# Modelling Player Combat Behaviour for Dynamic Difficulty Scaling in First Person Shooter Games

Paul Williamson
School of Computing and Mathematics
University of South Wales
CF37 1DL, Pontypridd
e-mail: paul.williamson@southwales.ac.uk

Christopher Tubb
School of Computing and Mathematics
University of South Wales
CF37 1DL, Pontypridd
e-mail: christopher.tubb@southwales.ac.uk

***Abstract*—Non-Player Characters (NPC) 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.**

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

## I. INTRODUCTION

This paper explores a player driven approach for dynamically adjusting the difficulty of Non-Player Characters (NPCs) in real-time. 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 two 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 perception of the model when human subjects conduct a deathmatch scenario with the skill of the NPC increasing with each round.

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.

In Section II, this paper provides a background for NPCs in FPS games and the role of difficulty. 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 two 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. 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 along with an evaluation of the feedback from human subjects, regarding the perception of the combat model. Lastly, an assessment of the combat model as a suitable solution for dynamic skill scaling. Section VII concludes the paper and discusses the impact of the combat model. Finally, Section VIII discusses potential future work that can be undertaken to build upon the work presented in this paper.

## II. BACKGROUND

### A. Non-Player Characters in FPS Games

An NPC is a character that exists within a video game that is not being controlled by a human player. NPCs can occupy any range of characters and can exhibit a variety of levels of perceived intelligence.

There are multiple roles an NPC can fulfil, and their stance towards a player can be friendly, neutral, or enemy [1]. This paper is only focused on NPCs in the role of an enemy and therefore a threat.

The purpose of an NPC is dependent upon the specific role it was designed to fulfil. However, NPCs should strive to appear as authentic as possible to maintain immersion. This is especially important when the NPC operates as a member of a team with human players, because if the NPC is identified, it can become the focus of the opposition if the NPC performs at a low level.

Poorly designed NPCs can have a significant effect on a game, because when the immersion is broken it can ripple through other parts of the game [2]. Therefore, careful consideration should be undertaken when designing the role and function of an NPC because it can negatively impact the game.

### B. Difficulty in Games

Difficulty is one of the areas where poorly developed NPCs can damage the overall enjoyment of a game. When NPCs are too easy, they do not represent a challenge and when they are too difficult, they can be frustrating and appear as unfair opposition.

This signifies a problem when discussing difficulty settings in video games. The term is subjective and so what is ‘easy’ to one player may not necessarily be ‘easy’ to other players. The issue exists when hardcoding arbitrary characteristics to perform at a defined level. The focus is not player-centric, but rather a generalised interpretation of what is considered 'easy' by the developers.

In First Person Shooter games (FPS), NPCs 'difficulty' is often expressed in their combat efficiency, and so difficulty settings reflect adeptness regarding individual combat behaviours, such as accuracy and reaction time. Part of this paper is to explore whether the skill of the NPC can be changed in real-time, and if the combat behaviours correspond precisely to the skill level. This would enable a player-centric based difficulty. The players skill is calculated in real-time, and then the NPCs are modified accordingly depending on the difficulty classification selected.

## III. MOTIVATION

The motivation of the paper is to address the purpose of varying difficulty and ultimately the distinction between the different difficulty classifications. While this is a subjective discussion, the difficulty of a game can impact how it is perceived by an individual. When a particular difficulty is selected, it is important that it is perceived accordingly otherwise there is a risk of a negative experience.

A combat game in the form of an FPS was chosen as the case study because it represents a well-founded genre and have heavily featured in the gaming industry since the early 1990s. As game genres can differ in gameplay and technicality, it was important to isolate one genre so that the scope of the research remains narrow so a conclusion can be derived from the data. Furthermore, in FPS games, the metric of difficulty is commonly associated with combat 'skill', such as reaction speed, precision, and decision-making. Therefore, it is a standard practice in the video game industry to statically increase reaction time, damage dealt and precision when increasing difficulty levels.

The motivation for exploring real-time skill scaling centres around the notion that one size does not fit all. When a game has static pre-determined difficulty settings, they cannot accurately cater to all potential players. By having NPCs skill based on the performance of the player, it could usher in a new player-centric style of difficulty, and ultimately provide more control to the player.

Williamson and Tubb [3] showed that player gameplay can be broken down into key behaviours and the patterns that emerged can be modelled. They also indicated that when an NPCs were poorly modelled, and the combat efficiency was too high, the resulting NPC was perceived as a player using cheats.

## 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 [4] 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. [5] 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. [6] 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. [7] 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. [8] 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. [9] 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. [10], 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. [11] 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. [12] states:

> *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. [13] 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. [14] 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 [15] discusses the notion of using player models to generate an individualistic experience. Their research shows that a few viable techniques have been examined [16]-[18]. 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.

## V. Experiments

A series of experiments were conducted to analyse the combat efficiency of human subjects so they can be directly modelled. This also enabled the same experiment to be undertaken by the NPCs, so a direct comparison could be performed and ensure combat efficiency was changing in accordance with the skill level set. Evaluating the perception of difficulty, an experiment was undertaken where human subjects played a series of deathmatch rounds against two NPCs. As the rounds progressed, the base skill level of the NPCs also increased.

The objective of these experiments is to identify the generalised combat efficiency of human players, use this data to develop a combat model that adjusts combat efficiency based on current skill level, and then evaluate the model by having human subjects compete against NPCs.

### A. Experimantal Environment

The experiments in this paper were developed using Unity3D, the files were upload to an online server. Each subject download and ran the experiment on their local machine. The first experiment took approximately fifteen minutes to complete. After each stage data was saved and uploaded to an online database. The second experiment took ten minutes, with the data also being saved online after each stage. There was also an accompanying questionnaire at the end of this experiment, which was completed via a web browser.

All subjects in both experiments were anonymous, no details were requested, and no experience was required. The data that was uploaded from their experiment session did not record any information which could be tracked to an individual.

### B. Combat Behaviour Experimental Protocol

The modelling experiment focused on five scenarios, which analysed and recorded the decisions and behaviours of the subjects as they undertook each scenario. Each scenario has three settings where targets spawns near, medium distance or far from the subject. During the experiment the subject cannot move except to rotate and targets randomly spawn in view. The scenarios in this experiment were used because they reflect commonly occurring combat situation in FPS games. While it is understood that in some modern games more complicated scenarios could appear, it was decided to model the fundamental scenarios only and gauge the effectiveness of the skill scaling.

The experiment runs four times. Each time the weapon or weapon aim stance will change, in the order as follows:

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

The purpose of these experiments is to identify if individual weapons have an impact on combat behaviours and the degree of change in combat efficiency when the weapon aim stance changes. This will help determine the specific and generalised weapon behaviours that will need to be modelled and what impact they may have on difficulty.

All targets use the same model and texture, they each have the equivalence of fifty health points and are immediately destroyed when its health is reduced to zero.

#### a) Normal Scenario

The normal scenario is a typical encounter in a video game. A single target appears, and the subject has a limited amount of time to dispatch it. Subjects have 2 seconds to eliminate the target before it disappears. As the three stages represent near, medium, and far distances. This experiment analyses what effect this has on accuracy, reaction time and helps determine a baseline for average reaction time.

#### b) Increased Spawn Rate

The increasing spawn rate analyses the effect of targets appearing in view when subjects are in the process of eliminating another target, and if the new targets have a negative effect on reaction time. The purpose of this experiment was to determine if external influence can have a negative effect on combat efficiency, and if so to what degree.

#### c) Grouped Targets

It is frequent in a modern game that multiple opponents can be present at a given time. This scenario analyses the pattern exhibited when numerous opponents suddenly appear.

Continuing with the three-stage approach, this scenario also increases the number of targets that simultaneously spawn as the stages advance. The near stage has three targets, medium stage has five targets, and the far stage has seven targets. All targets remain for five seconds before disappearing.

*d) Varying Size*

This scenario is a repeat of the normal scenario stage. However, the target size is decreased to determine the degree of correlation between target size and combat efficiency.

*e) Moving Target*

In this scenario, targets spawn every 2.5s and self-destruct at 5s. They move from left to right at a constant speed, changing direction when reaching the edge of a predefined boundary. This enables some overlap of targets on screen if they are not eliminated fast enough. This scenario explores if a moving target has an influence on combat efficiency of an individual.

## C. *Dynamic Difficulty Experimental Protocol*

Evaluating the effect of dynamic difficulty, the experiment is a deathmatch. The objective is to achieve a set number of eliminations before the opposition. In this experiment, the requirement is set to 5 eliminations. There are three stages, as the stages progress the base skill level of the NPCs is increased. The stages are as follows:

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

There are two NPCs opponents, which operate in an all verses all scenario. One of the NPCs will use a pistol and the other will use the assault rifle. Each weapon has a sub model that influences attack distance and has its own attributes such as clip size and bullet damage.

The subject will have access to three weapons. Each weapon has its own ammunition stash and can be equipped by pressing 1, 2 or 3 on the keyboard. The weapon characteristics are as follows:

- 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 three medic-packs and three ammunition-pack throughout the map. The medic-pack provide 50% health and the ammunition provides one clip for the equipped weapon. When a medic-pack or ammunition has been collected, it will respawn in the same location after five seconds.

The purpose of this experiment is to evaluate the combat model and to determine if increasing the base skill level has an effect on combat efficiency. The skill scaling is important because in a real-world setting, there is a spectrum of player skill levels, this flexibility needs to be reflected in the model. If NPCs are able to increase or decrease their combat efficiency in real-time, it would provide a suitable solution to improving challenging NPCs. As NPCs could be changed during a game to match the skill of the current player.

*a) Combat Model*

The combat model being used in this paper was derived from subject data captured in the ‘Combat Behaviour Experiment’. The purpose of this model is to have NPCs imitate human-like combat behaviours, with key behaviours directly linked to a skill variable, so the combat efficiency accurately reflects the NPC skill at a given time. For this paper, the skill of the NPC will be between 1 and 10, with 10 representing very high combat efficiency and 1 very poor efficiency. Therefore, an NPC with a skill of 5 will represent the generalised combat efficiency resulting from the combat behaviour experiment. The definition of skill will therefore be based around improving or worsening the generalised data.

As the combat model was used to influence key combat behaviours by modifying how the NPC operates in combat situations. This means the purpose of the combat model was to represent a generalised combat behaviour exhibited by human subjects during combat encounters. As the data used for this model was directly sourced from human subjects, it was generalised to provide a base level for how an average skilled NPC should play.

As the development techniques being deployed are standard in the gaming industry, it was important that a range of these techniques were compatible with the data acquired. Therefore, when developing the model, it was decided that the best approach would be to use object orientated programming to encapsulate the functionality of the model. After an object of the class is generated, the other components of the NPC can directly access the combat model. This is vital because during run time, several scripts and coroutines are running at the same time and potentially require access to the same data.

Ensuring NPCs did not appear generic, it was decided that the skill attribute should be influenced by modifiers but have an upper and lower restriction. This would stop NPCs snowballing and becoming too good or regressing and becoming too bad. It was important that the influence applied by the skill attribute is a direct reflection of the previous passage of play, accumulating from the past few combat interaction outcomes. The modifiers are:

- Death: Being eliminated has a negative effect and decreases skill modifier
- Eliminations: Eliminating an opponent is positive and increases the skill modifier

The modifier change is +0.5 for an elimination and -0.5 for a death. This amount is added to an accumulative counter but is capped at +2.5 and -2.5. This limitation was added to stop NPCs diverging too far from their base skill. For instance, a run of eliminations without being eliminated will take an NPC to peak performance of base skill level + 2.5.

Players generally have a preferred weapon of choice. Therefore, NPCs generate a preferred weapon order when initially spawned. The top three weapons have a positive influence on active skill, the amount is determined by the weapons position in the weapons order. For this experiment however, NPCs were not given the option to change weapon and were equipped with a predefined weapon. The weapon skill modifier was always set to +1.

When calculating the active skill, the base skill, weapon modifier and a hot-streak/cold-streak modifier are all added together. This approach means the active skill will always be close to the base skill but has some arbitrary variation because there is potential for the NPC be having a "good" or "bad" round.

Equation (1) shows how the initial reaction time was calculated using an active skill calculation.

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

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.

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.

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

*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.

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

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. When shooting off the hip, the crosshair momentarily increases in size, this effect is accumulative, so the longer the weapon is being continuously fired, the more inaccurate it becomes.

The shooting stances therefore have unique characteristics that display different combat behaviours based on the weapon being used and active skill of the NPC.

## VI. RESULTS

The results indicate that modelling human behaviour is a suitable method for having dynamically skilled NPCs and it is possible to generalise combat efficiency. While the skill scaling proved to be a very effective solution for modifying the NPC combat efficiency in real-time.

*a) Combat Model Analysis Comparison*

The results suggest that while the performance of the model was well received, there were some areas of combat that require more attention. Figure 1 details the average accuracy for both NPCs at each stage and subjects at stage 1. It shows that while the scaling worked, they were in general over-tuned.

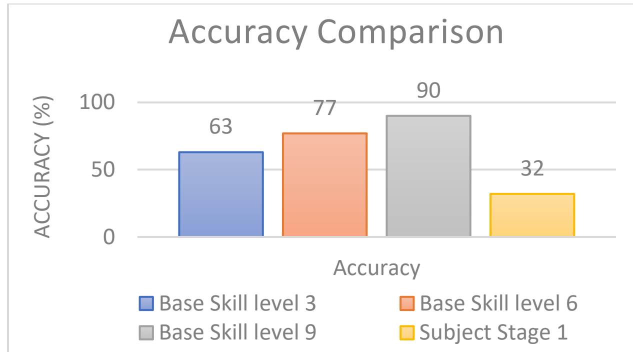


Figure 1. Accuracy Comparison.

When specifying where combat believability was the weakest, it follows a similar trend. Figure 2 shows that when asked about specific behaviours of combat, 85.7% of the responses thought accuracy was not realistic.

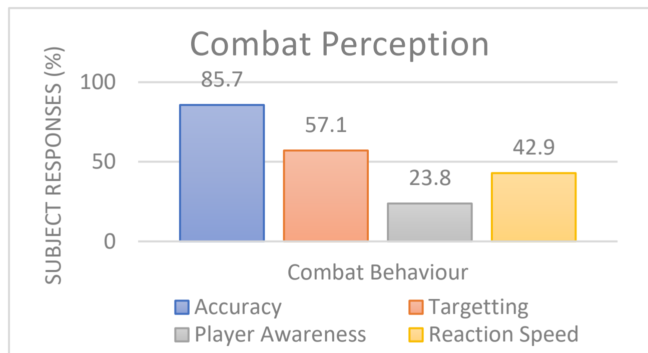


Figure 2. Combat Perception Analysis.

Reaction time was also elevated. This suggests that subjects had a difficult time competing with the NPCs. However, this problem can be solved by reducing the weight of the modifier system in the combat model, which suggests more experimentation is required to tweak the model.

Figure 3 shows the overall combat perception of the NPCs. While 50% thought the NPCs were somewhat human-like, the rest thought they did not display a good representation of a human player.

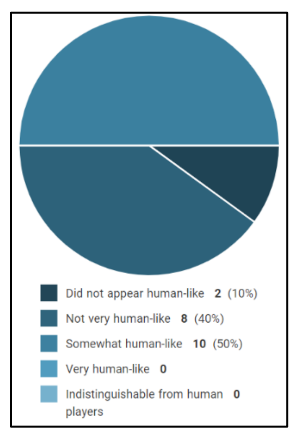


Figure 3. Combat Feedback.

While these results may not suggest the NPCs accurately imitated human players, it shows that this method does hold some promise and by fine tuning the model it could yield better results.

*b) Gameplay Influence*

When analysing the feedback, it became apparent that the other gameplay behaviours were having a direct influence on the perception of the combat believability. This meant that the perception of the pathfinding was negatively affecting the opinions of the subjects regarding the combat of the NPCs. As subjects were requested to fill out a questionnaire at the end of the deathmatch experiment, a question was specifically asked about the combat behaviours exhibited by NPCs. Figure 4 singles out a reply from one of the subjects. It underlines that other gameplay behaviours, such as navigation, can have an impact on the perception of combat.

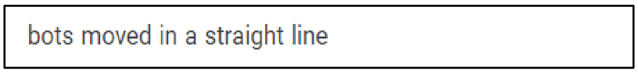


Figure 4. Specific Combat Subject Feedback.

When one behaviour is modelled poorly, it can affect the perception of other behaviours and have undesirable effects. When modelling certain behaviours, it is important to be aware of how it may affect the other behaviours in certain scenarios.

*c) Skill Scaling*

The skill scaling showed a high degree of effectiveness when asking the subject if they noticed a change in difficulty as they progressed through the stages (Figure 5). While 57.1% noticed a change in difficulty, none of the subjects thought the difficulty did not change.

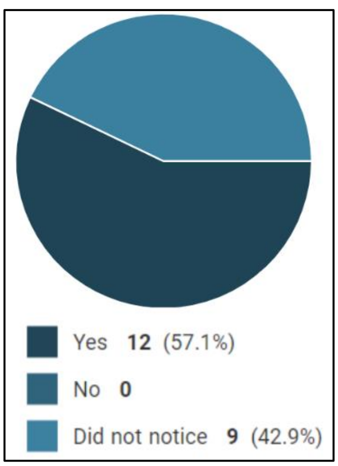


Figure 5. Difficulty Identification Feedback.

This shows the combat model could be a suitable solution for enabling real-time adaptive NPC difficulty. This further confirms that players, to a degree, have awareness about the combat efficiency of opponents. This emphasises that generalisation of difficulties cannot satisfy all players.

When analysing the pistol combat performance between the three difficulties (Figure 6). A positive trend is evident where the amount of damage done by the NPC increased as the base skill is increased.

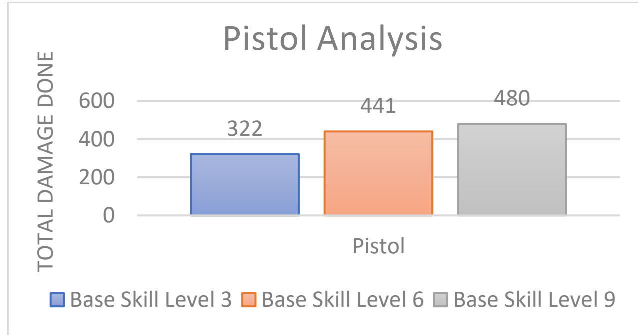


Figure 6. Pistol Damage Done Skill Comparison.

Combat efficiency increased with base skill level. This is supported when analysing the average initial reaction time for the assault rifle across all three stages (Figure 7). The results show a slight correlation between reaction time and active skill level. While there is some deviation, this could be due to the fluctuation in active skill level, due to hot and cold streak being triggered.

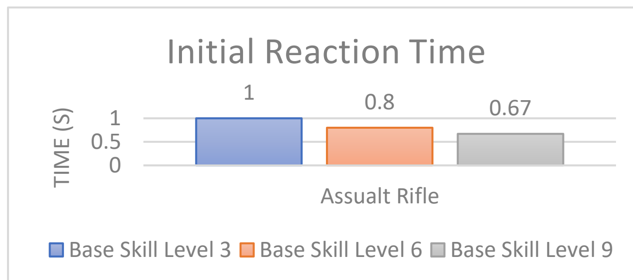


Figure 7. NPC Skill Reaction Time Initial Comparison.

When analysing the 1st and 3rd stages (Figure 8) the average number of eliminations achieved for each character was considered. On average, subjects did not perform very well and the NPC with the assault rifle was overly efficient especially on stage 1.

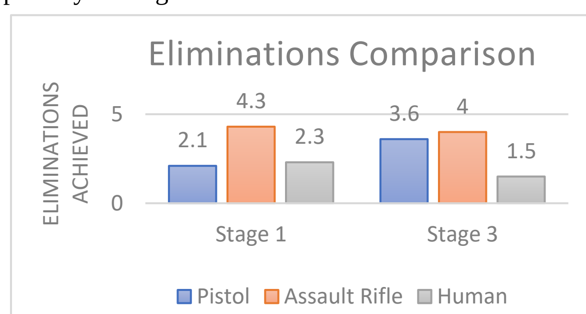


Figure 8. Eliminations Comparison.

This data supports the suggestion that the performance of the NPCs was over tuned. However, when analysing the NPC with the pistol, the data shows that it did get better as its skill was increased. This had a significant effect because both the subject and assault rifle NPC elimination count dropped. While more experimentation and fine tuning of the model is needed, this represents a positive result.

The novelty of this model and algorithms is that the skill variable directly influences the behaviour and efficiency of the

Copyright (c) IARIA, 2022.

NPC in combat. Further research is required to capture real-time skill of the player, so the NPC can tweak its skill to match the desired difficulty outcome. This would represent a personalised difficulty structure, where the player skill is taken into consideration.

## VII. CONCLUSION

The objective of this research was to develop a dynamic skill scaling combat model based on data acquired from human subjects. This paper has shown that the combat model provided a good solution for modelling human combat behaviours, however, more data is required to improve the modifier weights 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, when asked to comment on combat behaviours, mentioned pathfinding and navigation issues. Gameplay behaviours are intertwined and when one gameplay behaviour is poorly modelled, it can influence perception of 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.

## VIII. FUTURE WORK

As the results indicated the combat behaviour was negatively impacted by the other gameplay behaviours, research is required to determine the extent of this influence. Navigation and decision-making models will need to be included in the NPC, the experiment repeated, 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.

## REFERENCES

[1] H. Warpefelt, “The Non-Player Character: Exploring the believability of NPC presentation and behavior,” Doctoral dissertation, Department of Computer and Systems Sciences, Stockholm University, 2016.

[2] P. Lankoski and S. Björk, “Gameplay Design Patterns for Believable Non-Player Characters,” DiGRA Conference, pp. 416-423, 2007.

[3] P. Williamson and C. Tubb, “Modelling Player Combat Behaviour For NPC Imitation And Combat Awareness Analysis,” ECMS, pp. 205-212, 2021.

[4] J. Orkin, “Three states and a plan: the AI of FEAR,” Game developers conference, pp. 4, 2006.

[5] C. Pezzato, C. Hernandez, S. Bonhof, and M. Wisse, “Active Inference and Behavior Trees for Reactive Action Planning and Execution in Robotics,” arXiv preprint arXiv:2011.09756, 2020.

[6] R. A. Agis, S. Gottifredi, and A. J. García, “An event-driven behavior trees extension to facilitate non-player multi-agent coordination in video games,” Expert Systems with Applications, pp. 155, 2020.

[7] X. Neufeld, S. Mostaghim, and S. Brand, “A hybrid approach to planning and execution in dynamic environments through hierarchical task networks and behavior trees,” In Proceedings of the Fourteenth AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment, pp. 201-207, 2018.

[8] E. Camilleri, G. N. Yannakakis, and A. Dingli, “Platformer level design for player believability,” Conference on Computational Intelligence and Games, pp. 1-8, 2016.

[9] M. Polceanu, A. M. Mora, J. L. Jimenez, C. Buche, and A.J. Fernandez-Leiva, “The believability gene in virtual bots,” The Twenty-Ninth International Flairs Conference, pp. 346-349, 2016.

[10] A. M. Mora, A. Gutiérrez-Rodrıguez, and A. J. Fernández-Leiva, "Optimising Humanness: Designing the Best Human-Like Bot for Unreal Tournament 2004," In International Work-Conference on Artificial Neural Networks, pp. 681-693, 2017.

[11] R. R. Wehbe, E. Lank, and L. E. Nacke, “Left the 4 dead: Perception of humans versus non-player character teammates in cooperative gameplay,” In Proceedings of the 2017 Conference on Designing Interactive Systems, pp. 403-415, 2017.

[12] J. D. Smeddinck et al. “How to present game difficulty choices? Exploring the impact on player experience,” CHI Conference on Human Factors in Computing Systems, pp. 5595-5607, 2016.

[13] M. Hendrix, T. Bellamy-Wood, S. McKay, V. Bloom. and I. Dunwell, “Implementing adaptive game difficulty balancing in serious games,” IEEE Transactions on Games, pp. 320-327, 2018.

[14] P. M. Blom, S. Bakkes, and P. Spronck, “Modeling and adjusting in-game difficulty based on facial expression analysis,” Entertainment Computing 31, 2019.

[15] S. Bakkes, C. T. Tan, and Y. Pisan, “Personalised gaming: a motivation and overview of literature,” In Proceedings of the 8th Australasian Conference on Interactive Entertainment: Playing the System, pp. 1-10, 2012.

[16] P. H. M. Spronck, I. G. Sprinkhuizen-Kuyper, and E. O. Postma, “Difficulty scaling of game AI,” In Proceedings of the 5th International Conference on Intelligent Games and Simulation, pp. 33-37, 2004.

[17] P. Demasi and A. J. de. O. Cruz, “Online coevolution for action games,” International Journal of Intelligent Games and Simulation, vol. 2, pp. 80-88, 2002.

[18] G. N. Yannakakis and J. Hallam, “Towards optimizing entertainment in computer games,” Applied Artificial Intelligence, vol. 21, pp. 933-971, 2007.