Dynamic Difficulty Adjustment in Video Games

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ABSTRACT

Dynamic Difficulty Adjustment (DDA) adjusts aspects of the game play either as a level is being built or during live gameplay in response to player's success. Developers would like to include DDA in all games to bring in a wider audience, but some players do not want DDA because DDA diminishes what the player accomplished. According to some studies, players play better with DDA active. Playing better can be tracked by a higher score, less deaths, or less failures; making the player enjoy the game more. However, there is evidence that suggests DDA can hurt the player's pride if the player finds out the game is helping. Players feel like the game is implying that the player lacks skill and needs help to win. If players know DDA is in a game, there are certain aspects that are more accepted than others.

Keywords

Players; Difficult; DDA; MDDA; EDDA; Confidence

1. INTRODUCTION

A game developer wants as many people to play the game as possible. Most games have varying levels of difficulty, such as easy, medium, and hard. The game can have more options, but having more options is not common. There are two issues with the current system. The first issue is that determining what difficulty the player should choose takes time (the player could complete a game while using the wrong difficulty). The second issue is that, a player may need to have a difficulty between easy and medium. If that is not an option, then the player has to choose between boredom (because the level is not difficult enough) or frustration (because the the level is too difficult). DDA can get rid of difficulty adjusters and cater the difficulty to the player's ability level. The game may become more or less difficult for the player, depending on the player's experience. The difficulty is one of the key appealing aspects for video games, so, getting the right difficulty for the player is very important.

For players to have a positive review of a game, and for developers to deliver what the players want, some games may need to include DDA. Studies in this paper will provide information on the DDA topic.

First, the paper will explore Hunicke's experiment, which looked at changing health to increase player enjoyment of a game. Then, the paper will look at how changing based on a player's emotions affected the player's enjoyment. The final study asked if players would like DDA in a multiplayer setting. The paper will end with some final thoughts.

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2. BACKGROUND

Before going into the experiments done there are some words that need to be defined: players, difficulty, flow, and Dynamic Difficulty Adjustment.

2.1 Players

A player is considered any person who plays video games throughout the paper. A "player of games" is a way to think about the term. The amount of time the person spends playing the game or how often the person plays does not matter.

2.2 Difficulty

Difficulty is the level of skill needed to beat a challenge. Constant et al. say difficulty is complicated to get correct because there are 3 different aspects to what can make a game difficult. There's motor, sensory, and logical strains with all of these requiring different levels of effort, both physically and mentally. In addition, the game has to keep the effort needed for all of these aspects uncertain to keep the player entertained. A more casual player prefers a difficulty lower than the player's skill, while a higher skilled player prefers to have the difficulty around the player's skill level [2].

2.3 Flow

Flow is a highly focused mental state. Being in a flow state can be referred to as "being in the zone." People in this flow state often lose track of time. The flow channel (See figure 1) is the area where a person will enter flow state. The difficulty must match the players skill for the player to be in a flow state [3].

For a player to be in a flow state the difficulty must match the player's skill.

2.4 Dynamic Difficulty Adjustment (DDA)

Dynamic Difficulty Adjustment (DDA) is a game changing the difficulty based on the player's skill. The intention of DDA is to put the player into a flow state. Being in a flow state provides the player with a better experience. In most games, as the player progresses throughout the level, the game will get harder. This is not a form of DDA be-

cause the game will get harder no matter the player's performance. With DDA, the game is supposed to get harder or easier depending on the player's performance. With a static difficulty, the game will get harder by increasing the amount of enemies or the amount of damage an enemy does to the player's health.

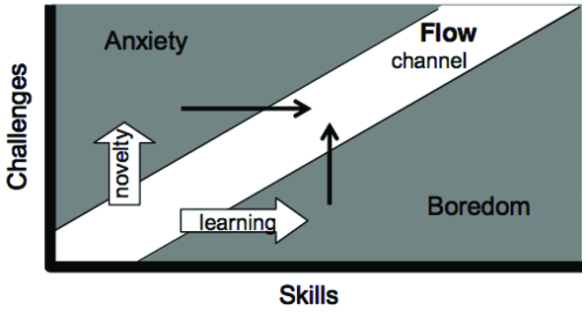

Figure 1: Flow channel [3]

3. THE DDA EXPERIMENT

Hunicke conducted an experiment to determine if players were overall happier with a game that had DDA. The goal of the study was to answer 3 questions: does the adjustment affect player performance, do the players notice the adjustment, and does the adjustment help or hurt player enjoyment [5]?

3.1 The Setup

Hunicke used the game *Case Closed*: a First Person Shooter (FPS) for the experiment. FPS games have a gameplay loop: explore for loot, fight enemies, and win or lose the fight. The player will proceed to the next area if the encounter is won, and the player will restart at the beginning of the encounter if the player loses. To keep the loop intact, Hunicke decided to give the players health instead of loot. Hunicke designed a formula to determine the probability of the player's death in a given instance. If the player had a greater than 40% chance of death, the game would give the player 15 health units in 100 tick intervals (3.3 seconds). The game would try to keep the player's health around 60 with a standard deviation of 15. The game would only give the player health during combat.

The study had 20 participants, each with varying skills and abilities. The participants read a game overview explaining how the game is played, then, the participants were directed to play the game for 15 minutes or more. Participant performance was tracked and stored for evaluation at a later time. The participants filled out an evaluation form after completing the experiment; the form was based on a 5 point scale (1 was low and 5 was high).

3.2 Hunicke Formula

Hunicke found the damage probability distribution to players by enemies to be in the form of Gaussian. Gaussian is commonly referred to as being normally distributed; commonly called the bell-shaped curve.

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

[5]

The Gaussian error integral is used to calculate F(d), which is the probability the player will receive d or less damage within a given tick.

$$F(d) = \int_{-\infty}^{d} p(x)dx = 1/[\sigma\sqrt{2\pi}] \int_{-\infty}^{d} e^{(x-\mu)/(2\sigma^2)}dx$$

[5]

The Gaussian error integral is calculated in the programming language C and C++ math library by the error function (ERF). This is used to calculate the average range of damage the player might take at some point in the future.

$$F(d_t) = 1 - \frac{1}{2}(1 + erf(\frac{h - \mu t}{\sigma\sqrt{2t}}))$$

[5]

During combat, the enemy's damage is recorded and the player's probability of death is calculated for each enemy in the area. The ERF calculation only took 0.6 microseconds. Meaning, calculations similar to the one used can be implemented without slowing down the game.

3.3 Results of The DDA Experiment

The players had an average death of 6.4 times with a standard deviation of 2.1 when there was no DDA. With DDA on, the average death was 4 with a standard deviation of 2.9. The players died on average 2.4 more times with DDA off. The players were able to determine the game being adjusted 30% of the time. There were only 2 participants who stated adjusting the difficulty would lessen enjoyment. Of these 2 participants, 1 of the trials was adjusted, but the player did not report noticing an adjustment. The players who rated themselves 3-5 in skill performed the same as the players who rated themselves 1-2. All players had similar death rate in adjusted and unadjusted games regardless of skill. The novice players did not report an increase in enjoyment in the adjusted version of the game. The novice players also reported themselves having to repeat tasks regardless of winning or losing an encounter. Hunicke noted an unfamiliarity of the FPS genre loop may cause novice players to have to repeat tasks, making Hunicke unsure if DDA will increase enjoyment to new players to the genre or not.

4. EMOTION-BASED DDA

In section 3, the game would assist the player when a formula determined the player needed help. This was determined when the health was at a certain point. In contrast, the current section will explore changing difficulty based on player emotion.

Frommel et al. tested out Emotion-based Dynamic Difficulty Adjustment (EDDA). *Space Jump*, which is a similar game to *Doodle Jump*, was used as the testing game. Dialogue-based self-reporting (DBSR) was used in the game and designed so the players did not think the DBSR was a self reporting system. At the end of a round, a non-player character (NPC) would ask the player 2 questions, if the previous level was frustrating and if the previous level was boring. The options given for both questions were: "Yes, it frustrated/bored me a lot!," "Yes, it frustrated/bored me," "Neither," "No, it didn't frustrate/bore me," and "No, it

didn't frustrate/bore me at all!" The game would get easier or harder based on the responses.

4.1 Game Setup

To test EDDA, Frommel et al. took 66 participants and gave each one of two self reports: a standard self report and the DBSR. There were three different versions of the game all participants tried: a constant difficulty (CD), increasing difficulty (ID), and EDDA (See figure 2). The participants were randomly assigned a self-report condition. The conditions were in game dialogue form prompted by the NPC (D), or, participants would take the standard self reporting questionnaire (Q). 35 players were subjected to the questionnaire and 31 were prompted from the NPC.

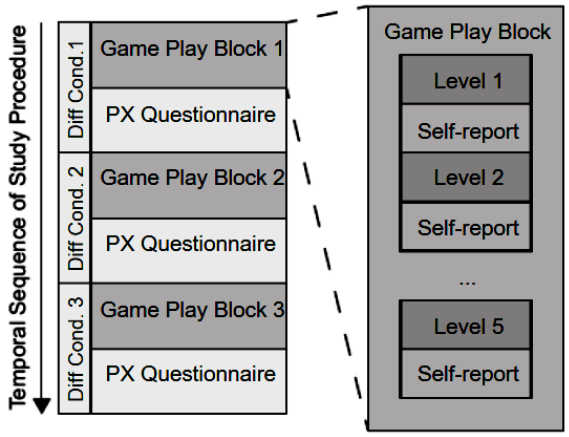

Figure 2: Shows the rotation for playing [4]

4.2 EDDA Results

The deaths from the EDDA version had a median (M) of 5.18 with a standard error (se) of .104. The CD version had a M of 4.86 with an se of .120. The ID version had an M of 4.99 with an se of .109. The calculation results mean the median score for the player in the EDDA version was higher than the CD version and ID version (note that a higher M and a lower se is better). Frommel et al. found the amount of failures over time decreased for the EDDA version (See figure 3). The CD version stayed around the same; implying the EDDA version was more suited for the person playing. Frommel et al. also found using DBSR is an effective way for players to self-report, but warn using DBSR prompts too often can become repetitive in display style. (See section 4.2.1).

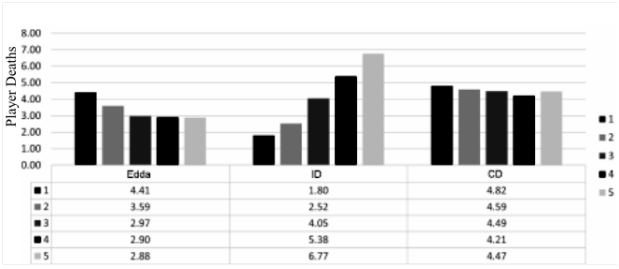

Figure 3: Shows the player deaths [4]

4.2.1 *EDDA DBSR Results*

The DBSR method measured the player's emotions during gameplay with similar accuracy to the questionnaire; DBSR methods can be used in games to accurately track the player's emotions. DBSR was not getting higher aesthetics, dynamics, or perceived competence scores. The lower scores can be partly due to the repetitive nature of the dialogues. The DBSR questions were kept the same as the standard self reporting questionnaire (Q), making the participants encounter the same dialogue multiple times. Giving variety to the questions may yield higher results.

5. PLAYER PERSPECTIVE OF MDDA

The previous cases of DDA have been for single player games, but the following will cover DDA being implemented in a multiplayer setting. However, the participants did not actually play a multiplayer game with the aspects implemented. The discussed study was focused on how people would feel about Multiplayer DDA (MDDA) and, if players wanted MDDA, how MDDA could be implemented.

5.1 Setting Up the Study

Baldwin et al. emailed a survey to students in an Australian university, posted on the social media sites Facebook and Twitter, and put on official game forums for Xbox, Playstation, Nintendo, and Steam. A link was provided so people could send the survey to anyone. To participate in the survey, the person had to be over 17 and had to have played a multiplayer game before. The player could be a novice or a professional. The participants were asked age, gender, and what competitive multiplayer games the participants played. Experience level was rated on a scale from 1 to 7 (1 being not at all experienced and 7 being extremely experienced) by the participant. Experience level was asked instead of self-rated performance because being skilled at one game genre does not mean you are equally skilled in another (a player may be good at FPS, but bad at racing games). Both games are multiplayer and competitive, but the technical skills and timings are different.

Component	Attribute
Determination	Pre-gameplay
	Gameplay
Automation	Applied by system (automated)
	Applied by player(s) (manual)
Recipient	Individual
	Team
Skill Dependency	Skill dependent
	Skill independent
User Action	Action required
	Action not required
Duration	Single-use
	Multi-use
	Time-based
Visibility	Recipient
	Non-recipient
	No one

Table 1: MDDA overview [1]

Pre-gameplay: The decision to intervene is based on past games and will be determined before the current game

begins.

During gameplay: Decision to intervene is based on how the player is performing throughout the match.

Applied by system (automated): The game will determine the need to intervene. The decision to intervene would be based on a number that can be tracked. These numbers could be the player's score, accuracy, or deaths.

Applied by player (manual): The player determines the need to use MDDA. This is common in fighting games by giving the losing or lower skilled player more health.

Individual: The boost is applied to the player that is performing poorly.

Team: If one player on the team is performing poorly, the whole team will get some sort of boost.

Skill dependent: The player must be able to make use of the boost. Example: in a first person shooter (FPS), a player getting an increase in speed will not guarantee a win or kill, but may give the player a better chance if the player is able to skillfully use the increase in speed.

Skill independent: There is no skill needed from the player with a boost to have an advantage. The boost being applied is linked to winning conditions for that game. Example: taking less damage in a FPS.

Action required: The receiver of the effect must interact with an interface to receive the effect (like clicking a button).

Action not required: The player will automatically be affected.

Single-use: The effect is applied only once throughout the match. Example: a player's health may be boosted, but only once in that match.

Multi-use: The effects of the boost may be used multiple times. Example: giving the player a health boost 3 times in a match.

Visible to recipient: The receiver of the boost is notified the boost has been applied. This can be done via audio, visual, or some text on screen.

Visible to non-recipients: Non receivers of the boost are notified about the receiver of a boost getting a boost. The following example would be displayed on the team of the player receiving a boost. Example: "Player A has received a speed boost."

Not visible: No one is notified of the boost a player receives. A skilled player may be able to figure out themselves or someone else is given a boost. The player could notice the enemy requires 1 more bullet to kill than normal; indicating a boost in defense or health.

The participants were asked to rate each MDDA attribute from 2 different perspectives; the low skilled player receiving help, and the high skilled player going against the low skilled player receiving the help. Some of the participants were interviewed in person at Queensland University of Technology and were asked for opinions on the MDDA framework (see table 1 and description below the table 1) and any prior experience with MDDA. Recruitment was done by local video game groups in Brisbane, Australia. The participants were required to have played at least 1 competitive multiplayer game in the past 12 months. The questions were structured around the MDDA Framework components with the same examples as the online survey.

5.2 The Results

The following are the average results from the participants ratings on player experience (see Table 2) with 1 being very negative and 7 very positive. The results are the average rating when in the perspective of a Low Performing Player (LPP) and compared to the perspective of a High Performing Player (HPP). Remember, the players were asked to view on each component when the player was the LPP and then when the player was the HPP. The LPP can be seen as the losing player and the HPP can be seen as the winning player.

Component	Attribute	LPP	HPP
Determination	Pre-gameplay	4.2	3.8667
	Gameplay	4.7067	3.78
Automation	Applied by system (automated)	4.6454	3.922
	Applied by player(s) (manual)	4.1418	3.766
Recipient	Individual	4.5664	4.021
	Team	4.1189	3.1818
Skill Dependency	Skill dependent	4.4478	4.6045
	Skill independent	4.5672	3.5896
User Action	Action required	4.5231	4.3923
	Action not required	4.4077	3.6615
Duration	Single-use	4.5827	4.5267
	Multi-use	4.9921	3.7795
	Time-based	4.685	4.189
Visibility	Recipient	5.0794	3.8492
	Non-recipient	3.9206	4.3571
	No one	3.881	3.6111

Table 2: Average of player responses [1]

In some cases, LPP and HPP prefer the same attribute over the other options (for example, both LPP and HPP prefer "applied by system (automated)" over "applied by player(s) (manual)"). The adjustment should be applied by the system to an individual player, with action required by the player to activate the boost. An interesting result within this is the LPP agreeing the boost should be applied to the individual player, not the whole team. If there are 2 teams, team A and team B (with team A being the winning team), team B has a higher chance of winning if the whole team gets a boost (when compared to individual players within the team getting the boost). The HPP wants the boost to be skill dependent and single use, while the LPP wants the boost to be skill independent and multi-use (with time-based being the middle option for both groups). The different preferences between the LPP and the HPP could be that the LPP is trying to maximize the potential for winning, while the HPP is trying to minimize the potential for losing.

The participants expected all forms of MDDA would have a positive player experience for the losing, or lower skilled, player because the boost would help raise the player's score. Given this knowledge, the HPP wants the instance to be single use, action required, and skill dependent. This setup gives the receiving player more control over the assistance provided. For this setup to happen, the game would need to be fully transparent in the mechanics. The players would have to know what exactly the game will change and for how long. LPPs did not show a major preference for skill dependency. Both HPPs and LPPs agreed the activation of a MDDA instance should be automated (this is the only time the HPPs are fine with less control). Both LPPs and HPPs noted a preference for automatic activation from the

game because of a fear of other players abusing the system. (A player could intentionally perform poorly, get the boost, then proceed to win because of a combination of a boost and having high skill). The participants believe the system is more impartial than a player. Also, LPPs may be embarrassed when a boost is applied by other players or when applying the boost to themselves. This could be seen as an acknowledgement of lower skill and may draw unwanted attention from other players of the game.

6. FINAL THOUGHTS

Studies show that DDA can help a player's performance which increase's the happiness of the player, but, the player's feelings and pride can be hurt because of DDA. If the game is easier than normal and the player finds out, the player could internalize this as being low skilled. Most people want to do well and win when playing games. For DDA to be implemented in games, the marketing team of that game has to be upfront about DDA and be careful when advertising the game. The marketing team could say the game's difficulty is designed around the players skill; avoid saying anything about lowering the difficulty for lower skill players or raising the difficulty for high skilled players.

Both the Hunicke and Frommel et al. studies had potential weaknesses because the studies had very few participants (20 and 35 respectively). In addition, both studies used only one game. A potential weakness of the Baldwin et al. study is asking participants to rate which components would be preferred instead of having the participants play with different components enabled.

These studies do not cover everything about DDA. Future studies could let the player choose what aspects get changed, such as more health, more ammo, more enemies, or any combination the player wants. To ensure more accurate results, the studies should have over 100 participants. Future studies can ask how players would feel about certain components in a game, but, the players should then play with and without the component(s) enabled.

7. ACKNOWLEDGEMENTS

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