

Engaging Players by Dynamically Changing the Difficulty of a Video Game

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Abstract

Automatically adjusting video game difficulty to match the ability of the player is an established approach to achieve player engagement. In this paper, we extend the approach by adjusting the rate at which difficulty changes over the course of the game; early in the game difficulty is rapidly adjusted to quickly match the player's ability, while later in the game the difficulty is adjusted more slowly in an effort to make the adjustments seamless. We compare this approach to a more traditional approach of adjusting the difficulty at a constant rate throughout game play. We will use the functionality provided by Dynamically Adjusted Difficulty Algorithms (DDA's) to accomplish this goal. The DDA takes into account how the player is performing to calculate a desired difficulty of the game. The game will then adjust its difficulty based on the previously defined difficulty and the new calculated desired difficulty to determine the adjustment to the actual difficulty. To determine the effectiveness of the different rates implemented into our DDA, we used the engagement of the player for a basis of comparison. A higher engagement represents a more effective rate. After testing the subjects we found no statistical significance difference between the two implemented DDAs..

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1 Introduction

Have you ever started playing a video game and instantly love it? Many video game players already know what type of games they enjoy playing and the ones they are good at. They also have a pretty good understanding of the games that they just can't seem to figure out. With a vast variety of different types of video games, including first-person shooters, arcade, adventure, real-time strategy, and side scrolling, along with different platforms to play them on, video games cover multiple different types of players. Game designers have to find the perfect balance in the challenge of the game and the learning curve of the player. Doing so incorrectly will cause players to leave the game for another due to boredom or frustration. With a wide range of types of players, finding this perfect balancing relies a lot on luck. An expert player and a novice player will have different experiences with the same game based on differences in play style. But what is it about a game that makes gamers to continually come back and replay the same game over and over again? There are many factors for this. However, part of what keeps a player coming back to a certain game is how engaged they are into the game. Video games are designed to try to keep players in a certain state of mind. A well developed video game will cause the player to undergo a sensation of becoming part of the physical game, as if it was truly them inside the game. Gamers generally lose track of time and become disconnected with their surroundings when they are deeply engaged into the game. Not responding or not even hearing when someone is directly talking to them can also occur during a high level of engagement. This is exactly what game developers attempt to create while designing a new game. The farther the game developers can bring a gamer and maintain a gamer at this state of being determines how successful their game will be. There are obvious other factors to a video game that can make it successful in the gamer community. However, some of these other elements of a successful game also contribute to engagement, such as realistic graphics, a realistic physics engine, or a compelling story line. With the gaming industry reaching a net worth of over 20 billion dollars, there is a lot to gain by having an engaging video game.

Previous research involving exactly what this high state of engagement is has coined the term "flow" to describe this state of being [3]. These researchers have developed a model for determining and explaining the different factors that contribute to a high engagement level and how to judge what is happening to

the gamer. Flow is defined many different ways but the most commonly agreed upon meaning is when a player feels as if they are in the game, as if the game has almost taken over [6]. This is an extreme version of Flow that many game designers try to achieve with their game. The flow zone is created when the difficulty of the game and the abilities of the player increase simultaneously. Figure 1 visualizes the description of the flow zone.

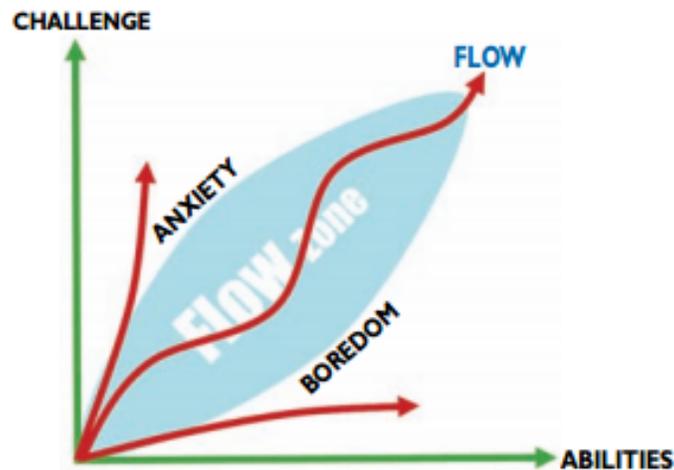


Figure 1: A visual representation of the flow zone [5]

If one of the variables was to increase at a different rate than the other, this can cause boredom or frustration in the player. A natural progress of a game is to become increasingly harder as the game nears the end of the story line. The final boss fight is generally the hardest mission in the entire game. One would expect that the player has gained either powerful new moves, gear, or other similar components depending on the game type. If at the boss fight, the player had the same capability as the initial configuration, the fight would be nearly impossible and cause extreme frustration to the player. Similarly, if the boss was no more challenging than the initial mobs but the player was max level, this would make for a very boring game. The key to a player entering the flow zone is to find this configuration that allows the player to

improve their abilities at the same rate the game increases its difficulty. This flow zone will not be the same from player to player. Some players prefer easier or harder game play than others and will not cause the same engagement for every player. The Flow zone is defined by the challenges presented by the game and the abilities of the player. For different players, the challenge could seem hard to one player and a simple task to another. A game designed with a static difficulty level will only allow for a specific flow zone to be created and will not incorporate the different player types. Figure 2 shows specialized flow zones for the different types of players.

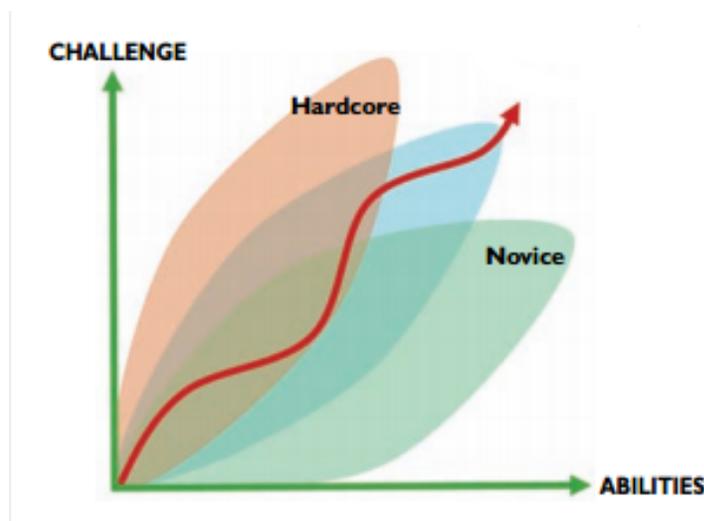


Figure 2: A visual representation of the different flow zones for different players [5]

What if the game was able to live-time determine how the player is performing and adjust the game to create a personal level of difficulty that will always allow the user to get the maximum enjoyment out of a game? The game would constantly measure the performance or the ability of the player and adjust the difficulty accordingly to match the players performance. A system capable of accomplishing this task would create unique player experiences and a personalized flow zone. This approach of manipulating the game's difficulty level based on the players current performance rating is called Dynamic Difficulty Adjustment (DDA) [4]. Using a Dynamic Difficulty Adjustment (DDA) algorithm, a video game will be able to determine how the player is performing and adjust the game as the user is still playing to keep the

player within a unique flow and difficulty zone [8]. If a player is able to stay within the Flow zone for longer than usual, the player will be able to achieve a higher level of engagement compared to a user playing the same game but without a dynamic difficulty adjustment algorithm if the game was to ever become too easy or too difficult.

We will be comparing different versions of a DDA that changes the rate at which the game adjusts its own difficulty. The rate of change of the DDA refers to the allowed distance the difficulty is able to change between the current difficulty level of the game and what the new calculated desired difficulty is based on player performance. The allowable change in difficulty is the actual rate we are manipulating. We will be comparing a DDA that changes its rate during the game play to a more traditional approach as the control. This DDA will be referred to as the non-constant DDA. The DDA uses a function of time to determine what the allowable change should be. This causes the game to start off with a higher allowable change but as the game progresses the fraction becomes smaller and smaller. This allowed us to determine if a DDA that has a non-constant rate of change is more effective at keeping a player deeply engaged rather. The concept is that a DDA that has a non-constant rate of change, where the changes in difficulty are larger to start and smaller towards the end, will be more effective. We believe that in the beginning stages of the game, a player is becoming familiar with the game and fluctuations in difficulty will occur. The DDA will be capable of rapidly changing to fit these fluctuations initial. After the player has gotten familiar with the game, the performance of the player should level out and stay around the same difficulty for the rest of the game. At this point, the DDA will be making smaller and smaller changes to the difficulty stabilizing the players difficulty. This will eliminate the outliers to greatly affect the difficulty. If the player continually out performs the current difficulty setting, the DDA will be able to slowly reach the desired difficulty without alerting the player of such a change. This approach will lead to a more continually accurate difficulty setting allowing the player to become more engaged in the video game. To test how efficiently these DDA's work and to be able to compare them to each other, we will be focusing on the individual's player engagement levels. The purpose of the experiment is to determine how successful each DDA is at engaging the player. A higher level of engagement will keep a player to continue to come back, over and over again, to the same game. This is essential for game developers for creating a successful game.

The remaining of the paper is structured as follows. The next section, Background and Related Work, will discuss previous work done with Dynamic Difficulty Adjustments along with research behind what truly defines engagement. The following section labelled Approach will look into the decisions made in development and how the final product came to be. In the fourth section, Methods and Experiment Design, will discuss the decisions made with determining what rate of changes to use as well as how we tested the subjects. The fifth section will present the results we obtained and the methods used to analyze these results followed by the Discussion of the results. This section also contains the threats to validity. To wrap the paper up, we will end in the conclusion to discuss what the results we gathered mean and how this relates to what we were trying to accomplish along with potential future work.

2 Background and Related Work

The study of dynamic difficulty adjustments and similar concepts, such as, dynamic game balancing (DGB) and profile-based adaptive difficulty system (PADS) has been conducted before. The First to look into different ways of programming the difficulty of a game to no longer be static was Michael. He and his team developed the idea of a game that would be capable of adapting its difficulty in the middle of game play. What he and his team came up with was the formation of Dynamic Difficulty Adjustments (DDAs)[4]. Andrade further developed Michaels work to better understand what the components of a DDA need to be. Andrade however experimented with automatic computer game balancing. He used a popular reinforcement learning algorithm Q-learning to optimize the difficulty of the game. However, using an optimal approach to determine the difficulty of the video game, the AI was adjusted to always outperform the player. The game would always be one step ahead of the player creating a very challenging game for every player. They adjusted the algorithm to perform a sub-optimal approach of determining the difficulty to better keep the difficulty within the desired range of the player. Some of the concepts Andrade researched was how the DDAs or DGBs actual work and how to make them perform the best. He discovered that the timing of the DDAs was crucial to keep the players awareness of the mechanics to a minimum. The DDAs need to be able to find the players desired difficulty as fast and as accurate as possible. The less the DDA needs to calibrate the better the DDA will perform [1]. These ideas of calibrating the DDAs led to Chang

Yun and his team, in 2009, to implement a way to use a dynamic difficulty adjustment algorithm along with profile basing beforehand. They conducted a small survey at the start of the experiment to determine which profile each subject fit into. They used six categories to place the subjects into based on questions of the player's years of experience (0 to 1, 1 to 3, and 3 to 5) and their goals in the game (victories, challenges, or both). Using this information obtained from the subjects, the information was then passed to the DDA to give the DDA an initial starting point for performance. Knowing some initial information about the player before the game even starts will allow it to make more accurate calculation based on how the player is performing[9].

In order to determine which of the DDA's greater enhances a players level of engagement, we needed a way to be able to correctly judge a players engagement and have a foundation to compare them to each other. Words generally associated with a players engagement are engagement, immersion, enjoyment, and flow [3]. Research in these fields was also required in order to come up with our own model of determining and comparing a players engagement for our specific experiment. Jeanne H. Brockmyer her team has conducted an experiment of the basis of what it means to be engaged. They constructed a 19 part questionnaire to convert into a quantitative representation of a players engagement [2]. Similar research was also conducted by Penelope Sweetser and Peta Wyeth to break down the individual components of engagement and flow. They questioned what these terms actually represented and broke down the problem to 8 elements that defined what engagement truly is. There are concentration, challenge, skills, control, clear goals, feedback, immersion, and social interactions [6]. We will be using these components to better construct our won model for evaluating the success of the DDA.

3 Approach

The concept researched was that a game that adjusts it's rate of change of difficulty, based on the time of the game, will allow the game to make rapid adjustments early on and then when the game has found an optimal difficulty it will start making smaller and smaller changes in it's difficulty. First we needed a way to adjust the difficulty of the video game dynamically. Dynamic Difficulty Adjustment algorithms (DDA) fit the description and provide the robustness we needed, as discussed in the Related Work section. When

determining how the DDA will adjust the difficulty there are two options to choose from. The first one is to allow the DDA to make absolute jumps in difficulty. With absolute jumps, the DDA will change its level based on a fixed number representing the distance the DDA can change. An example of this is, if the current difficulty is 6 and the fixed allowable delta is 2, the resulting difficulty can, at most become 4 or 8 depending on the direction of difficulty change. In terms of the non-constant DDA, this fixed value will decrease based on the time in the game. The second option is to have the DDA use a percentage of the distance. Instead of limiting the DDA with a fixed number of difficulty levels it is allowed to change, we restrict the DDA to be adjust the difficulty based on a percentage of the distance between the difficulties. An example of this is, if the previous difficulty was 5 and the new desired difficulty is 10, a DDA with an allowable delta set to one half or 50 percent, the new difficulty will be 7.5. For the experiment we conducted, we chose to use percentages instead of absolute. Using the percentage method works extraordinary as a function of time giving the DDA the exact functionality we were going for. The changes in difficulty felt to be more accurate and precise rather than limiting by absolute jumps in difficulty.

With the functionality of the DDA's determined, we needed an apparatus to implement them into. There were lots of available different option to choose from. We first had to decide weather or not we wanted to use a pre-made game or create on from scratch. We chose to design a game from scratch for better understand how to manipulate in the game in terms of difficulty. The next step was deciding the type of game that best fit the experiment. The goal was to design a game that was simple to learn and play and had obvious way of manipulating the difficulty. An endless shooter with characteristics of a point and click style game was implemented with the DDA's. This was designed to be very simple and plain. Doing so in this way limits a majority of the other factors that could contribute to the engagement of the game. Compelling story lines, realistic graphics, and mission objectives will play no major role in the engagement of the player because they do not exist in the infrastructure of the game. The only issue with implementing game play this was created the game to be pretty dull. However, without any of these other factors, we have isolated the changes in player engagement to be entirely reliant on the implementation of the DDA's.

Now that we had a game that has isolated the engagement based on the performance of the DDA, we had to determine what variables would need to be adjusted in the game to manipulate the difficulty of the

game. Since the game was designed to be an endless-shooter, the targets will determine the majority of the cause of difficulty. The variables available to choose from were size, the amount of targets on the screen, speed, re-population rate, damage caused to player, rate of explosion, and the amount of targets to explode. The final decision was to manipulate only the size, speed, and number of targets on the screen at any given time. One reason for only choosing a select few attributes was that manipulating all of the attributes of the target caused a drastic change in difficulty every time there was a change. A single level of increase in difficulty became noticeable to the player and the difference between the easiest setting and the hardest setting were too far apart. By limiting the amount of variables manipulated, the changes in difficulty were very easy to hide and seemed almost seamless. We will now look into how the previous three attributes were selected. When the re-population speed became too slow with the easier difficulty settings, the player was able to eliminate all of the targets on the screen before any more would re-spawn. The player then had to wait for a new target to spawn and was able to destroy that target once again before any more would appear. This caused the player to enter an unwanted loop of killing the target, waiting for another to spawn, and immediately killing that one. We fixed the spawn rate to one half of a second to eliminate the possibility of a player entering this loop. The damage done to a player by an exploding target also became fixed to do 10 damage points to the player. Since the player had a starting health of 100 points, the health became a representation of a hit counter with the player being able to survive ten target explosions. We changed the health and damage done to a player to be better visualized by adding lives in place of health. Now the player will be able to tell exactly how many explosions it will take for the game to end. The player would now start with five lives clearly indicated at the top left of the screen. The rate of explosions was also fixed at a time value of ten seconds of being on the screen. Once a target was left on screen for ten seconds, the target will enter a detonation phase. The player will then have exactly one second to destroy the target to prevent the explosion from happening. This eliminated the need for the variable that kept determined the number of targets allowed to explode based on the difficulty level. Any and every target left on the screen for a total of eleven seconds will explode resulting in a lose of life to the player. The selected variable will effect the difficulty based on how the targets are constructed. Upon construction, the targets are given base attributes for size, and speed. The difficulty variable is then used as a factor to determine the speed and

sound based on the difficulty.

The next stage in development was to determine the variables that would be used in the calculation of determining the players desired difficulty. The possible choices were health, the number of exploded targets do far, the score, the number of destroyed targets, the number of targets missed, the number of total shots taken, the time alive, and the previous difficulty. Since as stated before, the players health has been removed from the class and converted to lives. Due to the direct correlation now with the number of lives left and the number of targets exploded, the number of targets exploded variable has been removed. The time alive is directly factored into the performance of the DDA. This lead to the conclusion to avoid using this variable in the calculation of the difficulty as it is already factored in. The DDA also factors in the previous difficulty setting to determine what the new desired difficulty should be. This is done by the calculation of the distance between difficulties. This leaves us with only the target information, targets hit, missed, and total attempts, to be used to determine the desired difficulty of the player. Since the number of targets hit plus the number of targets missed is equivalent to the total number of shots taken, the variable for targets missed was disregarded. The remaining information was used to calculate the players accuracy which equals the number of targets hits divided by the number of shots taken. The accuracy is always calculated as a fraction with possible options ranging from zero to one assuming the player is not allowed to hit more than one target with a single shot. This format fit perfectly in determining the players desired difficulty level by multiplying the accuracy by ten. The result was always guaranteed to be in the predetermined difficulty levels of zero through ten. The new desired difficulty is then compared to the previous difficulty to determine the distance between the two difficulties. This difference is then multiplied by the allowable delta determined by a function of time to find the allowable delta. The allowable delta is then added or subtracted, based on the direction of the change, from the previous difficulty resulting in the new difficulty to set the game to.

After completing the apparatus and the DDA implementation we had to develop a way of testing the effectiveness of the different rates implemented into the DDA's. We decided that testing the effectiveness of the DDA would be based on its ability to engage a player. However, with engagement set as the component of comparison, we now needed a method of determining the players engagement. Possible ways to mea-

sure engagement effectively is with a heart rate monitor or using the player's brain activity. The equipment needed to measure these components would get in the way of a natural gaming environment. The player could become distracted by the machinery and become nervous under these testing situations. A player hooked up to these monitors would start off in a different mindset and affect the results. A proper procedure, although not as accurate, would consist of a method that does not interfere with natural game play or the mind set of the player. The Game Engagement Questionnaire [2] is a nineteen question questionnaire comprised of the key factors of video game engagement presented in a way of asking simple questions to the player. The questionnaire was presented to the player after the experiment was over to avoid any initial information that could effect the player's game play. In order to compare the results, the answers were converted into a numerical representation of the player's engagement. Certain body positions and gestures including verbal gestures also indicate very basic engagement levels but these are less precise. Body positions can indicate whether a player is engaged or not but can not answer the question of how engaged a player is. These indicators were recorded separately during actual game play and given values of -1, 0, and 1. A negative one was assigned to the player if their body positions indicated a lack of engagement, a zero if there was no evidence, and a positive one if the body positions indicated a presence of engagement.

4 Methods and Experiment

The dynamic difficulty adjustment algorithms will not take into account any personal player data. Originally the game was implemented with easy, medium and hard modes to start the DDA of with a little information pertaining to how difficult the individual player preferred to play at. However, this has been removed from the implementation to allow the DDA to adjust more specifically to how the player is performing and not how they would like to be. The algorithms will perform the same for every player regardless of the skill of the player. The first algorithm will adjust the game's difficulty based on varying factors that will determine the player's success constantly throughout the entire duration of game play. These variables are, the player's target hits versus targets missed ratio. The non-constant DDA will account for the same variables as the other. However, when the game is initially launched, the DDA will be adjusting its difficulty with much larger jumps than the first one to try to find the optimal difficulty of the player as

Game Engagement Questionnaire (GEQ) items.

1	I lose track of time
2	Things seem to happen automatically
3	I feel different
4	I feel scared
5	The game feels real
6	If someone talks to me, I don't hear them
7	I get wound up
8	Time seems to kind of stand still or stop
9	I feel spaced out
10	I don't answer when someone talks to me
11	I can't tell that I'm getting tired
12	Playing seems automatic
13	My thoughts go fast
14	I lose track of where I am
15	I play without thinking about how to play
16	Playing makes me feel calm
17	I play longer than I meant to
18	I really get into the game
19	I feel like I just can't stop playing

Table 1: This is the Game Engagement Questionnaire developed by psychologists and used by Jeanne H. Brockmyer [4]. This will be modified to better fit this experiment

fast as possible. After a few minutes of game play, the DDA will try to optimize the difficulty and slowly stop adjusting the difficulty as wide spread as previous. Meaning the rate of change, or the distance the difficulty is allowed to change, will continue to decrease as the DDA obtains more information as the game continues. The constant DDA will take into account the previous difficulty it has calculated and will adjust the difficulty half way to the new desired difficulty.

Both DDA's are designed to adjust the games difficulty based on the player's current player rating (PR). The PR is calculated using the variables listed above. The scale is out of 10, 0 being the worst and 10 representing flawless play. The PR is then passed to the DDA to determine how to adjust the game. The variables that the DDA can adjust for the difficulty of the game are, the size of the targets, the amount of targets, and the speed of the targets. With the constant rate of change DDA will move between difficulty levels at a constant rate. This means at each time step the DDA adjust, the DDA is able to change its difficulty to half way to the new desired difficulty depending on the PR. An example of this is the difficulty of the game is currently set to an 8, however the player's PR was just recorded at 4. The DDAs allowable change is set to a constant one-half of the distance between the current and desired difficulty. Therefore with the current difficulty set at 8 and the desired difficulty set at 4. The resulting difficulty of the game will be set at 6. The non-constant DDA will start with the same zones as specified as before. However, the allowable delta is set to a function of time. The allowable delta is $2/x$ where x is the time since the game started in minutes. This will cause the allowable change to start high but as time continues the fraction of the jump allowed to make will decrease. This means that the DDA will take into account the previous PR along with the current difficulty setting and make a jump accordingly. Lets assume the same situation as before, however this time the player has been playing for 1 minute. The players new difficulty will be set to 4 since the allowable change is greater than 1. Now lets assume the player has been playing for 4 minutes, the new difficulty will be set to 6 since the allowable change is set to $2/4$.

Using python to create a very basic game, point click and shoot style game, we have limited the other factors that could cause a person to become engaged while playing. The graphics of the game are 2D and there is no storyline or any other objective other than simply staying alive. Limiting the factors of engagement implemented into the game, we have created a direct link between the performance of the

DDA and the players engagement. The dynamic difficulty adjustment algorithms that will be tested will be implemented into the game.

During the testing, the subject was placed in an isolated room removed from all other distractions. A person was placed to the left or right of them to record body positions and movement. This includes how often the player looks away from the screen, his or her position in the chair, and how often they change positions. The person recording the information was not allowed to interact with the player besides for testing purposes. The recorder was instructed to speak only once during the game play for purpose of later evaluation. The game itself will print the needed variables after every time the player dies and starts a new session. The variables printed were the average difficulty, the time played, and their score. After the subjects allowed time to play is up, the player is asked to take the game engagement questionnaire [1] that has been modified to better fit the individual experiment. All these results are combined together to create a numerical system for determining a players level of engagement as well as the success rate at keeping a player in the flow zone

The goal is to get 20 participants all with varying gaming experience. They will be placed in an isolated room and play the game for no longer than 10 minutes but are free to stop whenever. If a player decides to stop before the ten minute time limit, this will contribute to the overall engagement level. After the player has launched the game, all data collection will begin to take place. After every game they player attempts their average difficulty, time played, and score will be printed to a file. This file will then be used to further analyze the player's game play. At the end of the game the player will fill out a short questionnaire to receive some background knowledge of the player's previous gaming experience. During the players time limit, We will be tracking player movement, facial expressions, and verbal communication to be incorporated into the engagement information. After the 10 minutes allowed or when they decide to stop playing, the player will fill out a questionnaire about their experience. All of the data collected will be combined and converted to a numerical value for engagement evaluation.

5 Results

After conducting the experiment and collecting the data, the information was then processed it for evaluation. A total of 20 participants were experimented on with ten subjects for each DDA. The mean engagement score, extracted from the Game Engagement Questionnaire for the constant DDA was 1.8. The non-constant DDA received a mean engagement score of 6.2. The non-constant DDA had the highest engagement level with a 17. The constant DDA had the lowest engagement level with a -4. After running a t-test on the two different versions of the DDA, we found a two tail p-value of 0.088. Assuming a statistical significance of 95%, these results are not statistically significant. However with a small sample size, these results are very promising and show a statistical trend that different rates do effect a players engagement. Figure 3 shows a visual representation of the player's engagement level and the DDA they received. We also analyzed the average difficulty of the DDA's to see if there is any correlation between the engagement score and their average difficulty level. There was no correlation between these two attributes. The players average difficulty can be seen in figure 4. As shown by the graph, the average difficulty level was lower in the higher engaging non-constant DDA.

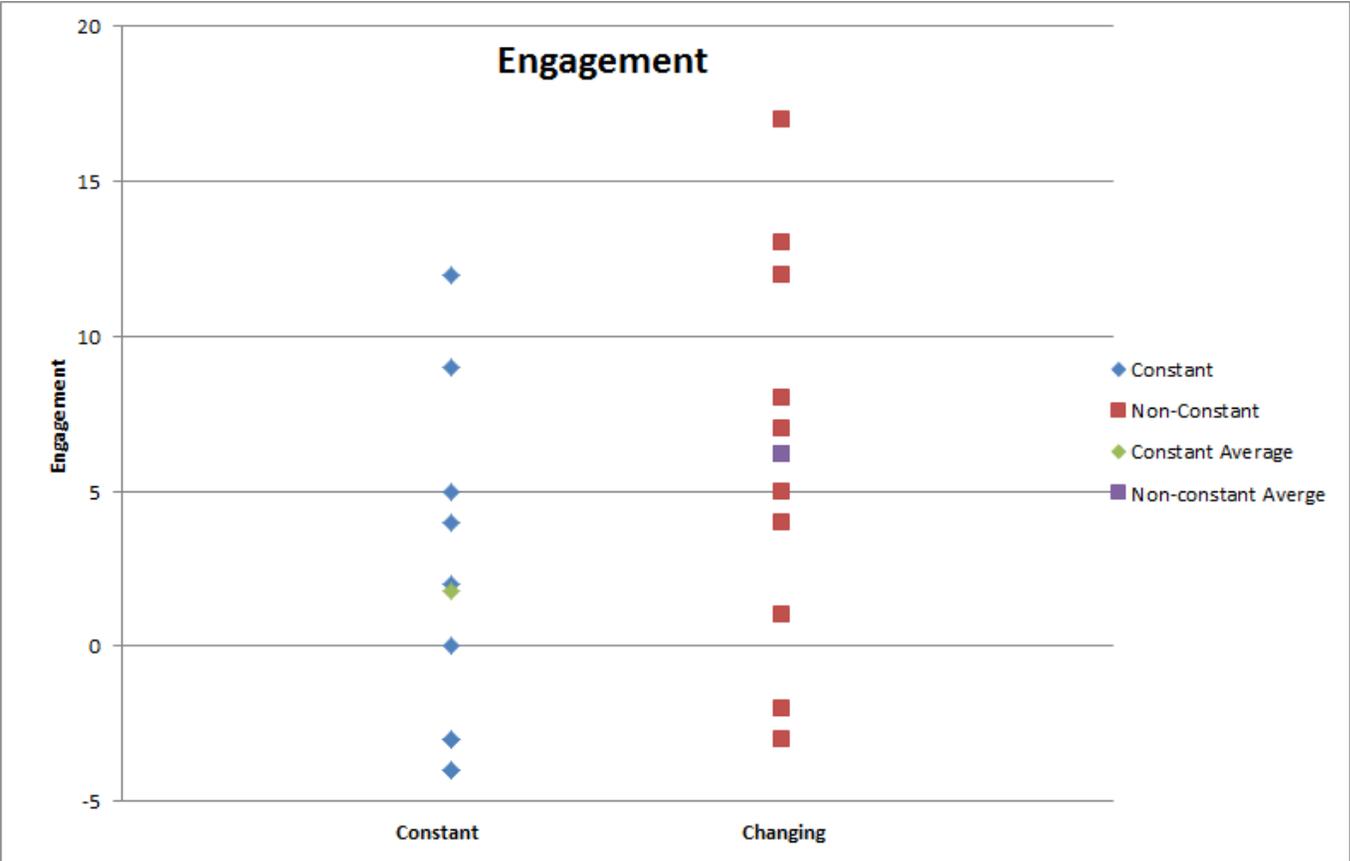


Figure 3: A visual representation of the scores from the GEQ. The mean for the constant DDA is 1.8 and the non-constant DDA is 6.2

We also analyzed the average difficulty of the DDA's to see if there is any correlation between the engagement score and their average difficulty level. There was no correlation between these two attributes. The players average difficulty can be seen in figure 4. As shown by the graph, the average difficulty level was lower in the higher engaging non-constant DDA. The raw data can be found in the appendix section along with the code used for the experiment

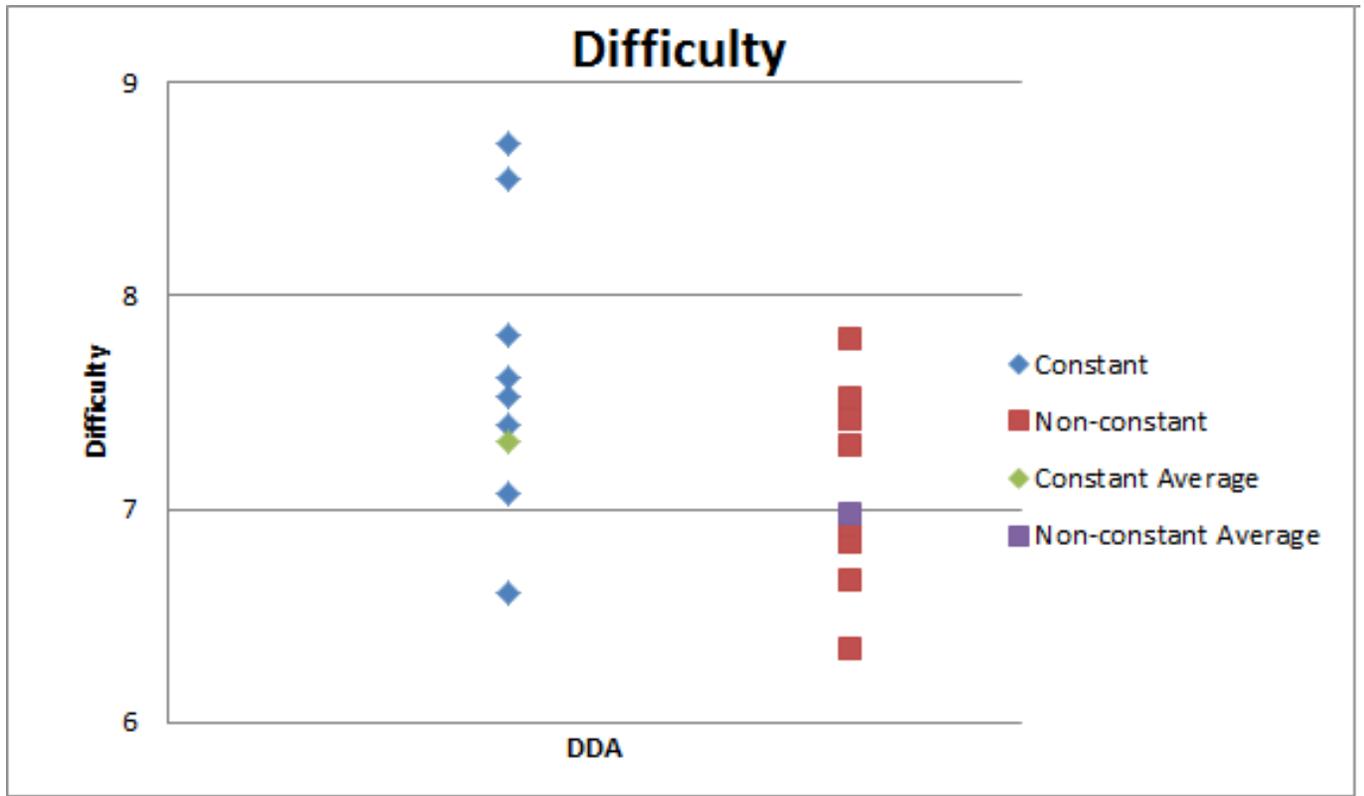


Figure 4: This graph shows the average difficulty level for each player corresponding with the DDA they received

6 Discussion

This paper was written to determine if the rate at which a video game adjusts its difficulty has an effect on an individual's player engagement. Based on the experimental results, there is no statistical significance (p value of 0.30) supporting that a non-constant rate of difficulty change leads to a higher engagement level compared to a constant rate of difficulty change. However, the results have a trend to show a higher average engagement level in the subjects who received the non-constant DDA. These results agree with our initial hypothesis of a video game that is able to make larger jumps in difficulty initially, with much smaller jumps towards the end, will be more effective at engaging a player than a DDA with a constant rate. On

average, the players who received the non-constant DDA, showed greater characteristics in body positions and gestures that are common in highly engaged players. Subject 4, who received the non-constant DDA, took a break in between games to clean his hands off from sweat and better reposition himself for the next game. The sweat on his hands indicate focus and stress caused by the game. Whereas stress is a possible negative component of engagement it is still a significant sign that the player was engaged by the video game. Subjects 8 and 10 both showed verbal signs of engagement by talking directly to the game. Subject 8 was recorded saying "Come on, stop moving away from me. You know I'm going to end up getting you.....OH NO. Are you kidding me?". The player was attempting to destroy a target that was moving exceptionally fast compared to the other targets and continually missed the target. At this point the target has entered the detonation phase and proceeded to explode resulting in the player having a single life left. Verbally talking to the game in this manner shows a form of communication with the game even though the player knows that it is not listening. Conceptually acting as if the game was some sort of being exhibits extreme engagement in the player. With the combination of the results obtained from the GEQ and the transcribed actions of the players, the players who received the non-constant DDA experienced higher levels of engagement throughout game play. Although the results were not statistically significant, we believe that our results are highly suggestive in support of the hypothesis. The following paragraph will discuss some of the threats to validity we encountered during the experiment.

The non-constant DDA determined its rate by a function of $2/x$ where x is the current time of game play in minutes. In order for the DDA to perform smaller jumps in the difficulty than the constant DDA, set to a rate of $1/2$, a player would have to play a single game for longer than four minutes. Out of all of the subjects tested only three of them achieved a game length longer than four minutes. Only two of these three were given the non-constant DDA. The average game play out of all of the subjects was roughly 2 minutes. This means that only two of the players experienced the functionality of the non-constant DDA that was being tested. With an average game play of two minutes, the non-constant DDA appeared to act as jumping directly to the desired difficulty rather than a fraction of it. Using a different function of time that allowed the DDA to perform as planned would be desired for more accurate testing. Another issue encountered during testing arose within the DDA calculation of the desired difficulty. Using the players

accuracy to determine what the new desired difficulty should be set to worked in almost all cases. however, there were a few cases where the accuracy was not a fair assessment of the players performance. Two of the subjects were continually placed in a higher difficulty setting than their performance should have indicated. The subjects took very few but very accurate shots hitting only the targets they new they were going to destroy. The game initially interpreted this as an excellent player and placed them near the highest setting possible. As the targets got faster, smaller, and more appeared, the subjects still continued to shoot very accurately but they could not handle the increase in the amount of targets. During the second time step, the players accuracy was still very high which kept them at the highest difficulty setting. The player was soon overwhelmed with targets in the detonation phase from failure to quickly eliminate the targets and would not make it too the third time step before losing the game. Using the accuracy to determine the desired difficulty also caused some issues with players figuring out that the faster the clicked, i.e becoming more inaccurate, lead to less targets on the screen. These subjects were not sure why this was happening but they found the correlation between the accuracy and the difficulty. For the majority of subjects, the accuracy was a fair assessment of the players performance. The players number of lives along with showing them there score had some unexpected influences in the engagement of the player. When a player's life count hit one remaining life, a spike in body position and gestures that represent engagement occurred. They were more determined to stay alive and became more focused than before. The players score also gave players an objective each time they lost the game. They were now trying to beat their previous high score each time they started a new game.

7 Conclusion

In conculsion we found that a DDA that uses a non-constant rate of change has a greater impact on a player's engagement level compared to the more traditional approach of a DDA with a constant rate of change. We found that on average the players who received the non-constant DDA had an engagement level 3.4 times higher as the constant DDA. We believe this to be true due to the functionality provided by the non-constant rate. The ability to change the difficulty in greater distances to begin the game with allows the DDA to find the exact difficulty the player desires. Once it has been given enough time to

determine this difficulty level, the DDA then forces the player to stay relatively close to this difficulty by only allowing the difficulty to change by a small fraction from the previous difficulty. By not changing the difficulty drastically after the first few minutes of game play, the player experiences a more uniform game play with the difficulty adjustments hidden in the background from the player. With the constant DDA, at any minute, a slight fluctuation in the player's performance will cause the DDA to jump further in distance creating the game to always be changing and forcing the player to adjust each time. This almost randomness in difficulty level forces the player to adapt to many times decreasing the engagement level of the player. Although the results were not statistically significant assuming a 95% accuracy, the results were still very promising with a p value of 0.088. With a larger sample size, we expect the data to get closer and closer to being statistically significant. Video game designers could use this information to greater further the success of their next video game they create. By allowing the game to decide the specific level of difficulty that best fits the player allows for all types of gamers to receive the maximum enjoyment of a video game. Not restricting the flow zone of the player by statically implementing the growth of challenge and the abilities of the player, game designers will see an increase in engagement to all players. Since we discovered no correlation between the difficulty of the game and the engagement of the player, this shows that every player enjoys a different style of game play and is completely personal to the individual. We hypothesized this functionality provided by the non-constant rate to be more effective at engaging players. After the research was conducted, our hypothesis was confirmed to be accurate.

To further this work one might adjust the function that determine the rate of change in the non-constant DDA to better adapt the average game play time. Another approach would be to determine a better way of finding one's player rating and performance to better fit every situation. We would also like to try this concept on a more advanced modern game for a different platform. Ideally we would use a First-Person Shooter to adapt this method into. Another approach other than using a non-constant rate would be to determine the optimal fixed constant rate to determine which is best at engaging a player.

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