Modelling Player Combat Behaviour for Dynamic Difficulty Scaling and Combat Perception Analysis in First Person Shooter Games

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***Abstract*—Non-Player Characters are a core aspect of a modern video game. They fulfil a wide range of roles and features in most genres. How they are perceived can have an impact on the overall enjoyment of the game, and when the NPCs are poorly modelled, the experience can be negative. This paper explores modelling human player behaviour to develop a combat model for NPCs, which will provide a dynamic solution for skill scaling. Game difficulty is a subjective notion and when games have a predefined classification, being able to satisfy all players is not realistic. This paper investigates if the combat model can therefore be used to scale the difficulty of the NPC in real-time, by dynamically adjusting a skill attribute, which is used by several key combat behaviours. As combat perception is critical to maintaining an immersive and entertaining experience, this paper also explores the degree of combat awareness exhibited by players.**

Keywords—NPC; Player Modelling; Difficulty; Combat Behaviour; Gameplay; FPS; Perception; Combat Awareness.

I. INTRODUCTION

This paper explores a player driven approach for dynamically adjusting the difficulty of Non-Player Characters (NPCs) in real-time [1]. This is achieved by modelling player combat gameplay. The model is then applied directly to NPCs. The combat efficiency is controlled by dynamically adjusting the variable parameters in real-time for the purpose of difficulty scaling. The reasoning behind modelling human-player gameplay is to help define the generalised upper and lower skill level of average players. These bounds are then, in determining how skilfully an NPC should behave, based on data rather than developer interpretation.

This paper conducts three experiments. The first experiment uses predetermined combat scenarios that records the data of human subjects, which is used to model generalised combat behaviours. The second experiment applies the combat model to NPCs, then evaluates the performance of the model when human subjects conduct a deathmatch scenario with the skill of the NPC increasing with each round. While the third experiment is also a deathmatch scenario, however, some behaviours have been altered to determine if subjects notice this irregularity.

The results show that generalising human combat data provides a suitable base for controlling the combat effectiveness of NPCs. It demonstrates that by using a variable to denote the skill level of the NPC, the difficulty can be dynamically adjusted to reflect a desired outcome.

The perception test had mixed results, with subjects generally displaying good combat awareness but lacking awareness of their surroundings. It also raised the question about the authenticity of subject opinions, because in several cases the subject made statements about the NPC that were not factual.

In Section II, this paper provides a background for NPCs in first-person shooter (FPS) games, the role of difficulty, and perception. Section III discusses the motivation behind this paper and what impact this research could have on the gaming industry. In Section IV, a literature review is undertaken to discuss relative research, which is consistent with the NPCs in the FPS genre. Section V details the three experiments, the first is used to capture and model human subject combat behaviour, while the second experiment evaluates the model by having human subjects compete against NPCs with the combat model in a deathmatch scenario. The third experiment assesses the combat awareness of subjects by implementing common flaws in the combat model and then having the subject compete in a deathmatch. In Section VI, the results of the experiments are analysed and displayed. Firstly, a numerical comparison between the human subject data and NPCs is discussed. An evaluation of the feedback from human subjects, regarding the perception of the combat model. An assessment of the model when determining if the combat model provided a suitable solution for dynamic skill scaling. Lastly, the data from the combat awareness experiment is analysed to determine the impact of the flaws had on the combat experience. Section VII concludes the paper and discusses the impact of the combat model. Finally, Section VIII discusses the potential future work that can be undertaken to build upon the work presented in this paper.

II. BACKGROUND

A. Non-Player Character

A non-player character (NPC) is a character in a video game that is not controlled by a player. In a first-person shooter (FPS) game, NPCs are often used to add depth to the game's story and provide opponents for the player to fight against. There are several types of NPCs that can be found in FPS games. Some NPCs are simply background characters that exist to add atmosphere to the game world. These NPCs may not interact with the player in any meaningful way and are simply there to create a sense of realism. Other NPCs are more interactive and may offer the player quests or other tasks to complete [2].

Some NPCs are friendly to the player and will offer assistance or information, while others are hostile and will attack the player on sight. There are also NPCs that are neutral and will only attack the player if provoked. The behaviour of NPCs is often determined by the player's actions and choices within the game.

NPCs can also play a role in the game's story by advancing the plot or providing important information to the player. In many FPS games, the player will encounter NPCs who are key characters in the story and will have to interact with them in order to progress through the game.

The appearance and behaviour of NPCs in FPS games can vary widely. Some NPCs may be highly detailed and realistic, while others may be more stylized or cartoonish. The AI (artificial intelligence) that controls NPCs can also vary in complexity, with some NPCs behaving in a very lifelike manner while others are more robotic in their actions.

Overall, NPCs play a vital role in FPS games by providing opponents for the player to fight against, advancing the game's story, and adding depth and realism to the game world.

Research has shown that poorly designed and/or developed NPCs can be detrimental to the overall enjoyment of a game, and that thorough modelling should be considered when created NPCs [3][4].

B. *Difficulty in Games*

Difficulty is a key factor that can greatly impact a player's enjoyment of a video game. For some players, a high level of challenge is an essential part of the enjoyment of a game, as it allows them to feel a sense of accomplishment upon completing a difficult task. These players may seek out games that are known for their high level of difficulty and enjoy the sense of satisfaction that comes from overcoming that challenge.

On the other hand, some players may find a high level of difficulty to be frustrating and may not enjoy a game that is too difficult. These players may prefer games that offer a more casual or easy-going experience, allowing them to relax and enjoy the game without feeling overwhelmed or frustrated.

The ideal level of difficulty for a game can vary widely from player to player, and many games offer options for adjusting the difficulty level to better suit the player's preferences. Some games may allow the player to choose from several different difficulty levels at the start of the game, while others may have the difficulty based on the type of experience the player is interested in playing. For instance, the difficulty could be ‘Story’ or ‘Challenge’.

In general, a well-designed game will offer a range of difficulty levels that allow players to choose the level of challenge that best fits their preferences. This can help to ensure that players of all skill levels can enjoy the game and find it to be a rewarding experience.

Ultimately, the enjoyment of a game is subjective and will depend on the individual player's preferences and skill level. Some players may find a high level of difficulty to be a key part of the enjoyment of a game, while others may prefer a more relaxed and easy-going experience. By offering a range of difficulty levels, developers can help to ensure that a wider range of players can enjoy their games.

In FPS games, difficulty is often represented in how adept NPCs are during combat encounters with the player. This presents a problem when having static difficulties because some players will have a skill level that is situated between two of the difficulty categories. Furthermore, when NPCs are artificially boosted, whether by increasing weapon damage or unnatural awareness, the player could feel a sense of unfairness.

C. *Definition of Combat Perception*

In an FPS game, combat perception refers to a player's ability to effectively and efficiently gather and process information about their surroundings, enemies, and allies during combat situations. This includes things like identifying enemy positions, anticipating enemy movements, spotting opportunities for cover and flanking, and using terrain and other environmental features to their advantage.

Good combat perception is crucial, as it allows players to make quick and accurate decisions in the heat of battle, which can be the difference between success and failure. There are many factors that can influence a player's combat perception, including their skill level, game experience, and the design of the game itself. Some players may have naturally strong combat perception, while others may need to practice and improve their skills over time.

As combat perception refers to the player's ability to gather and interpret information about the game environment, opponents, and their own character to make strategic decisions and take actions in real-time. Good combat perception involves being aware of one's surroundings, anticipating enemy movements, and reacting quickly and effectively to changing circumstances.

- Situational awareness: This refers to the player's ability to understand what is happening around them in the game world. This includes things like knowing where enemies are located, what weapons they are using, and what their current objectives are. It also involves being aware of the layout of the environment, including cover, choke points, and potential flanking routes. Good situational awareness allows the player to make informed decisions about how to approach combat situations.
- Target acquisition: This refers to the player's ability to identify and engage enemy targets effectively. This involves aiming and shooting accurately, as well as choosing the appropriate weapons and tactics for different ranges and situations. Players with good target acquisition can quickly and effectively eliminate enemy threats.
- Movement: In many FPS games, the player's character can move around the game world in a variety of ways, including walking, running, crouching, and jumping. Good combat perception involves being able to use movement effectively to avoid enemy fire, take cover, or position oneself for an attack. Players may also need to consider factors such as the speed and agility of their character, the layout of the environment, and the positioning of enemies when deciding how to move.
- Decision-making: Good combat perception also involves being able to make quick and effective decisions in the heat of battle. This may involve choosing the right

weapons and tactics for a given situation, deciding whether to attack or retreat, or choosing which objectives to prioritize. Players with good combat perception can adapt to changing circumstances and make informed, strategic decisions.

Therefore, when modelling NPCs from key human-based combat behaviours, it is pivotal to identify and model generalised combat patterns. This should help control the degree of skill of NPCs and help maintain a realistic combat experience where NPCs operate in a similar manner as human players.

III. MOTIVATION

A goal of this paper is to explore the purpose of different difficulty levels in video games and to consider how these levels might be classified. The difficulty of a game can affect how it is perceived by players, and it is important that the chosen difficulty level is perceived appropriately in order to avoid negative experiences. This is a subjective topic, as different players may have different preferences when it comes to the level of challenge they prefer in a game.

An FPS game was chosen as the subject of study because it is a well-established and popular genre in the gaming industry and can provide useful insights into how players perceive and respond to increasing difficulty. FPS games often rely on player skills such as quick reaction time, accuracy, and decision-making in combat situations, which makes them a suitable choice for evaluating how players perceive changes in difficulty. By focusing on a single genre, the scope of the research can be kept narrow and more specific conclusions can be drawn from the data. It is common practice in the video game industry to adjust certain gameplay elements such as reaction time, damage dealt, and precision when changing the difficulty level in FPS games.

The idea behind real-time skill scaling is that a single, fixed difficulty setting may not be suitable for all players. By adjusting NPC abilities based on the player's performance, the game can offer a more personalized and player-centric approach to difficulty. Maintaining immersion in combat is important because NPCs and human players are often perceived differently in FPS games, even when they are fulfilling similar roles. Real-time skill scaling could allow developers to balance uneven teams with NPCs without breaking immersion for the player, by making NPCs indistinguishable from human players. Combat perception is also a key characteristic of distinguishing which players are human or NPC controlled. The motivation around determining the generalised awareness of players, is to provide a better understanding which where a combat model for NPCs can be improved, with the focus of maintaining immersion.

A study undertaken by Williamson and Tubb [5] indicated that gameplay could be categorised into fundamental behaviours and patterns that could be modelled. They suggested that the effects of having poorly modelled and designed NPCs, such as high accuracy in combat, can result in a negative experience and that their opponent could be mistaken as cheating.

IV. RELATED RESEARCH

A. Non-Player Characters in Combat Roles

When discussing NPCs in a combat role, the focus will be primarily on the FPS genre. While NPCs have been present since the inception of the FPS genre, there has been some progress in the scope of their capabilities. Orkin [6] showed that NPCs could display seemingly complex characteristics, such as tactics, by using Goal Orientated Action Planner (GOAP), which enabled individual actions to be undertaken based on current circumstance. This technique sparked a host of research based around maximising the effectiveness of using action planners. Influenced by GOAP, Pezzato et al. [7] researched a technique that uses active interference and Behavioural Trees (BT) to develop decision-based plans, which are adaptable and created in real-time for robotics.

However, Agis et al. [8] suggest that because GOAP are individual by design, NPCs are not actively cooperating with allies and just giving the illusion of working as a team. They proposed using a new form of Event Driven Behavioural Tree (EDBT), where three extra nodes are added for communication purposes between same team NPCs. These nodes facilitate actions in a sub-tree, so the sender can request the receiver/s to perform certain actions.

Neufeld et al. [9] propose that behavioural trees are a good approach to NPC decision-making, when combined with a Hierarchical Task Network (HTN). The HTN was able to instruct multiple NPCs what to do but leave the low-level execution of tasks to the BTs. When comparing this hybrid approach against a pure HTN solution. The results showed the hybrid approach to be more flexible and fail less often.

B. Human Imitation

The idea to measure and quantify the skill of human players is not a new idea and in essence this research is akin to work undertaken to develop NPCs to appear more believable. While believability can have many interpretations depending on the context of the topic, this paper is focused on NPCs with a generalised skill level. Camilleri et al. [10] identify believability as:

> *Player believability is a highly subjective notion commonly viewed as the ability of a game playing character to convince observers that it is being controlled by a human player*

This suggests that for an NPC to be deemed as a believable character, it needs to exhibit human-like behaviours. So, observers are convinced the character is human controlled. In the context of the FPS genre, these behaviours will range from combat efficiency to pathfinding characteristics and decisions.

Polceanu et al. [11] presented two solutions for imitating human player behaviour. The first is a human behaviour mirror technique, while the second uses interactive genetic algorithms. This is supported by Mora et al. [12], they combined the techniques to create a hybridisation model. When experimented in a Turin Test scenario, the results showed that a high level of “humanness” was achieved.

The importance of imitating human players extends beyond difficulty scaling. Wehbe et al. [13] argue that the difference between playing with other human participants and

NPC is profound because it intersects the artificial world of the game with real life. They also imply that quasi-feudalistic tendencies of human players should be encouraged in NPCs where possible.

C. Difficulty Control in FPS Games

When discussing difficulty control, it is important to define the terminology in the context of a video game. Smeddinck et al. [14] state:

> *Game difficulty choices that are presented in menus with typical labels such as "easy, medium, hard" can be found even in very early and simple games. The "classic way to present difficulty choices" has arguably evolved largely as a matter of technical circumstance.*

This suggests that difficulty has been part of video games for a long time and has needed to evolve out of necessity.

Hendrix et al. [15] showed a positive result when developing a six-point system, which gathers data and applies an algorithm to determine the capabilities of the player through engagement.

Blom et al. [16] have taken a different approach to identifying the currently perceived difficulty experienced by the player. They developed a system that monitors facial expressions to determine the difficulty the subject is experiencing, achieving 72% accuracy. The model was able to adapt to the individual's performance level via their facial expression and establish which tasks or challenges presented the most difficulty.

The research shows that while difficulty may be an easily defined concept, problems occur when putting the theory into practice. For the remainder of this paper, difficulty will be defined as:

> *The degree of challenge presented to an individual when undertaking game related tasks or mechanics.*

These tasks can range from game objectives, such as solving puzzles or combat interactions that relies on eliminating opponents.

The idea of a personalised approach to NPC development is not a novel idea. Research by Bakkes [17] discusses the notion of using player models to generate an individualistic experience. Their research shows that a few viable techniques have been examined [18]-[20]. These techniques mainly use NPC training methods or manipulate external constraints, such as environmental, to achieve the desired outcome. However, the purpose of this paper is to use generalised player data to control the combat efficiency of NPCs, which can be adapted in real-time.

D. Impact of Perception

There is a growing body of research relating to combat perception and/or behaviours in FPS games. Moreira et al. [21] argue that there are negative experiences when playing against an opponent that is much weaker or stronger. For weaker players, they experience frustration because they are likely to lose, and the stronger players have a lower sense of challenge which can manifest into boredom. They proposed three systems to help bridge the gap between the varying skill levels:

- Better aim assist: They used a system in which implements a bullet magnetism effect, which is where bullets are slightly attracted to the target.
- Activation and duration: This system dynamically controls when aim assist should be active.
- Variable manipulation: This system varies some of the game variables, such as weapon damage.

While this approach yielded extremely positive results, and the overall enjoyment of their subjects increased, there is an issue of fairness which could manifest into something negative if a player thinks their opponent is be artificially boosted because it could appear as though their opponent is cheating. This perception is essential to this research because when a player 'feels' they are at a disadvantage through no fault of their own, it can affect the entertainment value [22]-[24].

Choi et al. [25] used a different approach in which they developed a cognitive architecture to control how NPCs act throughout an FPS game. They created a system called 'ICARUS' which exhibited reactive and goal orientated behaviours, that were designed to imitate human-like gameplay. This system is based on psychological theories of human intelligence, it differentiates between short-term and long-term memories, and stores information in symbolic list structures. It operates in cycles of recognition and action, and its learning process is incremental and integrated with performance. The ICARUS architecture records the actions and observations of the NPC during exploration and tries to explain how these actions contributed to achieving the goal. It does this by linking known skills and concepts, and by creating generic templates for basic action models to explain any unexpected changes. ICARUS converts these explanations into new skills that can be used to achieve similar goals in the future, including strategies, route knowledge, and ways to overcome obstacles.

J. Asensio et al. [26] conducted research on the idea of imitating human behaviour by implementing a two-tier system. The system used symbols to represent and understand the world and artificial neural networks (ANN) to replicate the human nervous system's ability to adapt and recognize patterns. When this system was tested using the Turin Test for Bots, the results indicated a positive trend towards the NPC's perceived "humanness". This research shows that players' perceptions of NPCs are important and experimenting via a Turin Test, it removes knowledge that the subject is playing against an NPC. Therefore, identifying the degree of generalized combat perception exhibited by players is crucial in determining how much imitation is necessary to pass as a human player.

V. EXPERIMENTS

A set of experiments were done to study the combat effectiveness of human subjects, including a perception test to measure their level of combat awareness. First, a combat modelling experiment was required, where subjects undertake a series of combat scenarios and their data recorded. The data is used to develop a combat model and then the NPC with the combat model undertakes the same experiment. Next, subjects are tasked with competing against NPCs with the combat model, with increasing difficulty as the stages progress. Lastly, subjects fight against NPCs with the combat model in a deathmatch scenario, however, key gameplay behaviours have been altered which will help evaluate the awareness of the subjects.

The purpose of these experiments is to find patterns in the combat gameplay, which can be modelled and applied to NPCs. After modelling, the experiments evaluate how well the model works in a deathmatch scenario, which is a popular game mode in FPS games. The objective for the perception test is to see where the focus of the modelling should be, because if subjects notice that the model has unnatural elements to the combat, it will mean the attention to detail of the model will need to be very high.

A. *Experimantal Environment*

The experiments in this paper were created using Unity3D and were uploaded to an online server. Participants had to download and run the experiments on their own computers. The first experiment took about 15 minutes to finish, and data was saved and uploaded to an online database after each stage. The second and third experiment took 10 minutes each, and also had an accompanying questionnaire that participants completed through a web browser. Data from this experiment was also saved online after each stage.

In both experiments, the subjects were not identifiable by name and no personal information was collected. No specific skills or knowledge were required to participate. The data collected during the experiments did not contain any identifying information that could be linked to a specific individual. As the subjects were anonymous participants and it was conducted online, a certain level of control was reduced. To help protect and verify the integrity of the data, the actions of the subjects was also saved, this enabled the researchers to watch all of the entries and look for any irregularities. It should be noted that as a consequence of anonymity, it was possible for participants to run the experiments multiple of times, there was no data to suggest this happened. For the combat behaviour experiment, a total of 30 subjects fully completed the experiment, and for the dynamic difficulty experiment, a total of 21 participants.

B. *Combat Behaviour Experimental Protocol*

The experiment involved five scenarios in which the actions and decisions of the subjects were recorded as they completed each task. Each scenario had three levels of difficulty, with the targets appearing at various distances from the subjects. The subjects were not able to move, except to turn, and the targets randomly appeared within their field of view. These scenarios were chosen because they represent typical combat situations in first-person shooter games. It was determined that it would be best to only model the basic scenarios and evaluate the effectiveness of the skill scaling system rather than including more complex scenarios that may not be applicable in all modern games. The specific scenarios were derived by analysing how combat emerges and the various conditions, and through an examination of literature focused on combat [6][27][28]. The importance of these scenarios can be seen in research undertaken by Conroy [27], they devised a model where NPCs calculated the degree of threat based on their current situation and part of the threat analysis is whether to engage in combat based on state of the opposition. They showed that distance to opponents has an impact on combat behaviour and was reflected in the results. While Rayner [28] conducted research focused on cursor-based mechanics, which partly discusses the implications of modelling player behaviour when the crosshair is in the centre of the screen. They also suggest that skill is therefore based on how fast a player can control the targeting across a 2D plane, whilst also being accurate so the target remains in the centre of the screen.

Figure 1 shows an example of a target, all targets spawn facing the subject and are eliminated from a single shot.

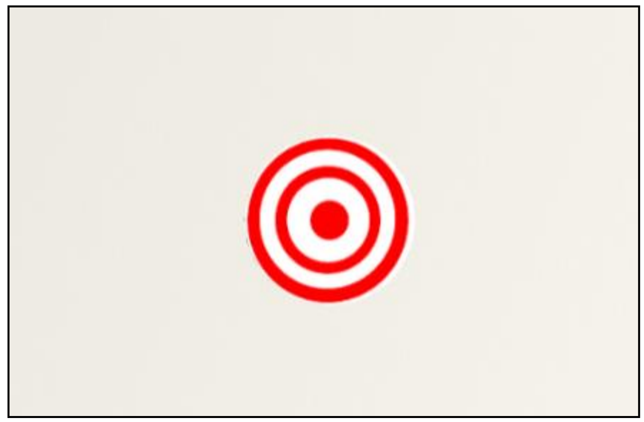

Figure 1. Example of Target

While it is understood that in most FPS games targets will take more damage if hit in a particular spot, however, this experiment does not employ such mechanics as the objective is to observe the combat behaviour as well as combat efficiency.

The experiment cycles through all weapons and stances until the subject has completed all scenarios using both weapons and both stances. The weapons and stances are as follows:

- Pistol: Off hip
- Pistol: Aiming down sights
- Assault Rifle: Off hip
- Assault Rifle: Aiming down sights

Figure 2 shows an example of both pistol and assault rifle from the perspective of shooting off the hip. In this stance each weapon has a crosshair in the middle of the screen and when shooting, the shots will be towards the centre of the crosshair. When the weapon is continuously shot, the size of the crosshair grows, making the weapon less accurate, until they stop firing and the crosshair recedes back to normal size. The purpose of this is see how accurate subjects are when tasked with this constraint, because it is possible to increase accuracy by controlling the about of burst firing.

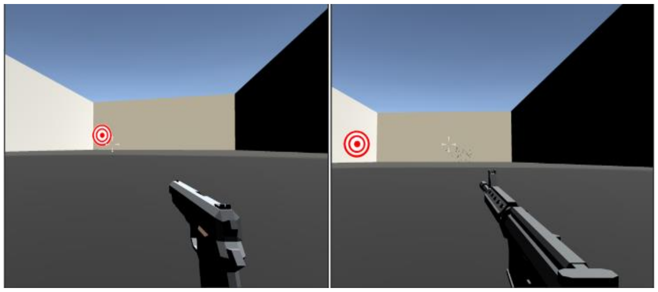

Figure 2. Off the Hip

Figure 3 shows an example of both assault rifle and pistol when aiming down the sights. When aiming down the sights there are no crosshairs, the subject will need to use pip on the sights. Both guns have kickback, with the pistol having a large kickback, and the assault rifle small. The reason this experiment is required is because it will compare how efficient subjects are when attempting the same problem with different means.

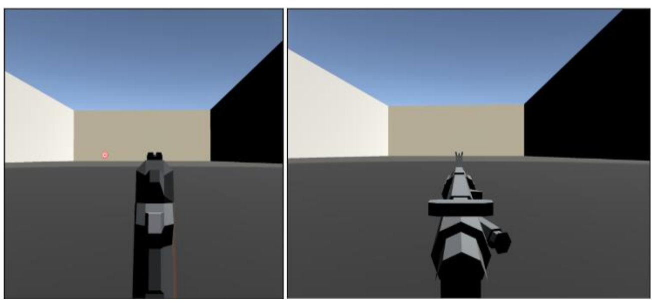

Figure 3. Aiming Down Sights

The purpose of the experiments is to understand how the use of different weapons and the way they are held can influence combat behaviour and effectiveness. This information will be used to create realistic models of weapon behaviour and to assess the impact of these behaviours on game difficulty. All targets in the experiments are identical and have a fixed amount of health that is depleted when they are hit. When the health of a target reaches zero, it is destroyed.

a) Normal Scenario

In this scenario, the objective is to eliminate the target before it self-destructs. Targets spawn one at a time and the subject has 2 seconds to eliminate before it disappears, a new target will not spawn until the current target is destroyed or self-destructs, there is also a small delay between target being destroyed and a new one spawning. The purpose of this scenario is to measure the player's accuracy and reaction time at different distances from the target (near, medium, far) to understand the average reaction time in a normal scenario. A total of five targets spawn at each distance, is within view of the subject’s field of view, and are facing the subject. Figure 4 provides an example of a target spawning at a medium distance.

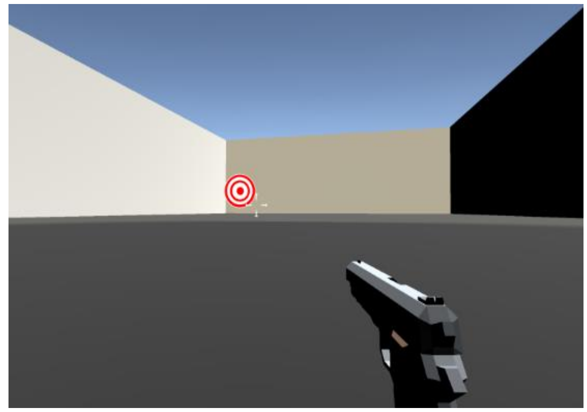

Figure 4. Normal Scenario Screenshot

This scenario represents a common encounter in an FPS game because it highlights how subjects react when they first observe their target.

b) Increased Spawn Rate

This scenario was conducted to see if the presence of additional targets while a subject is already in the process of eliminating another target, affects the subject's reaction time and combat efficiency. Specifically, the experiment aimed to investigate whether external influences can negatively impact combat efficiency and if so, to what extent. There are three stages which correspond to near, medium, and far distance, each stage will have a total of five targets. Similar to the single target scenario, the target self-destruct after 2 seconds, however, the spawn rate of targets is increased as the stages advance. The first stage (near) has a spawner time of 1.8 seconds, second stage (medium) 1.6 seconds, and last stage (far) 1.4 second, this provides a situation where a subject is likely to have multiple targets on the screen at a given time. While more aggressive spawn times could have been used, it was decided that the scenario was to observe how subjects react when a new target appears and if it affects their combat performance and decision-making, rather than overwhelming subjects.

Figure 5 shows an instance of the scenario when the targets are at a far distance.

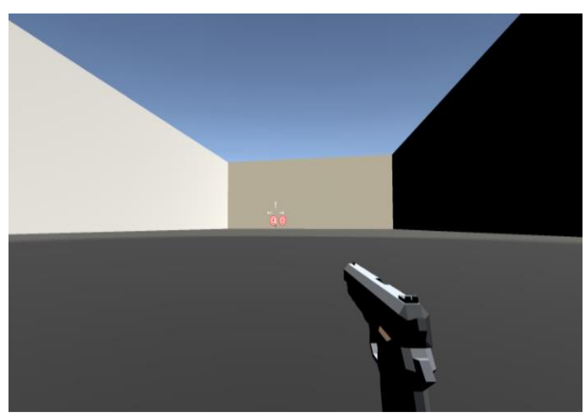

Figure 5. Increased Spawn Rate Screenshot

The importance of this scenario is to observe the combat behaviour when a new target appears, because in most FPS there will be times when combat is underway, and a new threat appears. It is important to determine if subjects' efficiency decreases because their focus is momentarily altered.

c) Grouped Targets

In this scenario, multiple targets may appear at the same time, as is common in modern games. The scenario also involves a three-stage approach, with an increasing number of targets spawning simultaneously as the stages progress. In the near stage, there are three targets, in the medium stage there are five targets, and in the far stage there are seven targets. Each target remains visible for five seconds before disappearing. This scenario is designed to study the pattern of behaviour exhibited when multiple opponents suddenly appear, rather than appearing after the combat is already underway.

This scenario differs from the increased spawn rate because the targets are all present and in view from the start of a round. The increase spawn rate scenario analyses how subjects adapt to a new target appearing while they are currently engaging a different target, whereas the grouped targets scenario addresses how subjects formulate attack strategies on multiple targets and the impact it has on combat efficiency.

Figure 6 displays a screenshot of the grouped targets at a medium distance.

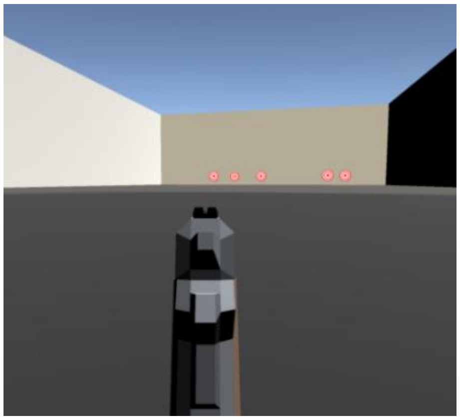

Figure 6. Grouped Targets Screenshot

This scenario is the often experienced when a player enters a new and/or open area, multiple enemies can be in view and then player needs to quickly form a targeting strategy.

d) Varying Size

In this scenario, the normal scenario stage is repeated but with target size decreasing as the stages progress. The purpose of this is to determine if precision has a significant impact on combat efficiency. The near stage will have a normal target size, medium stage the size will be 0.9x and the far stage a size of 0.8x. This scenario will help factor precision into the modelling, if the results suggest that there is a combat performance drop due to the target size. Figure 7 shows a screenshot of a target during the last stage when the targets spawn far away from the subject.

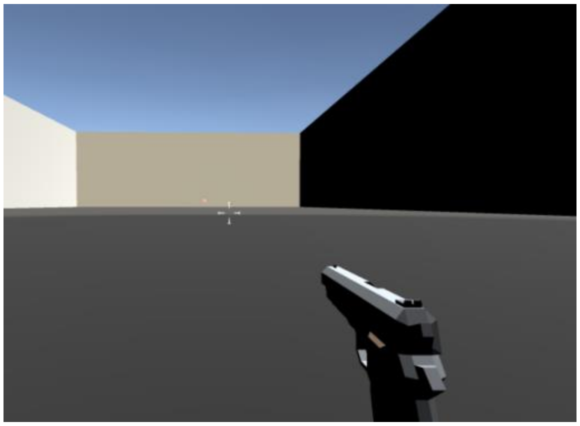

Figure 7. Smaller Target Screenshot

This scenario represents conditions when a player spots a target that is far away, or when smaller and specific parts of the target provide bonus damage when attacked. For instance, it is common in FPS games when attacking a humanoid enemy in the head, often referred as a 'headshot', it yields a lot higher damage than attacking not critical parts such as arms or legs.

e) Moving Target

In this scenario, targets appear every 2.5 seconds and disappear after 5 seconds. The targets move from left to right at a constant speed, reversing direction when they reach the edge of a predefined boundary. It follows the same set up as the normal target scenario, regarding near, medium, and far stages. A total of five targets spawn per stage, and when moving targets rotate to face the subject, this was to keep the targets area size the same regardless of the offset angle from the location of the subject. A new target spawns every 2 seconds, therefore, if the targets are not eliminated quickly enough, they may overlap on the screen. The purpose of this scenario is to see if combat efficiency is affected by the presence of moving targets.

C. Dynamic Difficulty Experimental Protocol

This experiment involves a deathmatch with the goal of achieving a set number of eliminations before the opposition does. In this case, the requirement is set at 5 eliminations. The experiment has three stages, and as the stages progress, the base skill level of the non-player characters (NPCs) is increased. The stages and their corresponding base skill levels are as follows:

- Stage One: NPC Base Skill is 3
- Stage Two: NPC Base Skill is 6
- Stage Three: NPC Base Skill is 9

Along with the subject there are two NPC opponents, as it is a deathmatch, all players are hostile, this means NPCs will attack each other as well as the subject. One NPC uses a pistol and the other uses an assault rifle. Both weapons have a sub model that affects attack distance and has its own attributes, such as clip size and bullet damage.

Subjects will be equipped with three different weapons, which can be selected by pressing 1,2 or 3 on the keyboard. All weapons have separate ammunition, weapon damage and bullet spread. Table 1 highlights the key attributes for each weapon.

Table 1. Weapon Details

Weapon	Description
Pistol	The pistol has high recoil and kickback, slow fire-rate, but deals high damage
Assault Rifle	This weapon has high fire-rate, medium damage, and moderate recoil
Shotgun	The shotgun fires 12 pellets per shot, each of which deal low damage, high recoil, and high pellet spread over range

There are two types of collectables scattered throughout the map. There are three medic-packs and three ammunition packs, the location for each collectable is the same across all instances and available to both subject and NPC. The collectable is collected by moving over it, after which it will be destroyed and then respawns 5 seconds later at the same location. The medic pack provides up to 50% health, depending how much missing health the character has, and the ammunition resupplies up to one clip worth for the currently equipped weapon. Figure 8 displays an example of a medic and ammunition pack.

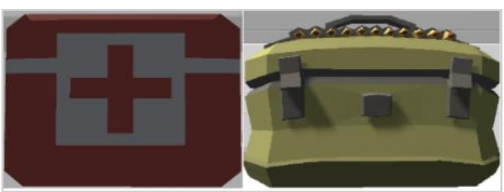

Figure 8. Health and Ammunition

The purpose of this experiment is to assess the effectiveness of the combat model in terms of adjusting the combat capabilities of NPCs based on the base skill level. This skill scaling is important because in a real-world setting, there is a range of player skill levels, and the model needs to be able to adapt to these different levels. If NPCs can increase or decrease their combat efficiency in real-time, it would allow for more challenging NPCs and provide a way to match the skill level of the player during a game.

a) Combat Model

The model is based on data and results from an experiment called the "Combat Behaviour Experiment." The goal of the model is to make the NPCs behave in a way that resembles human combat behaviour. The NPCs' combat efficiency is linked to a skill variable that can range from 1 to 10, with 10 representing very high efficiency and 1 representing very poor efficiency. In this paper, the NPC's skill level is set to 5, which represents an average level of efficiency based on the data from the Combat Behaviour Experiment. The concept of skill in this context refers to how well the NPC performs in combat compared to the average performance level observed in the experiment.

When creating the combat model, only standardised development techniques were considered during the modelling, which were suitable with the data captured from the combat behaviour experiment. As the experiment uses Unity3D, it was decided that scripting and object orientated programming would be the best solution, as the model will be using coroutines and multiple scripts accessing the model data at a given time.

It was important to capture some of the highs and lows that players often experience during a game. This is when players have a run of successful eliminations called ‘hot streak’, or a run of losses called ‘cold streak’. These streaks are directly linked to the combat efficiency of a player, therefore, the model tracks how well the NPC is currently performing and adjusts the active skill level to incorporate cold and hot streaks. However, it was important that there was a limit to how much influence a streak can have on the NPC, this prevents NPCs drifting to far from the initial base skill level. There are three main factors that affect the active skill level (Table 2).

Table 2. Active Skill Modifiers

Modifier	Description
Weapon	Like players, NPCs have a ‘preferred’ weapon/s. When they have a favourite weapon equipped, it increases the active skill by up to +1.
Death	Resets the active hot streak, if the NPC is not in a hot streak, they enter a cold steak adding -0.5 to the active skill.
Eliminations	Resets the active cold streak, if the NPC is not in a cold streak, they enter a hot steak adding +0.5 to the active skill.

The active skill is accumulative, with an upper limit of +2.5 and a lower limit of -2.5. Therefore, if an NPC has a base skill level of 5, the active skill level can be a maximum of 7.5 and a minimum of 2.5.

As NPCs could not change weapons during this experiment, it was decided to provide them with +1 to the weapon skill modifier.

The activate skill is determined by the base skill, weapon modifier and current streak. This allows for some flexibility in how the NPC performs, rather than a static or manufactured combat efficiency. The active skill directly features in the equations for reaction time and accuracy.

Equation (1) shows how active skill was used to control the aiming speed, considering the location and size of the target in the field of view of the game camera.

$$\text{Reaction Time} = \frac{Ts + ((S * M) * Dx)}{Dz} \quad (1)$$

Where, *Ts* is the target size, *S* the active skill attribute, *M* is a generic modifier, *Dx* the 2D distance from the centre of the screen to the target and *Dz* the Euclidean distance from the NPC to the target. This represents a comprehensive approach to targeting because it considers not only the size of the target (*Ts*) but also the distance (*Dz*). This was required because the further away the target was in game, the smaller it would appear on the screen. This underscores the importance of precision when determining the initial reaction targeting speed.

The Equations (2) and (3) are for accuracy, it was decided to separate the two shooting stances as looking down sights should provide better control than shooting off the hip.

$$\text{Aiming} = \text{Vp} + \text{Vf} * (\text{Mx} + (\text{My} * \text{S})) \qquad (2)$$

Vp is the vector position and *Vf* the vector forward direction of the NPC, *Mx* and *My* are generic modifiers and *S* the active skill of the NPC.

$$\text{Off Hip} = \frac{\text{Vp} + \text{Vf} * (\text{Mx} * \text{S})}{Sx * Ws} \qquad (3)$$

Like the aiming equation, *Vp* is the vector position and *Vf* the vector forward direction of the NPC, *Mx* a generic modifier and *S* the active skill of the NPC. However, *Sx* is the locale scale of the crosshair and *Ws* is the equipped weapon bullet spread. As previously stated, the bullet spread is focused on the crosshair, and the longer the weapon is continuously fired, the bigger the crosshair grows, making it more inaccurate.

D. Combat Perception Experiment

The perception experiment was developed in the same way as the dynamic difficulty experiment. It consisted of a deathmatch in which the subject will be against two NPCs in an all vs all scenarios. As the intention is to determine if subjects can identify inconsistencies in the combat, both NPCs have a static skill level of 5. This represents an averaged skilled opponent, and it was important to maintain an even level of combat efficiency so that perception was consistent across all subjects.

The objective of the experiment was to achieve 8 eliminations before any of the NPCs. There were three combat perception focused areas:

- Omniscient Player Awareness: When the NPC is ambushed and attacked from behind, the NPC will be given the location of the attacker. This will enable them to have omniscient awareness of its target in combat only.
- Aggressive Combat Personality: During combat the NPCs will make a beeline towards the subject, attacking as it moves. The NPC will not break off combat until its target is eliminated or it loses sight of the target for a period.
- Non-Smooth Pathing when Roaming: During roaming the path smoothing has been removed. This is where when the NPC requests a path, no extra smoothing technique has been used. This makes NPCs movement somewhat jagged/jerky at times, when scrutinised from an observer.

These perceptions were specifically designed as they target different areas of interaction with players. The omniscient player awareness will determine if subjects can identify that they have no advantage when trying to ambush the NPC. This is essential because it will show that players have an understanding about opponent reaction times, and when they know their opponent has not seen them, the reaction behaviour should different than when they know they have been spotted.

The aggressive combat personality will determine if subjects can identify and form opinions of opponents attacking behaviours. If subjects identify the aggressive attacking, it will mean that to fully encapsulate believability, NPCs will need to have a range of combat personalities in which how the engage in combat will impact if they are believable.

The non-smooth pathing when roaming will test the observational ability of subjects when not in combat. The main purpose is to see how much attention subjects give to their opponents, or if the main concern is focused on maximising their combat advantage. If subjects can notice the NPCs sometimes jagged pathing, it will mean that all areas of the NPCs behaviours will be under scrutiny by players. This has a severe impact on the modelling because it means that a consistent level of detail will be required across all gameplay.

VI. Results

According to the results of the study, it is effective to model human behaviour in order to create NPCs with dynamic skills in a video game. It is also possible to generalize the efficiency of combat in this way. Additionally, the method of skill scaling, which adjusts the combat efficiency of NPCs in real-time gameplay, was found to be very effective. However, when evaluating the level of awareness possessed by players, specifically when in combat situations, the results was mixed. Furthermore, some subjects had negative opinions regarding the combat, which were based on a false awareness that NPCs had perfect accuracy.

a) Combat Model Analysis Comparison

The analysis of the combat model shows that it was generally well received, but there are some areas of the combat that need more attention. The purpose of this analysis is to determine two key objectives about the combat model:

- Statistically: How does did the model perform from numerical perspective, when compared to human subjects.
- Perceptually: What was the overall perception of the combat behaviour of NPCs and how human-like did they appear.

The results suggest subjects were fairly accurate in their perception of NPC combat efficiency because the combat model was over tuned which increase NPC accuracy.

The graph in Figure 9 illustrates the average shooting accuracy for both NPCs at each stage, as well as the overall shooting accuracy for all subjects when playing against NPCs with a base skill of 3 (stage 1). The data suggests that while the scaling was effective, the NPCs may have been too difficult in general.

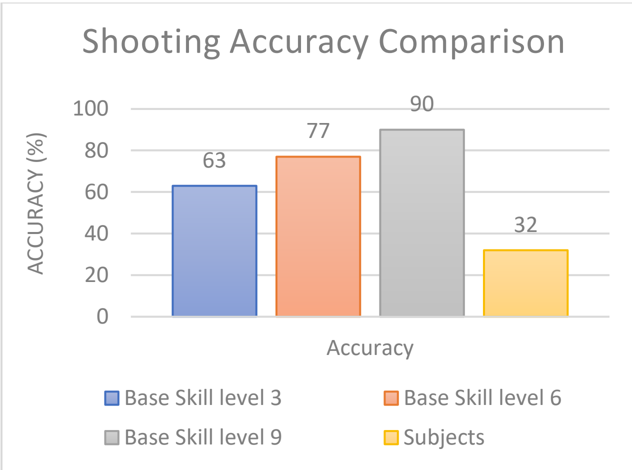

Figure 9. Shooting Accuracy Comparison.

Figure 10 displays the feedback from subjects when asked which part of the NPCs combat behaviour was the weakest. This was a multichoice question, therefore, subjects were able to select more than one aspect of combat. The accuracy relates to the overall shooting accuracy of NPCs, the targeting refers to how much the NPCs lock on to subjects, player awareness is focused on how much omniscient awareness did the NPC appear to have, and reaction speed in how quickly NPCs could aim and shoot when spotting a subject.

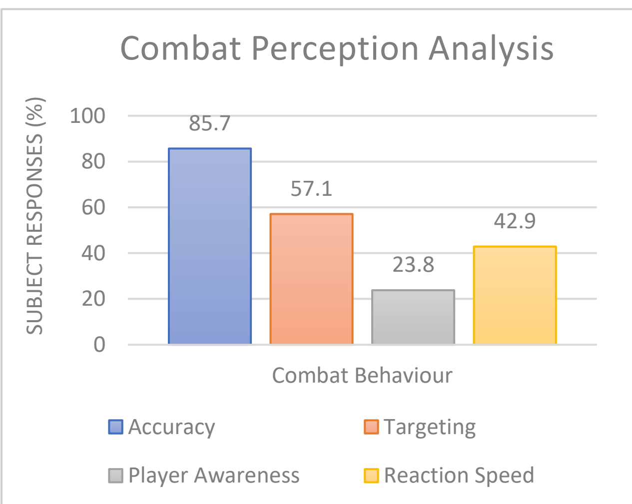

Figure 10. Combat Perception Analysis.

The results highlight that accuracy was significantly the most pressing issue, with more than 85% of the subjects stating it was not human-like. This is followed by targeting with more than half of the subjects suggesting NPCs had unnatural targeting in combat. The reaction time of the subjects was higher than expected. This indicates that the subjects had difficulty competing with the NPCs. One potential solution to this issue is to lower the modifier in the reaction time equation. However, more testing will be needed to determine the optimal adjustments to the model.

When asking subjects about how believable the NPCs appeared, in relation to human players, the results were mixed. Figure 11 shows that none of the subjects thought the NPCs were human-like, but 50% thought they were somewhat human-like.

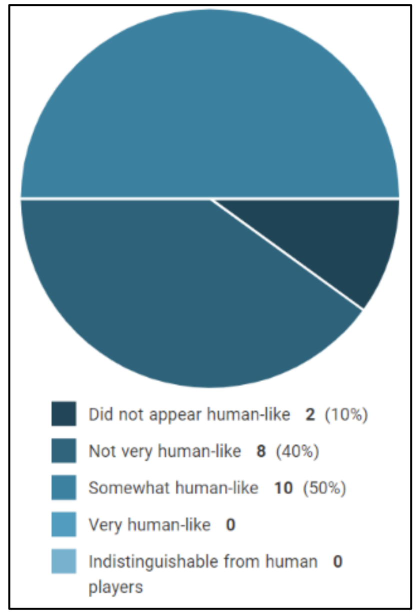

Figure 11. Combat Feedback.

While the feedback did not state that the model had human-like combat behaviour, it did show that potentially, the model could be tweaked and revised to be more accurate.

b) Gameplay Influence

When looking at the feedback, it became clear that other gameplay elements were influencing people's perceptions of the combat's realism. This meant that issues with the NPC's navigation were causing subjects to have negative views on the NPC's combat abilities. This is highlighted when analysing the specific responses from subjects when asked about non-combat elements. One of the responses, shown in Figure 12, emphasises that other gameplay aspects like navigation can affect how believable the combat appears.

bots moved in a straight line

Figure 12. Specific Combat Subject Feedback.

This shows that different gameplay elements are interconnected. When one aspect is not modelled well, it can affect the perceptions of other elements and cause undesirable results. This means that when creating models for certain behaviours, it's important to consider how they may impact other behaviours in certain situations.

c) Skill Scaling

The skill scaling seemed to work well based on the feedback, when asking the subjects if they noticed the difficulty increasing as they progressed through the stages (Figure 13). Of the respondents, 57.1% noticed an increase in difficulty, while 42.9% did not notice if the difficulty changed as the stages progressed.

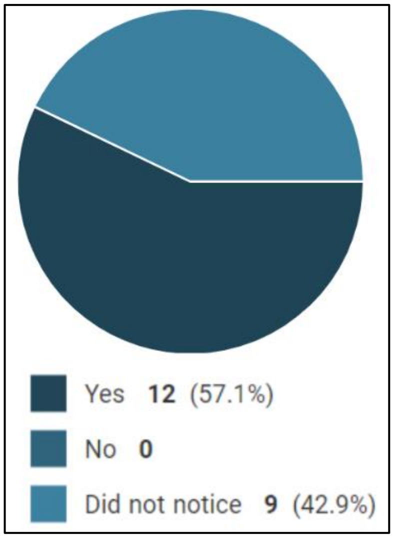

Figure 13. Difficulty Identification Feedback.

This suggests that the combat model could be a viable option for creating NPCs with adaptable real-time difficulty. It should be noted that this is the perception of difficulty, and it could be suggested it is common for a player to experience higher difficulty when getting familiar with a game. However, when analysing the combat efficiency of NPCs, the data shows they did become better, and this could have been noticed by the subjects. This would support the idea that players have some understanding of the combat abilities of their opponents. As a result, this would emphasize that a one-size-fits-all approach to difficulty will not work for all players.

When looking at the pistol combat performance for the three different difficulties, a pattern emerges where the individual combat behaviours improved as the base skill level increased (Figure 14).

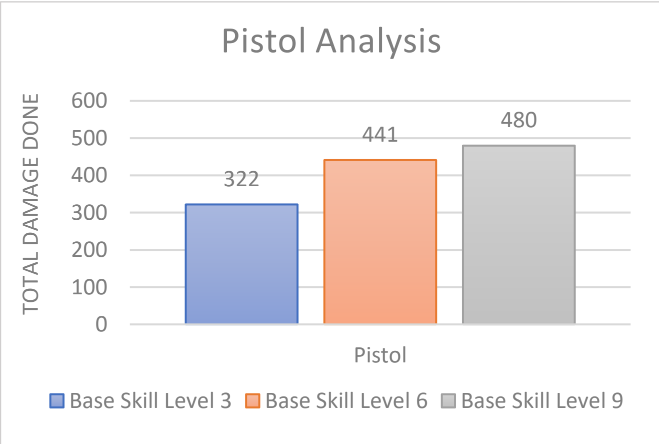

Figure 14. Pistol Damage Done Skill Comparison.

This indicates that as the base skill level increased, the average amount of damage inflicted by the NPC also increased. This suggests that the NPC's combat efficiency improved with a higher base skill level. This is supported by the analysis of the average initial reaction time for the assault rifle across all three stages (Figure 15).

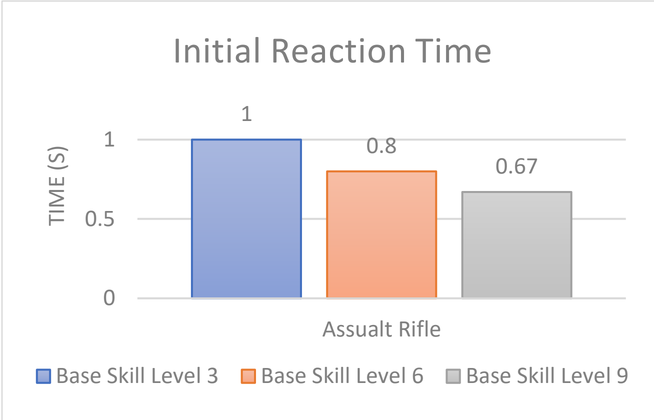

Figure 15. NPC Skill Reaction Time Initial Comparison.

The results suggest that there is a small relationship between reaction time and active skill level. While there is some variation, this could be caused by changes in active skill level due to the triggering of hot and cold streaks.

Figure 16 looks at the first and third stages only and shows the average number of eliminations for each character. On average, the subjects did not perform very well and the NPC with the assault rifle was particularly effective, especially in the first stage.

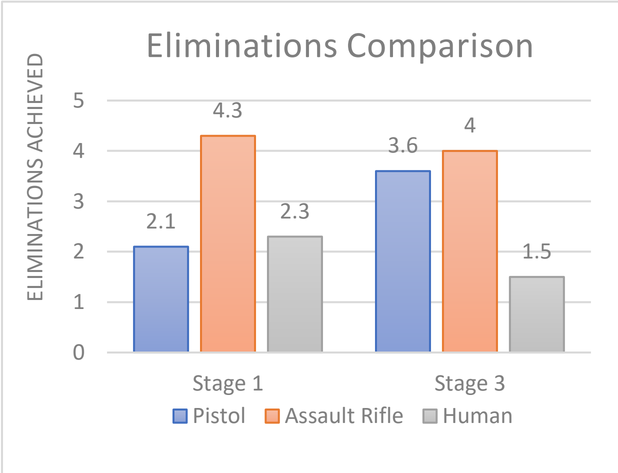

Figure 16. Eliminations Comparison.

This data supports the idea that the NPC's accuracy was too high and will be less effective after balancing. However, when looking at the NPC with the pistol, the data showed that it improved as its skill level increased. This had a noticeable impact because both the subjects and the assault rifle NPC's elimination count decreased. While further experimentation and refinement of the model is necessary, this is a promising result.

This model and set of algorithms are innovative because they could allow the NPC's combat efficiency to be directly affected by the skill level of the player. More research is needed to accurately track the skill of the player in real time so that the NPC can adjust its own skill level to create a personalized difficulty experience that is tailored to the player's individual skill level.

d) Perception

The results indicate that subjects had a good sense of awareness. When specifically analysing the omniscient player awareness test, most of the subjects stated not only did they notice the unnatural ability to locate the subject when they are ambushing, but it has a detrimental effect on how the NPC was perceived. Figure 17 shows a selection of responses from subjects when they were asked which aspect of the NPCs combat was the least believable when compared to a human.

the aim was pretty cracked
Locating players from long range.
As said before, they target you very quickly no matter where you are related to where they're facing.
the accuracy
Accuracy
The AI always had better awareness than me and out shot me
laser like accuracy

Figure 17. Combat Perception Feedback

This is further supported when highlighting the subject responses when asked a multichoice question about key combat behaviours from the combat perception experiment only (Figure 18).

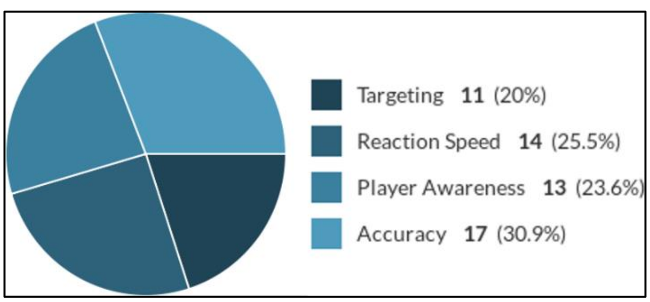

Figure 18. Combat Multichoice Feedback

This negative reaction shows that when developers try to take shortcuts on NPC combat modelling, the results can severely impact the perception of the NPC. This is further supported when discussing the aggressive combat personality because a selection of subjects commented on how they noticed NPCs would move in such a way, where it appeared, the NPC was always committed to a destroy or be destroyed mentality (Figure 19).

the fact it did not run to get ammo when it ran out of mach9ine gun bullets and switched in an inferior weapon
Returning fire at long range instead of taking cover.
They could've been hit many times and they would still attempt to kill you when they have very little chance to win in the engagement.

Figure 19. Specific Feedback

This feedback highlights that subjects' perceptions may not always be correct or a fair reflection of the NPCs. The comment about NPCs not acquiring ammunition is factually incorrect, as the data shows NPCs consistently looked for ammunition when they were below a threshold. When scrutinising the feedback further, it became apparent that subjects' opinions about some of the NPC's characteristic was wrong. The main complaint about the NPC combat was that they were overly accurate and never missed, however, the data shows that while the accuracy was higher than an average subject, NPCs did not have perfect accuracy when shooting. This adds complexity to the modelling because if the subjects' perceptions do not match the numerical data, it could mean the modelling will need to account for incorrect perceptions.

It is interesting that subject perceptions were significantly higher in combat situations, than when they were observing the NPCs from a distance. Figure 20 shows the feedback from subjects when asked to comment on the navigation performance of the NPCs, and which part of the pathing finding was the least believable.

They always seemed to move in a straight line and never tried to dodge or strafe
Straight line walking
they walked directly towards me and often stood still while shooting at me
Seemed to move in dead straight lines
move towards me in combat
I guess they moved in straight lines
Looked 'off'
bots moved towards me attacking, its not realistic

Figure 20. Navigation Feedback

There is no commenting on the NPCs having a jagged pathing when roaming, but significant feedback on how the NPCs moved in combat. This suggests that perceptions are not even across all aspects of gameplay, instead the subjects were more likely to perceive something as 'off' when directly interacting with the NPCs.

VII. Conclusion

The objective of this paper was to develop a dynamically skill scaling combat modelled based off data acquired from human subjects.

This paper has shown that the combat model provided a good solution for modelling human combat behaviours, however, more research is required to improve the modifier weight in relation to the active skill of the NPC. There is evidence to suggest that modelling combat alone would not be enough to create dynamic NPCs, several subjects referred to the pathfinding/navigation when asked to provide feedback on the combat behaviours. Therefore, it could be argued that gameplay behaviours are uniquely intertwined and when one gameplay behaviour is poorly modelled, it can influence other behaviours.

The skill scaling showed a positive result, the data highlighted that there is a somewhat linear change in reaction time and accuracy, as the skill of the NPC was increased. This was noted by 57.1% of the subjects, with zero subjects stating that they thought the NPCs did not increase in difficulty. However, the combat efficiency of the NPC was deemed to be too high, even on the easiest difficulty stage, this was supported when analysing the number of eliminations achieved and the NPC with the assault rifle significantly outperformed the subjects.

The perception feedback indicated that subjects had specific awareness about their opponent when engaging in combat. The data suggests that subjects knew there was something unnatural when NPCs were able to know where they were when they were ambushed. This proved that subjects were able to assess the actions of an opponent during real time, and when something was 'off' it impacted how they viewed the opposition. However, there was data to conclude that not all the opinions were correct, and the incorrect assumptions influenced perceptions. This presents an interesting problem because when modelling combat for NPCs, should they be modelled on human gameplay, or on how players 'think' the NPCs should behave. There is the possibility that the problem could be with the experimental protocol, and that by telling the subject their opposition is an NPC, it subconsciously influences their perception. Therefore, an experiment should be undertaken where the subject does not know whether they are competing against NPCs or human.

VIII. FUTURE WORK

As the results indicated the combat behaviour was negatively impacted by the other gameplay behaviours, research is required to the extent of this influence. This means navigation and decision-making will need to be modelled then the experiment run again, and results compared.

Identifying real-time player skill level could further enhance the effectiveness of dynamic skill scaling, research in this area could help determine if dynamically adjusting NPC skill based on the current player perform provides a more engaging experience.

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