

Dynamic Pressure Cycle Control: Dynamic Difficulty Adjustment beyond the Flow Zone

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Abstract—The degree of difficulty is a key element of fun in digital games. Players enjoy games and improve their skills if the difficulty is set in their personal Flow Zones. The existing Dynamic Difficulty Adjustment (DDA) is a suitable technique to automatically control the difficulty within the proper range in games. However, sometimes players feel uncomfortable when they recognize that the difficulty is being modified automatically. We devised a new game design concept called "Dynamic Pressure Cycle Control," which still adds fun for players even when the difficulty exceeds the proper range. Our method's fundamental idea is to modify the difficulty extremely, increasing and decreasing it beyond the Flow Zone. We implemented our method combined with DDA and conducted experiments to verify it through playtesting. Results show that the proposed method succeeds to add a new element of fun to the game. Also, show the existence of a game design method which offers comfort to players even when they recognized the intentional change of difficulty during gameplay time.

Keywords - *Digital Games; Game Design; Dynamic Difficulty Adjustment; Dynamic Pressure Cycle Control; Flow*

I. INTRODUCTION

Games were only based on competition by rules, before the appearance of digital games. They added a new play style to challenge given tasks, not against opponents. According to challenge of tasks, the concept of level was born, and the difficulty came to be determined by the level design. Difficulty is an important element of digital games such as video games [1][2][3].

According to the Csikszentmihalyi's Flow theory, giving tasks match the skill level of players in the game, they feel fun and improve play skills [1][4]. This state is the Flow Zone, and if the task's difficulty is beyond that range, players feel anxiety and pressure. On the other hand, if players improve

their skill level beyond the range, they feel that the task is boring, and the motivation to play is lost [5][6].

In general game mechanics, adjusting the difficulty level so that it falls within the Flow Zone [1][5]. In recent years, there are also many researches on Dynamic Difficulty Adjustment (DDA) focusing on FPS [7][8]. However, in games in which DDA is implemented, there is a problem that players may feel uncomfortable for the modification of difficulty during to play [9]. Because the sense of agency to play is lost, and the sense of ownership is lost too [10][11].

We proposed a game design to resolve the following two problems:

- Discomfort due to setting difficulty level beyond the Flow Zone
- Discomfort due to dynamic change of difficulty level

Our method "Dynamic Pressure Cycle Control (DPCC)" intentionally sets it as a high difficulty and causes the players to feel a tension by pressure. And DPCC lowers the difficulty before players fail, and they could overcome the high risk situation. This success is intentionally made, but we thought it would be a good game experience.

By repeating this operation, we thought that players could enjoy high difficulty beyond the Flow Zone. That leads to the fun of "Ilynx" by Caillois [12]. Roller coasters have the fun of Ilynx, but passengers can't drive the coaster and have no sense of agency. Similarly, we thought that players were not uncomfortable, even though the intentional operation of DPCC was recognized by them.

We implemented the proposed method using "Tetris [13]" and verified its effect by playtesting.

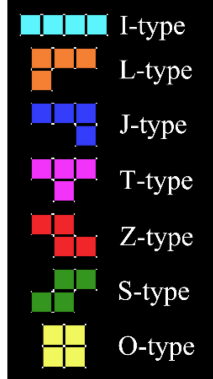


Figure 1. Seven types of Tetriminos

II. METHOD

We implemented the proposed method DPCC in a simple game and verified its effect from the result of playtesting. The points to consider when implementing the proposed method are as follows:

- Clear change of difficulty
- Quantification of the pressure in play
- Accustomed play by the players

In ordinary DDA, the game was implemented in a way that players could not recognize the modification of difficulty level during play. Allowance of clear change of difficulty simplifies the DDA of DPCC. It also serves as a clue for them to recognize intentional operations.

Tetris has seven types of blocks called "Tetrimino". All kinds of Tetriminos are shown in Figure 1. The difficulty of Tetris changes with the type and speed of the falling Tetrimino [14]. The mechanics of Tetris is dropping a Tetrimino randomly. If the same type of Tetrimino falls continuously, players sense that some intentional operation was done.

Quantification of the pressure to players, makes it easy to set the timing of difficulty change. They feel a lot of pressure in the increment of the stacked Tetriminos' height. The Stack's height that one stack's top block height, is visible to the players. And it is easy for them to feel the change of the pressure from the Stack's height. We considered two particular elements that create a pressure in playing Tetris [15][16]:

- Pressure from remaining time
- Pressure due to the narrowness of the space

Tetriminos were going to stack, so that the players operate time of falling Tetrimino is shorten from start dropping to fixing. Moreover, the space where Tetrimino can move is narrowed, and pressure increases.

If players are familiar with the game, it does not put unnecessary stress on playtesting. Since so many players have

experience of playing Tetris, it seems perfect for our experiments.

A. Implemented game

The implemented game named "KP-ris"¹ has a field of width of 10 blocks and height of 20 blocks. Rules in KP-ris are basically the same Tetris' rules. However, the following features have not been implemented:

- Display next Tetrimino
- T-spin

The reason not to show the next Tetrimino is to decide the difficulty from the playing situation, to drop Tetrimino accordingly. At this time, if DPCC drop Tetrimino that can't erase the stacked blocks, the height of the stacked blocks will rise and the pressure will increase. On the other hand, if DPCC drop Tetrimino that can effectively erase the stacked blocks, the height of the stacked blocks will go down and the pressure will decrease.

T-spin is a special rule to make play complicated, omit for suppressing to a simple rule.

1) Playing Status

The playing status is decided by two parameters:

- Stack's height: one stack's top block height
- Total gaps: the total value of the difference between the height of the adjacent blocks

Stack's height and Total gaps shown in Figure 2.

We added a set of new rules to suit our research and idea, if the Stack's height is high, the pressure is also high. On the other hand, if the Stack's height is low, the pressure is also low. In the case of the same Stack's height, we decided that the higher the number of the Total gaps, the worse.

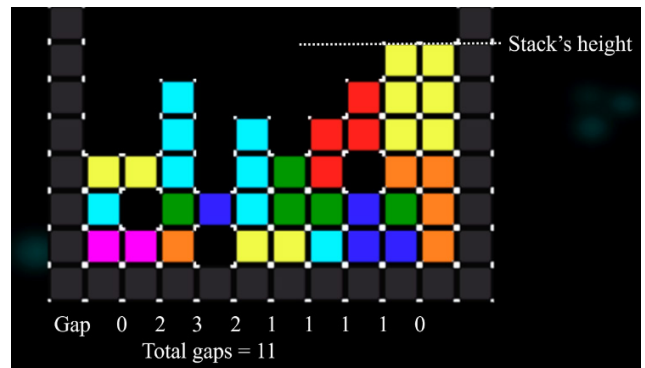


Figure 2. Stack's height and Total gaps

¹ KP-ris: "KP" is the programmer's handle name.

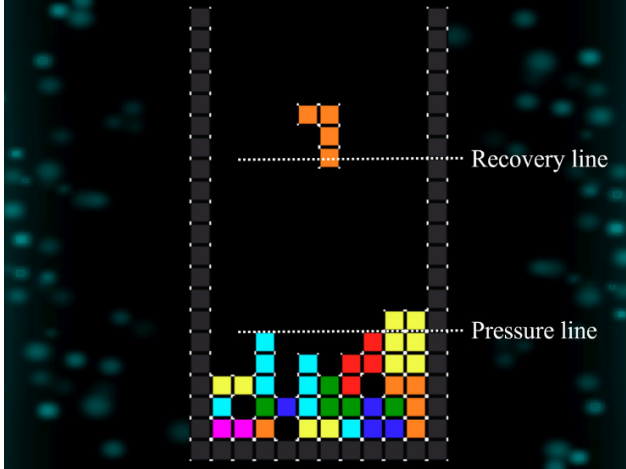


Figure 3. Mode switching lines: Recovery line switch best mode and Pressure line switch worst mode.

2) *Selection of Tetrimino to drop*

Seven types of Tetriminos were classified into the following 3 types, in the case of most efficient placing, by the difference before and after the stack's status:

- Best Tetrimino: Lowest difference
- Bad Tetrimino: 3 Tetriminos from the higher difference
- Worst Tetrimino: Highest difference

The game has the following 3 modes for determining to drop Tetrimino:

- *Random mode*: Select from all Tetriminos at random
- *Worst mode*: Select from bad Tetriminos, the worst Tetrimino = 50%, other bad Tetrimino = 25% each
- *Best mode*: Only best Tetrimino

Two lines were set for switching of the mode on the field. Shown in Figure 3.

3) *Pressure Cycle*

To decide when to switch modes, we set the following rules:

1. When the game started: set to *Random mode*
2. When the Stack's height reaches the Pressure line, switch to *Worst mode*
3. When the Stack's height reaches the Recovery line, switch to *Best mode*
4. When the Stack's height is below the Pressure line, switch to *Worst mode*, and repeated from 3

The falling speed of Tetrimino is another element of pressure, this element has great influence on the difficulty [17]. In the game in order to match the difficulty to the players' skills, the falling speed simply raised gradually until the Stack's height reaches the first in the Pressure line. The falling speed was set to a constant value after reaching the Pressure

line, to control the difficulty only by switching the mode. The flowchart of the proposal DDA is shown in Figure 4.

Players started KP-ris and when the Stack's height reached the Pressure line, DDA of DPCC is switched to *worst mode*. No matter how good players are, they are not able to clear all lines and the Stack's height will keep increasing, and the game become more difficult. The play space is reduced then players feel pressure. Since the reduction of the space occurs due to their actions, they usually do not notice that this pressure is induced by the designer on purpose, they don't recognize it's artificial.

When the Stack's height reaches the Recovery line, the game switches to *Best mode* and the Stack's height is lowered by the expected outcome proper operation. Players get exhilaration and sense of accomplishment. But if proper operation is not performed, the game is over.

4) *Comparison with original Tetris*

In addition we prepared a *Random mode* only version like original Tetris named "R-type" in order to compare to the KP-ris. The falling speed is increased if the Stack's height is lower than the Pressure line, to end the game.

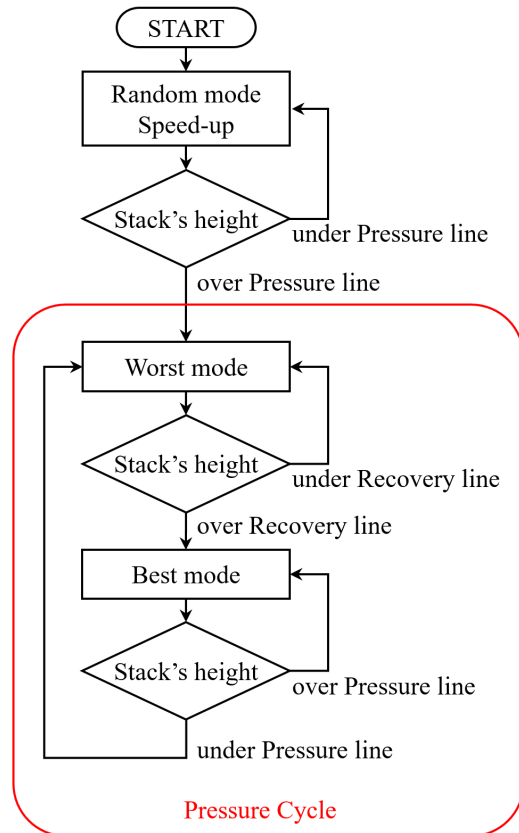


Figure 4. The flowchart of the proposal DDA.

Table 1. The result of our experiments.

Which one do you think is the most interesting mode: R-type or KP-ris	Recognize DDA controlling			Total
	1. Not recognized	2. Vaguely	3. Recognized	
1. R-type is more interesting than KP-ris	0	0	0	0
2. R-type is slightly more interesting than KP-ris	0	0	0	0
3. There is no difference	1	0	0	1
4. KP-ris is slightly more interesting than R-type	5	3	3	11
5. KP-ris is more interesting than R-type	1	4	6	11
Total	7	7	9	23

B. Experiment

Players tested both types of the game, R-type and KP-ris, freely. And we interviewed them about the following points after playing

- Which one do you think is the most interesting mode: R-type or KP-ris?
 1. R-type is more interesting than KP-ris
 2. R-type is slightly more interesting than KP-ris
 3. There is no difference
 4. KP-ris is slightly more interesting than R-type
 5. KP-ris is more interesting than R-type
- Did you sense that Tetriminos are controlled by DDA?
 1. No, I didn't
 2. Vaguely
 3. Yes, I did
- Played impressions

III. RESULT

Experiments were done at Tokyo Polytechnic University in 2015 until 2016. We asked 23 students to play the games. The result shows in Table 1.

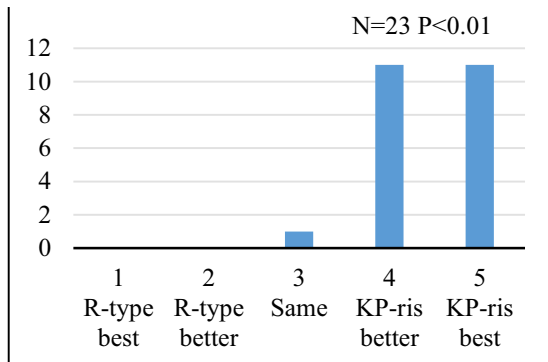


Figure 5. Comparison of R-type and KP-ris.

For KP-ris and R-type, t-test was conducted by comparing the head number of five choice as scores. And P-value was 6.81×10^{-11} . KP-ris was more interesting than R-type that had the same Tetrimino selection as the original Tetris. Shown in Figure 5.

Regarding cognition of the operation of DDA, a comparison test was conducted between unrecognized players and clearly recognized players, but there was no significant difference. There was no correlation between the cognition of DDA operation and the evaluation of game, and the proposed method was good regardless of recognition of DDA operation. Even if an operation by DDA is perceived, depending of the difference in game design, players do not feel uncomfortable.

The following comments are samples of the comments obtained from players. Shown in Table 2.

Putting together all the comments that we received, analyzing the results, we can see that players considered that our proposal method DPCC added fun to the game we developed.

IV. DISCUSSION

We had consideration based on the result that KP-ris implementing the proposed method DPCC is more interesting than R-type has same rule as Tetris. We discussed the comments by the players' characteristics.

A. Did not recognized DDA operation

There were "KP-ris has a higher difficulty" and "KP-ris feel a higher pressure" comments. We thought DPCC was successful intended in entertaining the players, with the high difficulty and the high pressure.

And the players focused only on the high difficulty and the high pressure, they did not feel bored the difficulty was being lowered beyond the appropriate range in *Best mode*.

Table 2. The following comments.

Group of testers	Comments
Did not recognize the change	<ul style="list-style-type: none"> • KP-ris has a higher difficulty. • KP-ris feel a higher pressure.
Vaguely recognized the change	<ul style="list-style-type: none"> • I felt the artificiality in a succession of straight Tetriminos. • KP-ris does not seem to have a low difficulty, I felt that I become a good player.
clearly recognized the change	<ul style="list-style-type: none"> • I felt “Omotenashi².” • Another way of enjoying was to predict which kind of Tetrimino will come next.
KP-ris was slightly interesting	<ul style="list-style-type: none"> • Usually this would be a painful scenario in which I would give up but I could play KP-ris without giving up.
KP-ris was interesting	<ul style="list-style-type: none"> • When the feeling of being trapped without stress was eliminated, it was fun. • The feeling of pressure and relief is a good stimulus. • The desperate situation of expecting for the expected Tetrimino is exciting. • KP-ris is “Tsundere³.”

B. Recognized DDA operation

The comment “I felt the artificiality in a succession of straight Tetriminos.” came from players that are skillful in Tetris. In Tetris rule, there is a higher score if there are more lines to erase at the same time. According to it, erasing four lines simultaneously is a common play style [18]. As shown in Figure 6, piling Tetriminos to open only one row vertically and waits for an I-type Tetrimino to come.

When the Stack’s height reaches the Recovery line, DPCC changes DAA to *Best mode* and drop I-type Tetrimino in succession to erase stacks. Since I-type Tetriminos dropped continuously each time the Stack’s height goes beyond the Recovery line, players recognized some intentional operation was done.

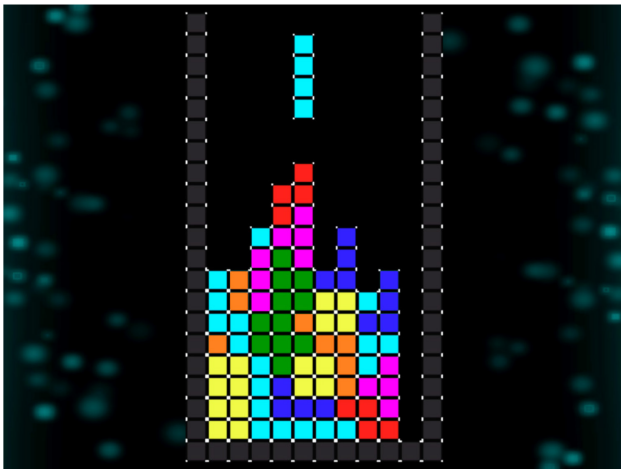


Figure 6. Play style of aiming to erase 4 lines concurrently.

There was a comment "I felt Omotenashi", in the case of players recognized DPCC's *Best mode* operation. In addition, there was a new perspective about fun seen in "Another way of enjoying was to predict which kind of Tetrimino will come next". We thought the original Tetris rule was Caillois's "Agon" in which converts the erased lines into points and competed. On the other hand, KP-ris had the pleasure of "Ilynx" in which enjoyed the high pressure with guaranteed to be absolutely safe playing. Furthermore, we thought also enjoying "Mimicry" in which performed ideal operation according to the predicted procedure [12].

The comment “KP-ris does not seem to have a low difficulty, I felt that I become a good player” can be seen in a game experience on experiments about intentional difficulty adjustment like DPCC [19]. It was due to not feeling unnatural when the process of the game is within the range not to interfere the ownership feeling against players' operation [20]. They did not feel anxiety to high difficulty because they thought themselves had good skills. We thought they were in the Flow Zone. It seemed they feel the game is pleasant, their motivation is maintained and the skills would be improved.

² Omotenashi: Japanese word used to describe a feeling of hospitality, a feeling of “taking care of someone”. This concept is all about offering the best service without expecting anything in return.

³ Tsundere: The one of stereotypical personality. The mind changes alternately between indifference and likes.

C. PDCC was interesting

The comment "Usually this would be a painful scenario in which I would give up but I could play KP-ris without giving up", players recognized the failure was caused by their own operation error, and if they can successfully operate, they feel that they were able to overcome a tough situation. Constant failure without seeing a possibility of success while playing will make players lose their motivation. But the failure of playing would be often leads to replay motivation [21]. If the players could see a solution to their cause of failure they would not give up playing. We thought that in KP-ris it is easy to have an image of success at the moment of failure, and the replay motivation would even become stronger.

Players who commented "KP-ris was interesting", were aware that KP-ris operated the difficulty to rise and fall extremely. DPCC recover tough situation automatically, however, it didn't make the players lose their sense of agency and ownership. This is because they thought they were controlling the DDA operation by themselves.

V. CONCLUSION AND FUTURE WORK

We used experiments to verify the following two effects of our proposed method DPCC.

- Players could enjoy the high difficulty beyond the Flow Zone, if the situation was recoverable and during short span of time.
- The existence of a game design method, in which the players don't become discouraged even if they recognized the DDA.

DDA can be used not only as a game difficulty adjustment but also as a tool to create a new way of playing. There is a possibility of the game design which does not become unpleasant even if an extreme production of game play existed.

As a future work, we would like to test our new method in other genres, different types of games to evaluate results and compare. It is a pity that this experiment was conducted in Japanese domestic only, and we would like to playtest widely with players from all over the world.

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