=output_file)
print("Config 3 (Auditory) - STD:", std_dev_config_3, file=output_file)
print("\n", file=output_file)
print("______________________________________________________________________________________\n",
      file=output_file)
print("CONFIG/LEVEL MATRIX", file=output_file)
print("                LEVEL 1        LEVEL 2      LEVEL 3", file=output_file)
for i in range(3):
    row_string = ""

    for j in range(3):
        row_string += f"           {config_level_counter[i][j]}"

    print(f"Config {i+1}" + row_string, file=output_file)

#endregion
```

```python
# Perform t-test
    print("______________________________________________________________________________________\n",
          file=output_file)

    t_stat, p_value = stats.ttest_rel([item for sublist in playtimes_config_1.values() for item in sublist],
                                      [item for sublist in playtimes_config_2.values() for item in sublist])
    print(f"T-Statistic for Visual-Mixed: {t_stat}", file=output_file)
    print(f"P-Value for Visual-Mixed: {p_value}", file=output_file)

    t_stat, p_value = stats.ttest_rel([item for sublist in playtimes_config_1.values() for item in sublist],
                                      [item for sublist in playtimes_config_3.values() for item in sublist])
    print(f"T-Statistic for Visual-Auditory: {t_stat}", file=output_file)
    print(f"P-Value for Visual-Auditory: {p_value}", file=output_file)

    t_stat, p_value = stats.ttest_rel([item for sublist in playtimes_config_2.values() for item in sublist],
                                      [item for sublist in playtimes_config_3.values() for item in sublist])
    print(f"T-Statistic for Mixed-Auditory: {t_stat}", file=output_file)
    print(f"P-Value for Mixed-Auditory: {p_value}", file=output_file)
```

APPENDIX B - Results from first set of simulations

Simulation with 5 players:

```
____________________________________________________________________________

Simulation settings:
There are 5 players in this simulation
Time may vary between different players by  up to 54s [Player Deviation factor is normaldistributed with mean 0 and std-dev 9.0](This is
due to varying previous experience in first person shooter games)
Expected playtime per level: 120s
Config 1 (Visual) deviation: 10s ; Config 2 (Mix) deviation: -10s ; Config 3 (Auditory) deviation 0s

____________________________________________________________________________

Player 1:
Level 1 - Configuration 2 - Playtime: 117.02 seconds
Level 2 - Configuration 1 - Playtime: 135.81 seconds
Level 3 - Configuration 3 - Playtime: 116.85 seconds


Player 2:
Level 1 - Configuration 1 - Playtime: 125.58 seconds
Level 2 - Configuration 2 - Playtime: 105.71 seconds
Level 3 - Configuration 3 - Playtime: 107.57 seconds


Player 3:
Level 1 - Configuration 3 - Playtime: 121.45 seconds
Level 2 - Configuration 1 - Playtime: 114.63 seconds
Level 3 - Configuration 2 - Playtime: 100.25 seconds


Player 4:
Level 1 - Configuration 3 - Playtime: 118.75 seconds
Level 2 - Configuration 2 - Playtime: 96.77 seconds
Level 3 - Configuration 1 - Playtime: 120.55 seconds


Player 5:
Level 1 - Configuration 1 - Playtime: 139.83 seconds
Level 2 - Configuration 3 - Playtime: 132.04 seconds
Level 3 - Configuration 2 - Playtime: 114.36 seconds

____________________________________________________________________________

Config 1 (Visual) - Mean: 127.28060469918012
Config 2 (Middle) - Mean: 106.82300213893456
Config 3 (Auditory) - Mean: 119.33340680780567


Config 1 (Visual) - STD: 10.470930111771887
Config 2 (Middle) - STD: 8.750687372818296
Config 3 (Auditory) - STD: 8.814600200668886

____________________________________________________________________________
```

```
CONFIG/LEVEL MATRIX
                 LEVEL 1        LEVEL 2      LEVEL 3
Config 1            2             1            2
Config 2            2             2            1
Config 3            1             2            2
```

```
T-Statistic for Visual-Mixed: 3.025785267203477
P-Value for Visual-Mixed: 0.038941307059928584
T-Statistic for Visual-Auditory: 1.9475032236109726
P-Value for Visual-Auditory: 0.12331010875865138
T-Statistic for Mixed-Auditory: -1.793912107095891
P-Value for Mixed-Auditory: 0.14727824389249403
```

Simulation with 10 players:

```
Simulation settings:
There are 10 players in this simulation
Time may vary between different players by  up to 54s [Player Deviation factor is normaldistributed with mean 0 and std-dev 9.0](This is
due to varying previous experience in first person shooter games)
Expected playtime per level: 120s
Config 1 (Visual) deviation: 10s ; Config 2 (Mix) deviation: -10s ; Config 3 (Auditory) deviation 0s
```

```
Player 1:
Level 1 - Configuration 2 - Playtime: 92.84 seconds
Level 2 - Configuration 1 - Playtime: 116.44 seconds
Level 3 - Configuration 3 - Playtime: 112.66 seconds


Player 2:
Level 1 - Configuration 2 - Playtime: 126.30 seconds
Level 2 - Configuration 3 - Playtime: 126.77 seconds
Level 3 - Configuration 1 - Playtime: 132.29 seconds


Player 3:
Level 1 - Configuration 3 - Playtime: 117.82 seconds
Level 2 - Configuration 2 - Playtime: 98.41 seconds
Level 3 - Configuration 1 - Playtime: 124.48 seconds


Player 4:
Level 1 - Configuration 2 - Playtime: 102.01 seconds
Level 2 - Configuration 1 - Playtime: 118.05 seconds
Level 3 - Configuration 3 - Playtime: 105.42 seconds


Player 5:
Level 1 - Configuration 1 - Playtime: 127.36 seconds
Level 2 - Configuration 3 - Playtime: 126.07 seconds
Level 3 - Configuration 2 - Playtime: 102.56 seconds


Player 6:
Level 1 - Configuration 3 - Playtime: 116.79 seconds
Level 2 - Configuration 2 - Playtime: 99.49 seconds
Level 3 - Configuration 1 - Playtime: 125.64 seconds


Player 7:
Level 1 - Configuration 2 - Playtime: 107.12 seconds
Level 2 - Configuration 1 - Playtime: 144.15 seconds
Level 3 - Configuration 3 - Playtime: 130.50 seconds
```

Player 8:
Level 1 - Configuration 2 - Playtime: 93.55 seconds
Level 2 - Configuration 3 - Playtime: 114.33 seconds
Level 3 - Configuration 1 - Playtime: 120.45 seconds

Player 9:
Level 1 - Configuration 2 - Playtime: 122.28 seconds
Level 2 - Configuration 3 - Playtime: 127.73 seconds
Level 3 - Configuration 1 - Playtime: 133.68 seconds

Player 10:
Level 1 - Configuration 1 - Playtime: 126.70 seconds
Level 2 - Configuration 2 - Playtime: 107.56 seconds
Level 3 - Configuration 3 - Playtime: 108.47 seconds

Config 1 (Visual) - Mean: 126.92475852309231
Config 2 (Middle) - Mean: 105.2114648939403
Config 3 (Auditory) - Mean: 118.65647663791393

Config 1 (Visual) - STD: 8.229855778967847
Config 2 (Middle) - STD: 11.20729744404571
Config 3 (Auditory) - STD: 8.701606173817941

CONFIG/LEVEL MATRIX

	LEVEL 1	LEVEL 2	LEVEL 3
Config 1	2	6	2
Config 2	3	3	4
Config 3	5	1	4

T-Statistic for Visual-Mixed: 4.647899036761992
P-Value for Visual-Mixed: 0.001205696424126677
T-Statistic for Visual-Auditory: 1.8129471424811838
P-Value for Visual-Auditory: 0.10325149001069295
T-Statistic for Mixed-Auditory: -3.7773517004647204
P-Value for Mixed-Auditory: 0.004366769123197118

APPENDIX C - Results from second set of simulations

Simulation with 10 players:

```
______________________________________________________________________________

Simulation settings:
There are 10 players in this simulation
Time may vary between different players by  up to 54s [Player Deviation factor is normaldistributed with mean 0 and std-dev 9.0](This is due to varying previous experience in first person shooter games)
Expected playtime per level: 120s
Config 1 (Visual) deviation: 5s ; Config 2 (Mix) deviation: -5s ; Config 3 (Auditory) deviation 0s

______________________________________________________________________________

Player 1:
Level 1 - Configuration 2 - Playtime: 109.24 seconds
Level 2 - Configuration 1 - Playtime: 112.61 seconds
Level 3 - Configuration 3 - Playtime: 121.31 seconds


Player 2:
Level 1 - Configuration 1 - Playtime: 127.02 seconds
Level 2 - Configuration 3 - Playtime: 118.25 seconds
Level 3 - Configuration 2 - Playtime: 111.69 seconds


Player 3:
Level 1 - Configuration 1 - Playtime: 114.74 seconds
Level 2 - Configuration 3 - Playtime: 120.15 seconds
Level 3 - Configuration 2 - Playtime: 112.60 seconds


Player 4:
Level 1 - Configuration 1 - Playtime: 142.19 seconds
Level 2 - Configuration 3 - Playtime: 142.17 seconds
Level 3 - Configuration 2 - Playtime: 127.82 seconds


Player 5:
Level 1 - Configuration 2 - Playtime: 110.10 seconds
Level 2 - Configuration 3 - Playtime: 128.14 seconds
Level 3 - Configuration 1 - Playtime: 128.10 seconds


Player 6:
Level 1 - Configuration 1 - Playtime: 111.69 seconds
Level 2 - Configuration 3 - Playtime: 120.12 seconds
Level 3 - Configuration 2 - Playtime: 103.24 seconds


Player 7:
Level 1 - Configuration 2 - Playtime: 123.12 seconds
Level 2 - Configuration 3 - Playtime: 141.62 seconds
Level 3 - Configuration 1 - Playtime: 142.25 seconds


Player 8:
Level 1 - Configuration 3 - Playtime: 118.29 seconds
Level 2 - Configuration 1 - Playtime: 128.51 seconds
Level 3 - Configuration 2 - Playtime: 119.55 seconds
```

```
Player 9:
Level 1 - Configuration 2 - Playtime: 120.74 seconds
Level 2 - Configuration 1 - Playtime: 136.95 seconds
Level 3 - Configuration 3 - Playtime: 119.88 seconds


Player 10:
Level 1 - Configuration 1 - Playtime: 129.95 seconds
Level 2 - Configuration 2 - Playtime: 111.95 seconds
Level 3 - Configuration 3 - Playtime: 128.22 seconds

____________________________________________________________________________

Config 1 (Visual) - Mean: 127.40036284416267
Config 2 (Middle) - Mean: 115.0046498480681
Config 3 (Auditory) - Mean: 125.81502704358564


Config 1 (Visual) - STD: 11.376717809390088
Config 2 (Middle) - STD: 7.494382203045877
Config 3 (Auditory) - STD: 9.202916970402217

____________________________________________________________________________


CONFIG/LEVEL MATRIX
                LEVEL 1        LEVEL 2      LEVEL 3
Config 1           5             4            1
Config 2           3             1            6
Config 3           2             5            3
____________________________________________________________________________

T-Statistic for Visual-Mixed: 3.6443670122609784
P-Value for Visual-Mixed: 0.0053643161096816275
T-Statistic for Visual-Auditory: 0.31929711539114086
P-Value for Visual-Auditory: 0.7567878661651776
T-Statistic for Mixed-Auditory: -3.2150284325768794
P-Value for Mixed-Auditory: 0.010573322681149478
```

Simulation with 15 players:

```
____________________________________________________________________________

Simulation settings:
There are 15 players in this simulation
Time may vary between different players by  up to 54s [Player Deviation factor is normaldistributed with mean 0 and std-dev 9.0](This is
due to varying previous experience in first person shooter games)
Expected playtime per level: 120s
Config 1 (Visual) deviation: 5s ; Config 2 (Mix) deviation: -5s ; Config 3 (Auditory) deviation 0s

____________________________________________________________________________

Player 1:
Level 1 - Configuration 2 - Playtime: 111.11 seconds
Level 2 - Configuration 1 - Playtime: 107.00 seconds
Level 3 - Configuration 3 - Playtime: 119.56 seconds


Player 2:
Level 1 - Configuration 3 - Playtime: 133.46 seconds
Level 2 - Configuration 1 - Playtime: 132.76 seconds
Level 3 - Configuration 2 - Playtime: 118.42 seconds


Player 3:
Level 1 - Configuration 3 - Playtime: 126.36 seconds
Level 2 - Configuration 1 - Playtime: 131.78 seconds
Level 3 - Configuration 2 - Playtime: 125.29 seconds
```

Player 4:
Level 1 - Configuration 3 - Playtime: 117.19 seconds
Level 2 - Configuration 1 - Playtime: 119.15 seconds
Level 3 - Configuration 2 - Playtime: 102.41 seconds

Player 5:
Level 1 - Configuration 3 - Playtime: 116.51 seconds
Level 2 - Configuration 1 - Playtime: 115.92 seconds
Level 3 - Configuration 2 - Playtime: 105.75 seconds

Player 6:
Level 1 - Configuration 3 - Playtime: 135.99 seconds
Level 2 - Configuration 1 - Playtime: 141.97 seconds
Level 3 - Configuration 2 - Playtime: 130.37 seconds

Player 7:
Level 1 - Configuration 1 - Playtime: 141.43 seconds
Level 2 - Configuration 2 - Playtime: 137.64 seconds
Level 3 - Configuration 3 - Playtime: 134.98 seconds

Player 8:
Level 1 - Configuration 2 - Playtime: 93.30 seconds
Level 2 - Configuration 3 - Playtime: 106.01 seconds
Level 3 - Configuration 1 - Playtime: 119.81 seconds

Player 9:
Level 1 - Configuration 3 - Playtime: 110.25 seconds
Level 2 - Configuration 2 - Playtime: 110.31 seconds
Level 3 - Configuration 1 - Playtime: 113.44 seconds

Player 10:
Level 1 - Configuration 1 - Playtime: 135.87 seconds
Level 2 - Configuration 3 - Playtime: 127.73 seconds
Level 3 - Configuration 2 - Playtime: 124.92 seconds

Player 11:
Level 1 - Configuration 3 - Playtime: 112.73 seconds
Level 2 - Configuration 2 - Playtime: 119.17 seconds
Level 3 - Configuration 1 - Playtime: 131.61 seconds

Player 12:
Level 1 - Configuration 2 - Playtime: 118.33 seconds
Level 2 - Configuration 3 - Playtime: 134.50 seconds
Level 3 - Configuration 1 - Playtime: 124.22 seconds

Player 13:
Level 1 - Configuration 3 - Playtime: 117.60 seconds
Level 2 - Configuration 1 - Playtime: 110.48 seconds
Level 3 - Configuration 2 - Playtime: 107.11 seconds

```
Player 14:
Level 1 - Configuration 1 - Playtime: 126.11 seconds
Level 2 - Configuration 3 - Playtime: 108.82 seconds
Level 3 - Configuration 2 - Playtime: 104.90 seconds


Player 15:
Level 1 - Configuration 1 - Playtime: 136.44 seconds
Level 2 - Configuration 3 - Playtime: 132.59 seconds
Level 3 - Configuration 2 - Playtime: 130.07 seconds

______________________________________________________________________________

Config 1 (Visual) - Mean: 125.86641170834437
Config 2 (Middle) - Mean: 115.93936590118422
Config 3 (Auditory) - Mean: 122.28627354760948


Config 1 (Visual) - STD: 11.209947180880324
Config 2 (Middle) - STD: 12.314715131085997
Config 3 (Auditory) - STD: 10.510076359247845

______________________________________________________________________________

CONFIG/LEVEL MATRIX
                 LEVEL 1        LEVEL 2      LEVEL 3
Config 1            4             3            8
Config 2            7             3            5
Config 3            4             9            2
______________________________________________________________________________

T-Statistic for Visual-Mixed: 2.1611215627492313
P-Value for Visual-Mixed: 0.048501100400278635
T-Statistic for Visual-Auditory: 0.8441608774246182
P-Value for Visual-Auditory: 0.41277234830092413
T-Statistic for Mixed-Auditory: -1.4676253863573288
P-Value for Mixed-Auditory: 0.1643107666593295
```

Simulation with 20 Players:

```
______________________________________________________________________________

Simulation settings:
There are 20 players in this simulation
Time may vary between different players by  up to 54s [Player Deviation factor is normaldistributed with mean 0 and std-dev 9.0](This is
due to varying previous experience in first person shooter games)
Expected playtime per level: 120s
Config 1 (Visual) deviation: 5s ; Config 2 (Mix) deviation: -5s ; Config 3 (Auditory) deviation 0s

_____________________________________________________________________________

Player 1:
Level 1 - Configuration 1 - Playtime: 118.36 seconds
Level 2 - Configuration 2 - Playtime: 114.81 seconds
Level 3 - Configuration 3 - Playtime: 114.67 seconds


Player 2:
Level 1 - Configuration 3 - Playtime: 121.02 seconds
Level 2 - Configuration 2 - Playtime: 117.42 seconds
Level 3 - Configuration 1 - Playtime: 120.06 seconds


Player 3:
Level 1 - Configuration 1 - Playtime: 120.64 seconds
Level 2 - Configuration 3 - Playtime: 121.26 seconds
Level 3 - Configuration 2 - Playtime: 101.63 seconds
```

Player 4:
Level 1 - Configuration 2 - Playtime: 120.56 seconds
Level 2 - Configuration 1 - Playtime: 127.03 seconds
Level 3 - Configuration 3 - Playtime: 115.20 seconds

Player 5:
Level 1 - Configuration 1 - Playtime: 114.06 seconds
Level 2 - Configuration 2 - Playtime: 107.28 seconds
Level 3 - Configuration 3 - Playtime: 116.14 seconds

Player 6:
Level 1 - Configuration 3 - Playtime: 125.39 seconds
Level 2 - Configuration 2 - Playtime: 109.94 seconds
Level 3 - Configuration 1 - Playtime: 131.43 seconds

Player 7:
Level 1 - Configuration 1 - Playtime: 109.82 seconds
Level 2 - Configuration 3 - Playtime: 118.72 seconds
Level 3 - Configuration 2 - Playtime: 109.48 seconds

Player 8:
Level 1 - Configuration 3 - Playtime: 126.02 seconds
Level 2 - Configuration 1 - Playtime: 118.39 seconds
Level 3 - Configuration 2 - Playtime: 125.97 seconds

Player 9:
Level 1 - Configuration 1 - Playtime: 132.49 seconds
Level 2 - Configuration 3 - Playtime: 136.25 seconds
Level 3 - Configuration 2 - Playtime: 116.76 seconds

Player 10:
Level 1 - Configuration 3 - Playtime: 119.57 seconds
Level 2 - Configuration 2 - Playtime: 106.86 seconds
Level 3 - Configuration 1 - Playtime: 125.91 seconds

Player 11:
Level 1 - Configuration 2 - Playtime: 115.80 seconds
Level 2 - Configuration 1 - Playtime: 134.38 seconds
Level 3 - Configuration 3 - Playtime: 128.09 seconds

Player 12:
Level 1 - Configuration 2 - Playtime: 115.41 seconds
Level 2 - Configuration 1 - Playtime: 125.14 seconds
Level 3 - Configuration 3 - Playtime: 113.76 seconds

Player 13:
Level 1 - Configuration 2 - Playtime: 112.52 seconds
Level 2 - Configuration 3 - Playtime: 127.28 seconds
Level 3 - Configuration 1 - Playtime: 134.52 seconds

```
Player 14:
Level 1 - Configuration 3 - Playtime: 131.98 seconds
Level 2 - Configuration 1 - Playtime: 127.61 seconds
Level 3 - Configuration 2 - Playtime: 116.50 seconds


Player 15:
Level 1 - Configuration 1 - Playtime: 135.39 seconds
Level 2 - Configuration 2 - Playtime: 111.93 seconds
Level 3 - Configuration 3 - Playtime: 128.51 seconds


Player 16:
Level 1 - Configuration 3 - Playtime: 135.12 seconds
Level 2 - Configuration 1 - Playtime: 149.73 seconds
Level 3 - Configuration 2 - Playtime: 133.75 seconds


Player 17:
Level 1 - Configuration 1 - Playtime: 134.29 seconds
Level 2 - Configuration 3 - Playtime: 123.13 seconds
Level 3 - Configuration 2 - Playtime: 127.84 seconds


Player 18:
Level 1 - Configuration 3 - Playtime: 129.30 seconds
Level 2 - Configuration 1 - Playtime: 142.28 seconds
Level 3 - Configuration 2 - Playtime: 128.21 seconds


Player 19:
Level 1 - Configuration 1 - Playtime: 122.67 seconds
Level 2 - Configuration 3 - Playtime: 112.57 seconds
Level 3 - Configuration 2 - Playtime: 111.92 seconds


Player 20:
Level 1 - Configuration 2 - Playtime: 109.24 seconds
Level 2 - Configuration 1 - Playtime: 127.50 seconds
Level 3 - Configuration 3 - Playtime: 118.27 seconds
```

```
Config 1 (Visual) - Mean: 127.58495669155526
Config 2 (Middle) - Mean: 115.69287016135212
Config 3 (Auditory) - Mean: 123.11253823928642


Config 1 (Visual) - STD: 9.601664578944684
Config 2 (Middle) - STD: 8.154657735866564
Config 3 (Auditory) - STD: 7.11946584650224
```

CONFIG/LEVEL MATRIX

	LEVEL 1	LEVEL 2	LEVEL 3
Config 1	8	5	7
Config 2	8	6	6
Config 3	4	9	7

```
T-Statistic for Visual-Mixed: 4.5841076743833
P-Value for Visual-Mixed: 0.00020262403260900975
T-Statistic for Visual-Auditory: 1.5169751233059126
P-Value for Visual-Auditory: 0.14573553501639508
T-Statistic for Mixed-Auditory: -2.9112594698639795
P-Value for Mixed-Auditory: 0.008954287167142009
```

APPENDIX D - Coin sound effect

https://drive.google.com/file/d/1SIZ1hpRdUvsnbIBNhw3v3CnUzuU0fnar/view?usp=sharing

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