Reducing Objective Difficulty Without Influencing Subjective Difficulty in a Video Game

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ABSTRACT

While dynamic difficulty adjustment techniques can enhance the player engagement, overly apparent difficulty adjustments may have a detrimental effect on the overall gaming experience. Hence, it is desirable to implement game difficulty controls as unnoticeable as possible. We interpret this issue as a research question: *Is it possible to decrease the objective difficulty of a game without influencing the subjective difficulty that players perceive?*, and propose two techniques for dynamically adjusting game difficulty that is imperceptible to players: *Collision Detection Area Adjustment* and *Time Elapse Manipulation*. We integrated these two techniques into a simple shoot'em up game and evaluated their effectiveness through a user study. The results support the claim that these difficulty adjustment techniques can reduce the objective difficulty of a game without influencing the subjective difficulty that players perceive. This study could be beneficial, not just as a rare example in the research in difficulty adjustment that distinguishes objective difficulty and subjective difficulty, but also as a practical technique for difficulty adjustment that can avoid the negative impact on the gaming experience.

CCS CONCEPTS

• **Applied computing → Computer games**.

KEYWORDS

gaming experience, dynamic difficulty adjustment, skill-challenge balance, subjective difficulty, objective difficulty

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1 INTRODUCTION

Achieving a suitable balance between the player's skill and game's challenge plays a vital role in enhancing the gaming experience. If a game's difficulty is excessively high, players may experience anxiety, whereas if it is overly easy, they may become bored, as suggested by Csikszentmihalyi's flow theory [3][4]. Therefore, dynamic difficulty adjustment (DDA), in particular, has garnered significant interest within the game research community, as it allows the game's difficulty level to be adapted based on the player's performance during gameplay. However, overly apparent difficulty adjustment is also considered to have a negative impact on the overall gaming experience[6][7][8].

In light of this, we have framed this issue as a research question: "*Is it possible to decrease the objective difficulty of a game without influencing the subjective difficulty that players perceive?*" In other words, we aim to investigate *whether or not the objective difficulty of a game can be reduced without influencing the subjective difficulty that players perceive*.

In this paper, we introduce two techniques for imperceptibly adjusting game difficulty to players: *Collision Detection Area Adjustment* and *Time Elapse Manipulation*. These techniques involve implicit changes in a parameter directly associated with the game difficulty, which players may hardly notice if the degree of the change is appropriately configured. Despite the simplicity of these methods, there are no publications that describe similar or identical techniques and evaluate their effectiveness up to date, to our knowledge.

We evaluated the effectiveness of these techniques by integrating them into a simple shoot'em up game and conducting a user study. The results clearly suggest that these techniques can effectively decrease the objective difficulty of the game without influencing the subjective difficulty perceived by the players, as intended. Such a study on independent control of the objective difficulty and the subjective difficulty of a game can be beneficial in preventing damage to the gaming experience caused by overly apparent difficulty adjustments.

2 RELATED WORK

2.1 DDA and Gaming Experience

According to the flow theory [3][4], the skill-challenge balance is considered a significant factor in achieving the state of 'flow'- an optimal experience where individuals are fully engaged, present, and focused on a specific task. This flow theory is applied to many fields today, and game research is no exception [1][5, Chapter 12.4]. Hence, dynamic difficulty adjustment techniques remain particularly relevant and continue to be actively investigated [9] among researchers and game designers, as they enable the appropriate adjustment of game difficulty for both novice and expert players.

Yet, some researchers have consistently emphasized that overly apparent difficulty adjustment may harm the overall gaming experience. Hunicke discusses "*if internal systems have unintended consequences, they can inadvertently thwart player goals and aspiration*" [6]. He further denotes "reactive changes run the risk of disrupting the player's sense of disbelief" and "*can make it difficult to interpret the immediate behavior of in-game obstacles, causing the game to appear schizophrenic*" in [7]. Endoh et al. also discuss dynamic difficulty adjustment can damage the player's sense of

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agency and ownership [8]. Thus, overly apparent difficulty adjustment is considered to damage the overall gaming experience.

2.2 Objective Difficulty and Subjective Difficulty

In order to delve into the impact of apparent difficulty adjustments on the gaming experience, it is crucial to establish a clear differentiation between the difficulty level manipulated through adjustment techniques and the difficulty level as subjectively perceived by players. For this purpose, Constant et al. proposed the terms *objective difficulty*, which is "directly estimated by observing gameplay variables and events" and *subjective difficulty*, which refers to "a psychological construct of the player." [2].

While this distinction appears to be advantageous for studying difficulty adjustment techniques from a gameplay perspective, only a few existing works in difficulty adjustment have considered this distinction. Among these works, Yanase provides two examples of difficulty adjustment techniques that specifically aim to control subjective difficulty. In [10], Yanase briefly outlines a technique for shoot'em up games that aims to heighten subjective difficulty while keeping the objective difficulty lower, by introducing enemy bullets deliberately shot in a direction close to the player character but that never actually hit, to create a perception for players that their gameplay is more skillful than it actually is. However, Yanase did not conduct any user study; instead, he solely reported that some players mentioned they felt more skillful during a demo session. Instead, Zhang reported his user study to investigate the effectiveness of this technique with the results that did not show a statistically significant difference [12]. Yanase et al. described another technique in [11] for a 'jump action game' (or a platform game). They adjusted the trajectory of the player character's jumping action to align it more closely with the anticipated ideal trajectory. They reported that their technique successfully created the illusion of improvement in play skills in the user study.

Zhang proposed a technique to control the subjective difficulty in shoot'em up games by adding 'fake' bullets that do not perform collision detection [12]. As they do not cause any damage to the player character, they do not influence the objective difficulty of the game. Yet, since they are indistinguishable from normal bullets, they may contribute to increasing the subjective difficulty perceived by players. He observed a statistically significant difference in the subjective difficulty when comparing game plays with and without 'fake' bullets, while the objective difficulty remained unchanged.

3 DESCRIPTION OF OUR TECHNIQUES

As noted earlier, we share a similar interest with Yanase and Zhang: *to control the subjective difficulty and the objective difficulty independently for better gaming experience.* We propose two techniques that enable adjustment of objective difficulty imperceptible to players, thereby maintaining the subjective difficulty of the game: *Collision Detection Area Adjustment* and *Time Elapse Manipulation.*

The Collision Detection Area Adjustment technique involves dynamic modification in the size of the collision detection area of the player character. Figures 1 (b) and (c) illustrate this technique. This technique reduced the size of the collision detection area of the player character recudes from 'normal' in Figure 1 (b) to 'easy' in Figure 1 (c). Since the collision detection area is not visible to players,

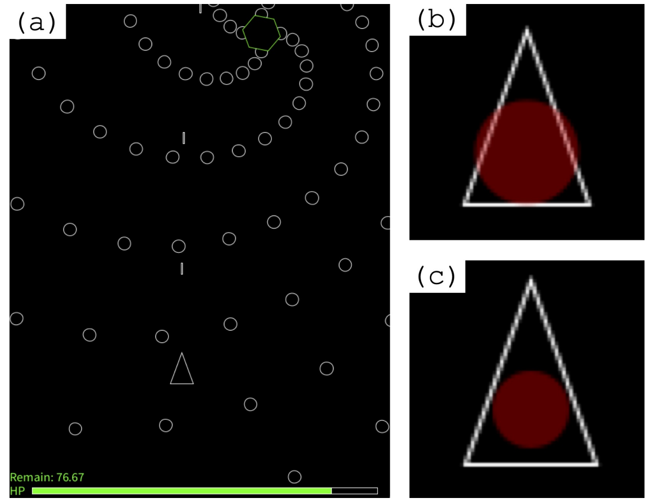

Figure 1: A screenshot of the testbed game is shown in (a). The player and boss characters are represented by the triangle and the hexagon respectively. The player character's collision detection areas are illustrated in (b) normal and (c) easy; note these collision detection areas are not visible to players.

it is expected that any changes in its size will be imperceptible to players if the degree of reduction is appropriately configured. With the reduced size, it is also anticipated that the player character will become less prone to being hit by enemy bullets, thereby decreasing the objective difficulty of the game.

The Time Elapse Manipulation technique aims to decrease the objective difficulty of the game by adjusting the speed at which the game timer progresses towards the time limit. By slowing down the speed that the time elapses, the player is provided with more to complete tasks or challenges within the game. Typically, players pay only sporadic attention to the game timer during gameplay, as their cognitive resources are primarily occupied by the game tasks and challenges they encounter. Hence, if the decreasing in the timer's progression speed is kept within a reasonable range, it may not be immediately noticeable to the player and may have a limited impact on the subjective difficulty, while it is expected that this manipulation of the speed of time elapse can effectively contribute to decrease the objective difficulty, as it virtually extends the time limit imposed on the players.

As above, both of these techniques we propose aim to decrease the objective difficulty of a game, specifically the likelihood of getting hit by enemies and the remaining time before the given time limit. The key objective here is to adjust these difficulty factors while minimizing any noticeable impact on the subjective difficulty that players perceive.

4 USER STUDY

4.1 Testbed Game

To evaluate our difficulty adjustment techniques, we developed a simple game as a testbed for the user study. The game is designed as one of the genre of shoot'em up video games called "bullet hell", in which the player must dodge large amounts of enemy bullets.

In this game, there is only one boss battle stage and the player has to destroy the boss character within the given time limit (90 sec). Figure 1 (a) shows the screenshot of the testbed game.

We have integrated the two difficulty adjustment techniques we proposed into this testbed game. The parameters used for this user study are detailed as follows. For the Collision Detection Area Adjustment technique, we have reduced the diameter of the collision detection area from the 'normal' objective difficulty mode to 70% in the 'easy' objective difficulty mode. Figures 1 (b) and (c) illustrate the collision detection areas for each mode respectively. For the Time Elapse Manipulation technique, we reduced the timer progress speed in the 'slow' mode to 80% of the speed in the 'normal' mode.

There is also slight difference int the game design between these versions. In the version for the Collision Detection Area Adjustment technique, the player character has a limit for enemy bullet hits, and the game is terminated upon the 15th hit, regardless of the remaining time. On the other hand, the version for the Time Elapse Manipulation technique does not have this limit for enemy bullet hits. Instead, each time the player character gets hit, they are momentarily immobilized and cannot be controlled for a duration of three seconds.

Gaming skills can vary greatly among participants. For this user study, it is necessary to match the game's objective difficulty as closely as possible with each player's skill level. If the objective difficulty is either too hard or too easy for the participants, it might not be possible to achieve a good skill-challenge balance, even with difficulty adjustment. Therefore, we prepared three variations of 'base objective difficulty' (base-hard/base-normal/base-easy) to better the skill-challenge balance during the experiment. These base objective difficulty variations are distinguished by the density of enemy bullets, with the 'base-hard' variation presenting the highest density and the 'base-easy' variation the lowest.

4.2 The User Study Design

To explore our research question (*Is it possible to decrease the objective difficulty of a game without influencing the subjective difficulty that players perceive?*), we formulate eight null hypotheses as below.

$\boldsymbol{H_{01}}$: The transition from the 'normal' mode to the 'easy' mode does not result in any significant difference in the subjective difficulty perceived by participants.
$\boldsymbol{H_{02}}$: The transition from the 'normal' mode to the 'slow' mode does not result in any significant difference in the subjective difficulty perceived by participants.
$\boldsymbol{H_{03}}$: No disparity exists in the subjective difficulty perceived by participants between the 'normal' mode and the 'easy' mode.
$\boldsymbol{H_{04}}$: No disparity exists in the subjective difficulty perceived by participants between the 'normal' mode and the 'slow' mode.
$\boldsymbol{H_{05}}$: The transition from the 'normal' mode to the 'easy' mode does not result in any significant difference in the number of enemy bullet hits.
$\boldsymbol{H_{06}}$: No disparity exists in the the number of enemy bullet hits between the 'normal' mode and the 'easy' mode.
$\boldsymbol{H_{07}}$: No disparity exists in the the number of game clears between the 'normal' mode and the 'easy' mode.
$\boldsymbol{H_{08}}$: No disparity exists in the the number of game clears between the 'normal' mode and the 'slow' mode.

The null hypotheses $\boldsymbol{H_{01}}$-$\boldsymbol{H_{04}}$ correspond to changes in subjective difficulty, and $\boldsymbol{H_{05}}$-$\boldsymbol{H_{08}}$ correspond to changes in objective difficulty. If $\boldsymbol{H_{01}}$-$\boldsymbol{H_{04}}$ are not rejected and $\boldsymbol{H_{05}}$ - $\boldsymbol{H_{08}}$ are rejected, the results support the claim that our techniques can decrease the objective difficulty of a game without influencing the subjective difficulty perceived by players.

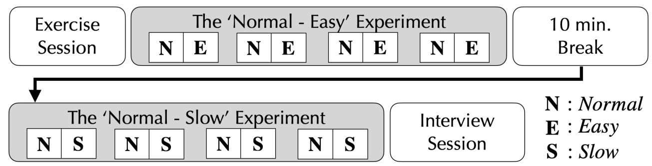

Figure 2: The structure of our user study

Figure 2 outlines our user study's structure. In this user study, the order of the 'normal' and 'easy/slow' modes was not randomized for the following reasons. Firstly, the tests for $\boldsymbol{H_{01}}/\boldsymbol{H_{02}}$ require an experimental design that transitions from the 'normal' mode to the 'easy/slow' modes. Hence, it is necessary to play the 'normal' mode before the 'easy/slow' modes. Secondly, it is also desirable to equally distribute two modes during each experiment, as some participants may improvements their game skills to a considerable degree even during the experiment session[1]. When there is an imbalance in the distribution, it can lead to a bias where skill improvement is disproportionately reflected in one of the modes. Moreover, this order may also impose more rigorous conditions on this experiment, as it maximizes the frequency of objective difficulty changes, providing participants with more opportunities to notice difficulty adjustment. Hence, we consider it is more desirable to not randomize the order to play these modes.

At the beginning of the user study session, participants began by playing the game's three 'base objective difficulty' variations to choose a suitable level that best matches their game skills. No data was collected here. The chosen 'base objective difficulty' was utilized throughout the following experiments. In the following first experiment, participants played the 'normal' mode of the game, to which any difficulty adjustment technique applied, followed by the 'easy' mode with the Collision Detection Area Adjustment. This sequence was repeated four times. Immediately after each game play (whether it was in the 'normal' mode or 'easy' mode), participants were asked to evaluate the perceived difficulty level on a 7-point Likert scale that ranges from 'very hard' to 'very easy.' We also collected data associated with the objective difficulty, which included the number of enemy bullet hits (how many times the player character was hit by enemy bullets) and the number of successful game clears.

After a 10-minute break, the second experiment with the Time Elapse Manipulation technique is conducted. Similar to the first experiment, participants play the 'normal' and 'slow' modes alternately (the order is not randomized for the reasons mentioned earlier). Following this second experiment, a brief interview was conducted with each participant to inquire about their observations

[1]In a preliminary experiment we conducted before this user study, it was observed some participants quickly improve their game skills during these iterations of game plays. This observation is reflected to our user study design.

during game plays. The objective of this interview was to ascertain whether any participants noticed that the objective difficulty of the game was manipulated through difficulty adjustment techniques.

4.3 Result and Discussion

Twenty undergraduate students (18-23 years old; 16 males/4 females) participated in the user study with the compensation amount 7 USD per hour. During the user study, participants were not informed that difficulty adjustment techniques were being applied.

Table 1 briefly summarizes the outcomes of our user study. The first two tests are conducted to assess the null hypotheses $\boldsymbol{H_{01}}$ - $\boldsymbol{H_{04}}$, which relate to the evaluation of changes in subjective difficulty. The 'subjective difficulty (paired)' test applied the Wilcoxon signed-rank test to the pairs of the subjective difficulty evaluation scores by participants (on a 7-point Likert scale) obtained from the pairs of neighboring normal and easy (or slow) modes. Yet, we excluded the first 'normal-easy' and 'normal-slow' pairs from these experiments, as the normal mode plays in these pairs are not preceded by an easy or slow mode play, unlike the other pairs. The 'subjective difficulty (overall)' test applied the Wilcoxon rank sum test to compare the groups of all the normal mode plays and the easy (or slow) mode plays, Similarly, we excluded the first 'normal' mode play in each experiment, as it is not preceded by an easy or slow mode play and differs in its playing condition from the other 'normal' mode plays.

As these two tests utilize the same data set, we applied the Bonferroni correction for multiple comparisons and set the significance level to p = 0.025 (2 tests: p=0.05 / 2). As indicated in Table 1, all the p-values are considerably large, and the confidence intervals encompass zero, signifying the absence of statistically significant differences (even without Bonferroni correction). Therefore, the null hypotheses $\boldsymbol{H_{01}}$ - $\boldsymbol{H_{04}}$ cannot be rejected; these results support the claim that the subjective difficulty perceived by participants were not influenced when transitioning from the normal mode to the easy/slow mode and that there was no difference in subjective difficulty both between the normal mode plays and easy mode plays and between the normal plays and slow mode plays in general.

Table 1: The p-values, mode/avg., and CI from the results.

Test Name	Normal-Easy	Normal-Slow
subjective difficulty (paired)	p=0.198	p=0.289
	CI:-1.50~0.50	CI:-1.50~0.50
subjective difficulty (overall)	p=0.697	p=0.864
	CI:-4.84e-07~1.00	CI:-1.00~1.00
mode	**N** 4: **E** 4	**N** 3: **S** 4
enemy bullet hits (paired)	p < 0.001 ***	p=0.509
	CI:1.86~4.31	CI:-0.67~1.22
enemy bullet hits (overall)	p < 0.001 ***	p=0.560
	CI:1.64~4.54	CI:-0.79~1.34
average	**N** 11.74: **E** 8.65	**N** 5.73: **S** 5.45
game clears	p = 0.009 **	p < 0.001 ***
	CI:-1.73~-0.27	CI:-1.90~-0.60
average	**N** 1.95: **E** 2.95	**N** 2.50: **S** 3.75

* **N**, **E**, and **S** represent the normal, easy, and slow modes, respectively.

* CI stands for confidence interval.

The next three tests are performed to test the null hypotheses $\boldsymbol{H_{05}}$ - $\boldsymbol{H_{08}}$, which are associated with objective difficulty of the game. The 'enemy bullet hits (paired)' test applied the paired t-test to the pairs of the number of enemy bullet hits on the player character obtained from the neighboring normal and easy (or slow) mode plays. Unlike the previous two tests, we included all pairs of normal and easy (or slow) mode plays in this test, as this value (number of enemy bullet hits) is objective and not influenced by participants' subjective perception. The 'enemy bullet hits (overall)' test involved applying Welch's t-test to compare the numbers of enemy hit counts between the normal mode plays and the easy (or slow) mode plays (in other words, not paired as in the previous test). Similarly as in The 'enemy bullet hits (paired)' test, we utilized the all values obtained from the entire experiments. These two tests also use the same data set. To account for multiple comparisons, we again applied the Bonferroni correction and set the significance level to p = 0.025 (2 tests: p=0.05 / 2) for these tests. The results in Table 1 show that there exists a statically significant difference between the normal and easy modes (p < 0.001 and confidence intervals do not include zero). These results suggest that the Collision Detection Area Adjustment technique clearly reduced the objective difficulty of the game in terms of enemy bullet hits in both tests. Therefore, $\boldsymbol{H_{05}}$ and $\boldsymbol{H_{06}}$ are rejected[2].

The last 'game clears' test applied Welch's t-test to the numbers of game clears between the normal and easy modes and between the normal and slow modes. This test doesn't perform multiple comparisons, we simply utilize a significance level of p = 0.05. As shown in Table 1, the results suggests statically significant differences in both cases (p < 0.01 and confidence intervals do not include zero), hence $\boldsymbol{H_{07}}$ and $\boldsymbol{H_{08}}$ are rejected. Thus,these three results also support the claim that both techniques effectively reduced the objective difficulty.

To summarize the discussion, since the null hypotheses $\boldsymbol{H_{01}}$ - $\boldsymbol{H_{04}}$ are not rejected while $\boldsymbol{H_{05}}$ - $\boldsymbol{H_{08}}$ are all rejected, the results of this user study suggest that our difficulty adjustment techniques decreased the objective difficulty of the game without influencing the subjective difficulty that participants perceived, as we claimed. We also note that there was no participant who reported any issue regarding difficulty adjustment in the interview.

5 CONCLUSION AND FUTURE WORK

We addressed the research question: *Is it possible to decrease the objective difficulty of a game without influencing the subjective difficulty that players perceive?* and introduced two difficulty adjustment techniques that may reduce the objective difficulty of a game without influencing the perceived subjective difficulty. Our user study endorsed the effectiveness of these techniques. These techniques are not only rare examples of research that consider the distinction between objective and subjective difficulties, but they also have good potential to be practically beneficial to game designers for enhancing the gaming experience. We plan to further investigate these techniques by identifying effective methods and timings for dynamically applying these techniques during ongoing gameplay.

[2]These tests between the normal and slow modes also indicate that the Time Elapse Manipulation technique did not influence the objective difficulty with respect to enemy bullet hits. This is indeed desirable, as it implies the technique may not significantly influence other aspects regarding objective difficulty.

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