DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

Adaptive Difficulty in Video Games to Foster Optimal Experience

Georg Eickelpasch

DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

Adaptive Difficulty in Video Games to Foster Optimal Experience

Adaptive Schwierigkeit in Videospielen zum Fördern optimaler Erfahrung

Author:	Georg Eickelpasch
Supervisor:	Prof. Gudrun Klinker
Advisor:	Daniel Dyrda, M.Sc.
Submission Date:	15.09.2020

I confirm that this bachelor's thesis in informatics: games engineering is my own work and I have documented all sources and material used.

Munich, 15.09.2020 Georg Eickelpasch

Acknowledgments

I would like to pay my special regards to my advisor Daniel Dyrda for supporting me during my study. Furthermore, I wish to thank all people who participated in the study or playtested the game.

Abstract

The aim of this thesis is to investigate the impact of adaptable difficulty on the flow experience of players and to see if it is possible to trigger flow in players regardless of their skill.
To research this question a game was created with an adaptive and a non-adaptive version. By using a short empirical survey, information is gathered and then presented. It can clearly be seen, that adaptive difficulty has a positive effect on flow.
The results suggest that adaptive difficulty is strongly impacting the flow experience of the participants of the study. However, it has to be concluded that adaptive difficulty alone is not enough to trigger the flow state in every player and other factors have to be considered too. Furthermore, the survey shows that players experience flow very differently.

Contents

1. Introduction

1.1. Motivation

The motivation for this thesis is raised by my personal interests and experiences. With the video game industry being a daily part of my life as a video game player as well as an "Informatics: Games Engineering" student I am excited to see that this sector is rapidly growing. But with the growth of the sector on the one side and the advancement of technology on the other side the concepts of games are changing too. Not all players of today will be satisfied if they play a game and it "feels good". Measuring the quality of a game is not a streamlined process and each person individually has to evaluate a game to know whether or not he or she thinks of a game as worth playing. The environment around a game can be important for that evaluation too. For example, recent scandals like Blizzards banning of a Hearthstone player called "Blitzchung" due to a political statement caused major backlashes [19]. A public image like that impacts the way players see a company and games offered by that company. There are many ways a game can be evaluated and depending on the purpose of the evaluation different methods are feasible. But the most important evaluation surely is how the game feels. Due to the subjectivity of this, it can often be difficult to express why one game is better than another.

If you compare today's mobile phone games with original arcade games there seems to be nothing alike. Not only the machine changed drastically, but also a lot of other factors. For example, the target group of video games changed from young interested players who would go out of their way to visit an arcade hall to almost everybody due to the rise of casual and social gaming. Because of this diversification of the player base, it seems impossible that one game appeals to everybody. This thesis will focus on this problem and how a single game might be able to adapt to the different skill levels of different players. While the difficulty surely is one of the major factors there are also a lot of other concepts that could be considered when thinking about who will like your game but this work will not research in which scale those factors also can be adaptive.

The reason why people play also evolved together with the games. These days entertainment is not the only reason for playing games. People want to spend time with their friends and socialize, experience a story, prove their ability, or even learn

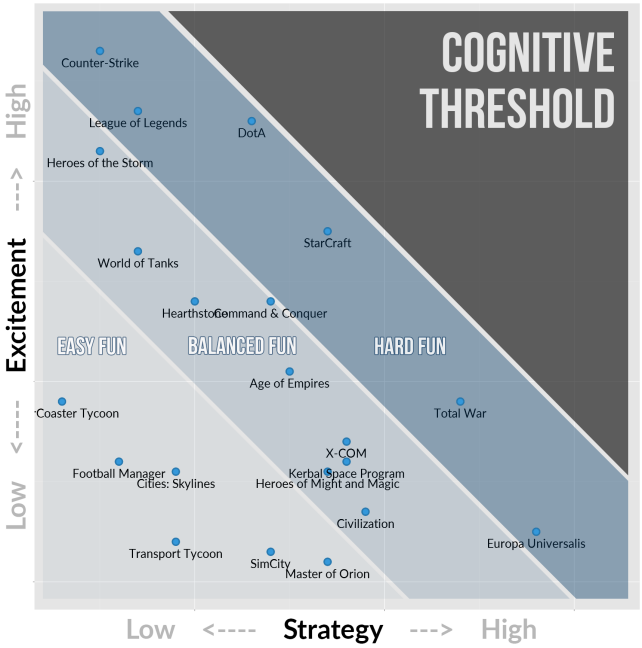

Figure 1.1.: Strategy and excitement evaluation for various games [Yee16]

certain skills through serious gaming. But no matter what your reason for playing a game is, you always want to have a good experience playing it. While difficult games like "Dark Souls" can be frustrating, the player should still feel immersed and in the flow. This concept of flow is crucial for a game to feel good. Therefore every game should be designed with the idea of an optimal flow experience for the player. And because every person experiences flow differently and the requirements for each person to reach that state are not the same, it can be very beneficial if the game can adapt to different players.

In figure 1.1 games are placed in a graph that shows the cognitive load of a game for the player. This cognitive load is influenced by two factors, one being the excitement the game causes which is highly correlated to the number of actions the player has to take in a limited amount of time while the other axis shows the strategy component of the game. This can be understood as the impact of each individual decision made by the player, for example, if you happen to make a mistake in a MOBA like League of Legends it usually will not lose you the game right away. However, the important feature of the figure is that the games are not ordered by difficulty as one might expect. This is because a high cognitive load does not mean that a game is difficult. Most of the games shown do have difficulty settings but even if you play a game with a

low cognitive load on a difficulty that is too difficult for the player, the player will not be able to complete the raised challenge by only using more cognitive power. This is because the concept of the game already defines the usable cognitive load. This division between cognitive load and ability to complete raised challenges is important when thinking about the difficulty. The difficulty that this paper will consider when talking about adaptive difficulty is the latter.

1.2. Problem Description

1.2.1. Approach

In this section, the approach of this thesis will be concretized. Firstly, the the underlying question of the title "Adaptive Difficulty in Video Games to Foster Optimal Experience" should be formulated. A possible question would be "Can the flow state be achieved for every simple task and for every user by adapting the difficulty to the player's skill?". If it is possible to reach the flow state for a task just by adapting the expectation of the user and the difficulty of the task, the consequences would be a powerful demonstration of how to motivate people to complete tasks through intrinsic motivation. But this also implies a way to achieve happiness and fulfillment in simple tasks.
A simple task is a task, that can be done by a person by thinking as little as possible about the task while doing it. Usually, that is something that the person has done so many times, that he or she can now do it without concentration on the task. For example, this could be washing the dishes or riding a bike along a very well known path e.g. from home to work. To simulate a task like that I created a game that tries to keep the cognitive load of the player as low as possible. Clear indications show at all times what the player is supposed to do and there are no decisions to be made that impact later stages of the game. You could say the game is solely a physical activity. Due to this, the adaption process is easier since the user presumably does not change his skill through learning while playing the game. Furthermore, the cognitive load can hardly be adapted in a non-discrete way. Adding a new mechanic or problem to increase the cognitive load for the brain of the player will not be a continous increase in difficulty (i.e. new mechanics cannot be added in infinitely small difficulty steps). So only focusing on and adapting the physical difficulty of the game is a feasible approach.
For the evaluation of this theory a user study will be performed. The users will play the afore-described game that adapts while they are playing as well as a version of the game that does not adapt to the player's performance. After each of the versions, the players are asked to fill in a questionnaire about their experience with the game and whether they experienced a flow state or not. Finally, it will be concluded if the results can be generalized for other tasks e.g. of the daily life.

1.2.2. Expectation

The expectations of the study are set before the study is executed. There will be a review afterward in the "Discussion" section to see which expectations were right and which were wrong and what may have caused the discrepancy. Since the tasks the player has to complete in the game are designed to be flow-inducing the players are expected to experience some form of flow. The adaptive version should increase the feeling of flow compared to the non-adaptive version of the game. However, the expectation is that there will be a noticeable difference between people who are playing a lot of video games or are experienced in using a computer mouse and those people who are not. People with little experience will notice a much stronger difference between the versions of the game since the non-adaptive version is set to an advanced skill level. Therefore it is unlikely that the difference will feel the same way for experienced players.
For the experienced flow, there are two different predictions. One type of player will enter the flow state and enjoy playing the game while the other type does not reach the flow state. This is caused by the problem that there is no goal provided except "finish the game for the study". This might cause some players to feel like they are wasting their time playing the game and are just idling. This is unlike a real simple task where there is a clear goal e.g. having all the dishes cleaned or arriving at home. Furthermore, it has to be considered that due to a limited sample size the result might differ from the truth and should not be taken as fully representative. However, some trends are still expected to be visible.

2. Related Work

2.1. Flow

2.1.1. What is Flow?

Flow is a state every human can experience. The founder of the Flow theory, Mihály Csíkszentmihályi, describes it as a feeling that is reached when your own skill is enough to perform well within a well-defined system that has a clear response on how well you are performing. Your entire focus is within the system so that you do not think about anything that is not important for the current task. This also leads to a distorted perception of time and sayings like "Time flies by when you are having fun" are a direct result of this distorted perception in the flow state. Furthermore, the feeling itself is so rewarding that there is no need for a reward outside of the system and your motivation for the task is intrinsic[Csí90]. Obviously, video games are prime examples of systems that are designed to reach this flow state, but everything that can be considered a hobby and everything that people are simply doing "for fun" is usually motivated due to reaching the flow state. Next to games, also playing sports or playing an instrument are very good examples. But also learning or working can trigger the flow state and in fact, using this flow state people can learn very efficiently. Because of this, the rise of serious gaming for training and learning in various contexts is getting more and more attention.

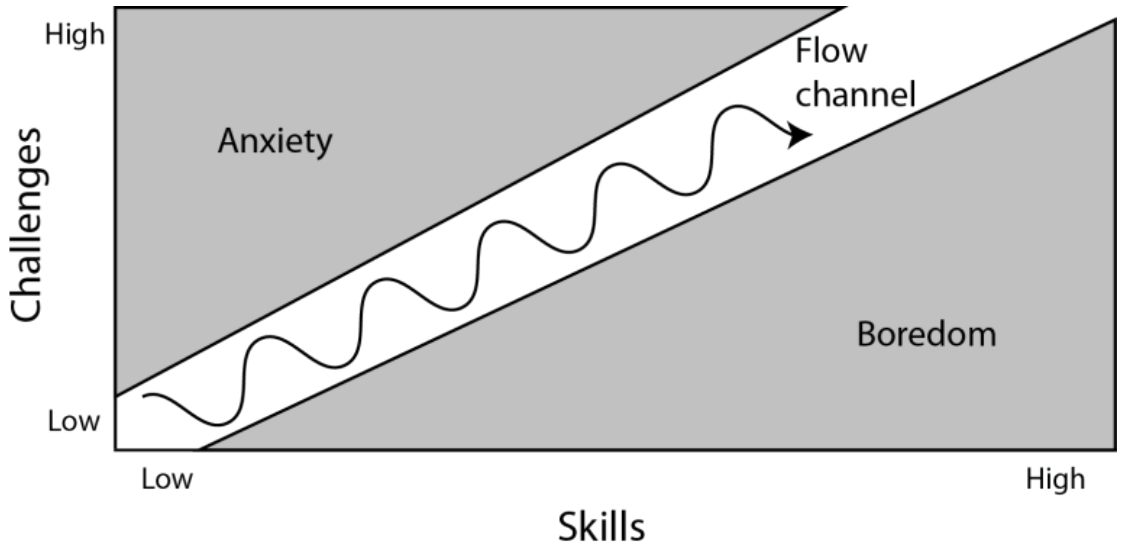

Figure 2.1.: The flow channel [Sch08]

There has been a lot of research regarding this state of optimal experience. According to Penelope Sweetser and Peta Wyeth [SW05] a flow experience consists of these eight elements:

1. A task that can be completed
2. Ability to concentrate on the task
3. Concentration is possible because the task has clear goals
4. Concentration is possible because the task provides immediate feedback
5. Ability to exercise a sense of control over actions
6. Deep but effortless involvement that removes awareness of worries and frustrations of everyday life
7. Concern for the self disappears but the sense of self emerges stronger afterward
8. Sense of duration of time is altered

Even though the activities done to achieve flow are very different, the resulting flow state is always described similarly. For video games, this means that even a beginner will have the same feeling as a very experienced player. The difference is merely the way how to achieve the flow state.

How to achieve Flow

According to M. Csíkszentmihályi [Csí90], seven criteria need to be considered to achieve flow:

1. A task that can be completed
2. Ability to concentrate on the task
3. Perceived skills should match challenges and both must exceed a certain threshold
4. Allowed to exercise a sense of control over actions
5. The task has clear goals
6. The task provides immediate feedback
7. Deep but effortless involvement; reduced concern for self and sense of time

These points can be mapped to videogames as done by Penelope Sweetser[SW05]. To see how these points compare with video games or how they are found in video games there will be a juxtaposition of those. You should be able to complete a task because the person doing it needs to receive feedback on the task. If the task seems endless, as many video games which do not have an end for example most MMORPGs, the task can be broken down into smaller tasks which again can be completed. In an MMORPG this might be defeating the next boss or improving certain equipment.
The need to concentrate on a game goes together with the next point. If you do not need to concentrate on the game then it might be too easy or boring because there is nothing to do. If you think of idle games like clicker heroes the player does not feel good because of the time he or she just waits but rather because of the tasks he or she completes every once in a while when he or she has to decide on his or her strategy and upgrade his or her heroes actively and with concentration.
The third point describes the flow channel that can be seen in figure 2.1. If a task is too easy for the player it will be boring or if the required skill is too high the player will feel anxious and, depending on the risk feel, bored, scared, or frustrated. The threshold means that there is a minimum skill required before a player can enjoy the game. Imagine two players who only know the rules of chess but no consistent way of evaluating if a move is good or not playing against each other. While the challenge is appropriate, neither of them understands which moves will lead to an advantage or to victory and they will not enjoy playing the game if they randomly move pieces.
The player needs to feel in control of his actions otherwise even if he or she accomplishes something it is not rewarding for him or her since he or she does not understand

how his or her actions impacted the result and it does not feel like he or she achieved anything.
Next up, clear goals are important for the player to receive feedback and to keep him or her motivated and interested.
To receive feedback while playing causes the player to either feel great for performing to his or her expectations or even above or can motivate him or her to try harder if the challenge seems appropriate but he or she just barely did not make it.
Deep but effortless involvement in video games is called immersion. The player should become a part of the game, forget about everything around him or her including himself and his or her problems in the real world as well as time.

Furthermore, for video games, social interaction needs to be mentioned. It is not a criteria of M. Csíkszentmihályi to achieve flow but rather can be a flow activity itself. Many video games directly foster social interactions due to being multiplayer games but even single-player games can have social interaction as a component, for example when you talk about the game with your friends or when you watch your sibling playing. The social interaction flow activity within gaming, which can be a flow activity itself, can also be a major motivator for people to play games and trigger for getting in the flow state.

2.2. Difficulty

2.2.1. Optimal Difficulty

"In the good old days, everything was better!" - you can probably hear statements like this throughout all aspects of life, but in video games, this sentence usually comes along with the person saying how games used to be a real challenge and today's games are all too easy. If games in the past were harder, it was not because harder games are more fun, but because an arcade would receive money every time the player failed or for sold games the person playing the game should have his or her money worth in playtime. And that was difficult to achieve without endless replaying because of the very limited memory available on older media. So old games were difficult for a different reason than player enjoyment, but if completing a game is fun, would it not be more fun, if every game was easy enough to just play it through without failing? While this thought might seem intuitive, an example makes it clear that this is not the case. Think of "Flappy Bird", but with the change that you cannot fail. Now the game suddenly seems very boring. So the answer to how difficult a game should be, is not that simple. A study by Jesper Juul suggests that people who fail a few times before finishing a challenge rate there experience higher than people who complete the

challenge without failing or people who do not manage to complete the challenge at all [Juu11]. However, achieving this optimal difficulty of failing a few times is easier said than done. A game that seems trivial to an experienced player might already be unsolvable to a player who does not have a lot of experience or a player who is at a disadvantage for other reasons e.g. a player's reaction speed might be slower due to the player's age. There are different approaches to solve this problem. A common approach that you will often hear as a principle for game design is "know your audience". That means that you should think about the skill level of your target players before designing the game and focus only on one group of players. For example, most shooting games require short reaction times and great reflexes. Of course, your grandparents could still play the game, but they would probably be at a natural disadvantage. Therefore the game might be too difficult for them, yet it was not designed for elderly players.

A different approach that works for some games is a well-designed learning curve. The game is easy at the beginning and introduces the player to how everything works and what to do but then quickly picks up the pace. Inexperienced players will gather the required experience along the way and maybe fail a few times more often but as long as they feel as if they are learning something new and they are making progress it will still be enjoyable. The experienced players will complete the first few levels fast but before they get bored the game is already difficult enough so that they are also challenged. Of course, designing a game along such a learning curve is a difficult task and it is not applicable to every type of game. But the most common approach is to have adaptive difficulty!

2.2.2. Adaptive Difficulty

There are different types of adaptive difficulty. The easiest way is to simply have the player select the difficulty that he or she thinks is most fitting for him or her before the start of the game. Thereby the game can be changed according to the player and provide a better experience than a game that has the same difficulty for every player. Another advantage of this method is, that it can offer a replay value to a game that otherwise would not have replay value. For example, after completing a game on "Normal" difficulty a player who wants to continue playing the game can play the entire game again, but this time on "Hard" difficulty for a challenge that is adapted to the experience of the player. However, there are many downsides to this approach too. Firstly, the experience is still discrete and not personalized. For example, if a game has the three difficulty settings "Easy", "Normal" and "Hard" there might be a player who thinks "Normal" difficulty is not challenging enough but "Hard" difficulty is already too challenging. Some games try to fix that by adding more discrete diffi-

culties e.g. "Skyrim" has a total of 6 different difficulty settings but that often does not solve the problem since players might not know what the ideal difficulty setting for them is. Another problem is that the names of difficulties are often misleading. "Easy", "Normal" and "Hard" should all provide the same challenge to differently skilled players, unlike the name which suggests that "Easy" is in fact easy. Instead, it is supposed to be easy for the average player but just right for a player who is less skilled than an average player. Furthermore, some players feel degraded if they can only play a game on an easy difficulty since it suggests that they are unskilled which is often a feeling that a player does not enjoy. Therefore players select difficulties that are out of their reach and then dislike the game because it is too challenging.

Another approach to the adaptive difficulty is a non-discrete player evaluation based on the player's performance and then use this evaluation to change the difficulty of the game while the player is playing. For example, in chess that could be realized by an artificial intelligence that plays worse the more it is ahead. By doing this the player is always in a situation where he or she is challenged, without the AI being so strong that the player has no hope of winning but also without the player gaining advantages so big that the game becomes boring. The main advantage of this method is that the game can adapt individually to every player and provide a challenge that is just right. However, depending on the game the evaluation of the player skill can prove to be a difficult challenge, and if done not accurately leave the player always frustrated or always bored. Another problem can be, that the player sometimes wants to feel superior as a result of his or her previous actions. If you are always challenged at the same level it can feel like there is no progress being made or that there was no improvement in the player skill, even though he or she did improve – but the game improved alongside him or her. Of course, this can be prevented by a well-thought implementation of the system but it is not easy to implement.

Another point that has to be considered in both approaches is the way the difficulty is improved. On the one hand, there is a simple stat boost. For example, every enemy has X% more health points and does Y% more damage. This can be found in many games e.g. the aforementioned "Skyrim". The advantage of this method is, that it can be implemented easily in a non-discrete way and therefore provides as much personalization as possible. Also, the player will behave the same way if everything stays the same, except the game is a little tougher. However, this can lead to unsatisfying encounters in some cases. For example, if a higher difficulty simply doubles the health points but the player is not getting any damage due to his or her dodging abilities, either way, the player is now in a game that is not more challenging but instead just

takes more time and it takes longer to reach interesting new mechanics which might exist later in the game. Therefore the result is contrary to what the intention was. The other option is to introduce new mechanics into the game to increase the difficulty. For example, an enemy gains a new attack pattern or an improved behavior. This will usually make the game more interesting since the player is facing a new challenge and has to find a solution to a new problem. However, the downside of introducing new mechanics is that it is discrete and therefore the new challenge might be too difficult for the player and it cannot be accurately personalized. Sometimes game mechanics are also essential for the feeling of the game and removing them for "easy mode" players is not possible without ruining their game experience. Furthermore, inventing new mechanics is much more difficult than simply changing some numbers and there are a minimum and a maximum of mechanics that a game needs or can offer.

It is feasible to use both, the simple stat change as well as the introduction of new mechanics so that the stat personalizes the challenge accurately while new mechanics keep the game challenging.

3. Circleflow

For the study, I implemented a game called "Circleflow" in Unity [figure 3.1]. The idea was to have a simple game for which it is possible to easily implement an adaptive difficulty version as well as a non-adaptive difficulty version so they can both be played and rated by the participants of the study.

3.1. About the Game

3.1.1. The Rules of the Game

The goal of the game is to reach a score as high as possible. The player receives points for hovering over lit-up areas. There are a total of six areas that can light up. Three areas are placed in a circle and three more are placed in a larger circle around the first circle and the entire circle rotates. After hovering a lit-up area for half a second, the current area will no longer be lit-up and instead, a random adjacent area will light up. The player then has to move his or her mouse cursor as fast as possible to the newly lit-up area. By doing so the player should move his or her mouse cursor only over the last lit-up area to reach the newly lit-up area. He or she should not touch any other areas besides the last one and the new one. The player loses if he or she does not manage to score any points for a short period of time. The remaining time is shown by a red bar at the top of the screen which constantly decreases and the bar refills every time the player receives points. The first time the bar is completely drained it refills completely and changes its color to a darker shade of red as seen in figure 3.2. This only happens once per game and this "second life" cannot be restored. In case the player is not hovering the last or currently active area of the circle, the feedback light behind the circle will turn red as seen in figure 3.2 and the time bar is drained twice as fast. Once the player is back on a valid area the feedback light will turn green again and the time drain speed resets to its original value. After hovering a lit-up area, there is a chance that instead of a new area lighting up the light might turn off instead. In that case, the player has to click the lightbulb in the center, turning the light back on (i.e. a new area lights up), and changing the direction of the rotation of the circle.

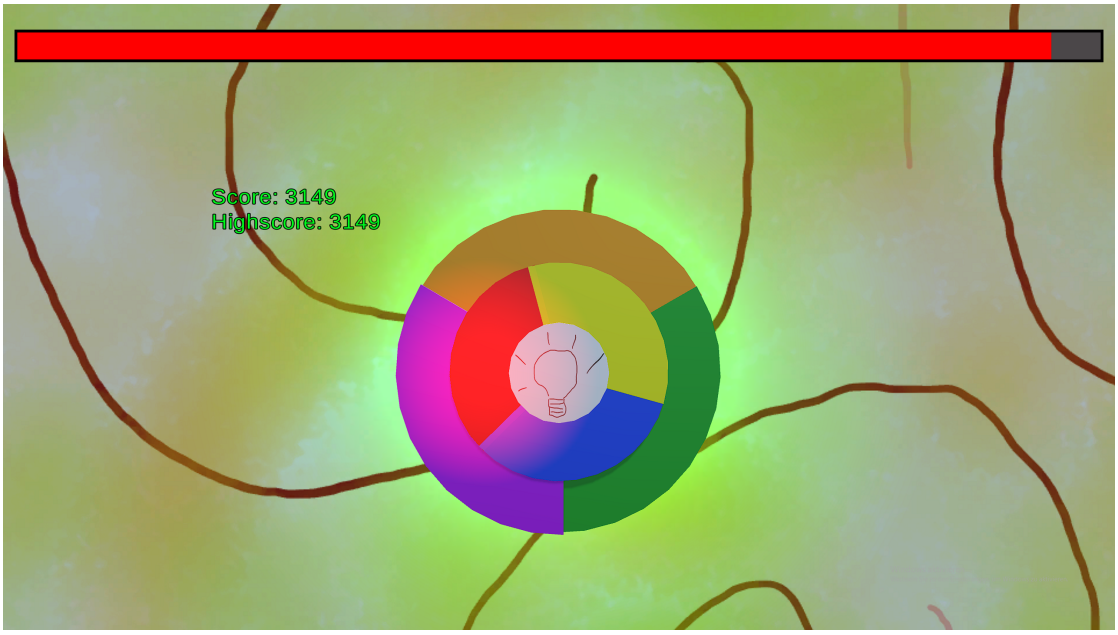

Figure 3.1.: A player performing well in "Circleflow"

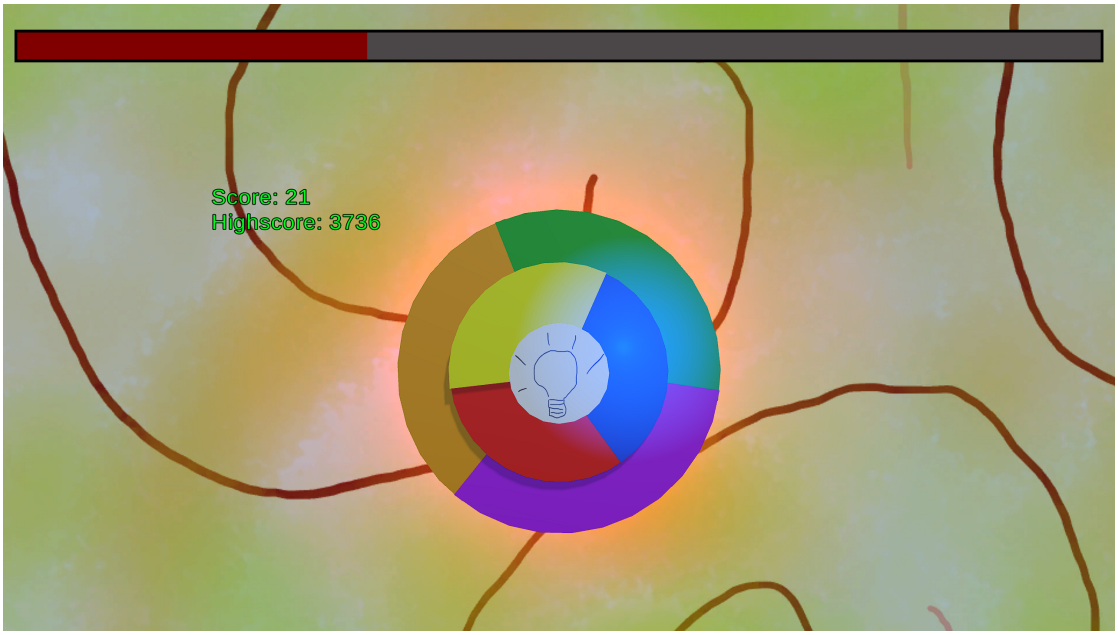

Figure 3.2.: A player performing poorly in "Circleflow"

3.1.2. Implementation of Difficulty

The underlying concept of difficulty is that the longer the player survives the more difficult it gets. This is implemented in two mechanics. The first one is that the rotation of the circle is constantly accelerating. Thereby it gets more difficult to survive because the player has to follow the rotation of the circle to hover the lit-up area. To a certain extent, the player can also use this, because the lit-up area can also be approaching the mouse cursor, reducing the distance that the player has to move the mouse cursor. The second mechanic is that the longer the game takes, the less time is available for the player, eventually leading to not enough time for the player to hover the next lit-up area and him or her losing the game.
In the adaptive version of the game, the player's performance is evaluated by two simple algorithms. For the time mechanic, the game measures how long the player needs to move his or her mouse cursor from the last lit-up area to the next lit-up area. Only the last five areas are considered since the performance of the player is expected to change while playing due to the changing speed of the rotation as well as the player improving his or her abilities. The time given to the player is the average of his or her past performances multiplied by a variable that decreases as the playing time increases. The speed mechanic is regulated by checking if the player manages to hover over valid areas. If the player hovers an area that is not valid (i.e. not the last or current lit-up area) the game stops increasing the speed for a short amount of time. This allows the player to accustom to a higher speed at his or her own pace and eventually caps at a maximum if the player keeps doing mistakes too often. In the non-adaptive version of the game, instead of averaging the past performance of the player to calculate the newly available time, the value is fixed. Of course, the total time still decreases as the game time progresses to eventually end the game. The speed mechanic cannot be influenced and the speed increase cannot be stopped. The rotation will continuously accelerate as if the player was not doing any mistakes.

3.1.3. Implementation of Flow

In this section, there will be an explanation of the different aspects of the game in regard to flow and why the game design decisions were made in the way that they have been. First of all, the seven criteria for flow according to M. Csíkszentmihályi [Csí90] and how they are implemented in the game will be shown.

- A task that can be completed:
  The game is clearly separated into small tasks. Each task is to hover a lit-up area for a short duration, which can be completed easily.

- Ability to concentrate on the task:
  When playing the game for the first time concentration will be required to comprehend all the inputs of the UI. Some testing resulted in the problem that once the player is familiar with the basic mechanic of hovering the lit-up areas without crossing the other areas, some players tend to "autopilot". To counteract this and to force the player to keep his or her full concentration on the game, the mechanic that requires the player to click on the lightbulb in the center was added. Because it has a different indication i.e. no lit-up area, and a different task - clicking instead of hovering - the player has to stay ready so that this task does not appear unexpectedly and does not catch the player off guard.

- Perceived skills should match challenges and both must exceed a certain threshold:
  This point is strongly influenced by whether the adaptive version is played or the non-adaptive version is played. The challenge has no upper boundaries in terms of how fast the player can move the mouse cursor from one lit-up area to the next. The expectation is that in the adaptive version the player perceives the challenge as matching to his or her skill because the time that he or she has for completing each task is equal to skill. Also, the speed of the circle should adapt to the player's performance. In the non-adaptive version, the game will usually end with the circle rotating too fast causing anxiety or a feeling of unfairness to the player. This should be prevented in the adaptive version.

- Allowed to exercise a sense of control over actions:
  Generally, the user has high control over the game. His or her actions are directly related to him or her scoring points or failing the game. However, the player cannot control which areas light up next, which does influence the game to a certain degree, especially because lit-up areas in the direction of the rotation are harder to reach than areas that are in the opposite direction of rotation since the player can wait for the area to move towards him or her or at least has less distance to travel. More important than this small randomness is the accelerating process in the non-adaptive version. If the circle accelerates too much, the player might feel out of control because everything is happening so fast that he or she cannot do the actions he or she would like to do. The adaptive version of the game counteracts this by regulating the speed of the circle.

- The task has clear goals:
  The goal of the task is to achieve a score as high as possible and it is clear what the player should do to achieve that. Furthermore, the points granted to the player are dependent on the current speed of the circle. If the points would be

a flat amount a player who does a lot of mistakes and plays with a slow circle in the adaptive version would end up with the same score as a player who does few mistakes and plays with a fast circle. This is to reward competitive players as considered by Robin Hunicke [Hun05] and give them clear feedback that they are performing better than somebody who does many mistakes and encourages the player to do fewer mistakes.

- The task provides immediate feedback:
  To provide immediate feedback to the player there are multiple mechanics in the game. The first mechanic is the scoreboard. After each completed task the player's score will increase and by that let the player know that he or she completed a task. The new area lighting up also indicates clearly that a task has been completed and that a new task is set up for the player. To give the player feedback if he or she does mistakes the background lighting is implemented. In case the player hovers over an area that is not valid the background lighting will turn red. Finally, the time bar also has two stages, turning into a dark red after running out for the first time. This also indicates to the player that he or she currently is performing below the expectation.

- Deep but effortless involvement, reduced concern for self and sense of time:
  To ensure deep involvement in the task the player is constantly set under pressure. If he or she is not involved in the task he or she will inevitably fail. This pressure is indicated by the time bar that is moving fast and shown in red at the top of the screen to remind the player that he or she has no time to slack off in between the tasks. To foster effortless involvement the task is as simple as possible and is completed only by moving the mouse cursor instead of clicking. Also, the target areas are clearly lit-up so the player does not need to think about what he or she has to do next. By redirecting the entire focus of the player on the game, the player will no longer focus on himself or the passing time, leading to the distorted feeling of time and reduced concern for himself.

The game design is closely related to the seven points for flow by M. Csíkszentmihályi. Furthermore, in video games one major factor to set players into flow is music which has been thoroughly tested by Joshua D. Sites et al. [SP18]. In the designed game there is intentionally no music since there is a risk that the music strongly influences the player's experience. Some players might enjoy the music that would be chosen, while other players could be disturbed by it. Having no music might reduce the average flow experience but the expectation is to have more clear results.

4. User study

The participants in the user study receive a link to an online questionnaire. First, they have to answer a few questions about their personal information like age, gender, and how familiar they are with computer games. After that, they receive clear instructions about how the game is played as well as a download link for the game. The participants are informed, that they will be playing an adaptive version as well as a non-adaptive version of the game. However, they are not informed what the adaption features are. They are then asked to randomly choose one of the versions, without being informed which version they chose. After playing the first version of the game for at least five minutes, they are asked to fill in a questionnaire about general flow experience. After that, the participants should play the second version of the game. Finally, they should fill in the same questionnaire again. In the following, meaningful results will be presented as well as evaluated.

4.1. Results

The questionnaire about flow every participant had to fill in twice is taken from research by Kazuki Yoshida et al.[Yos+13]. In their release paper, they state that

> *"...this scale is specialized to measure the comparative change in flow, rather than absolute flow."*

Therefore, in this thesis, it will not be used to calculate the flow experience of individual players but rather to see the difference between the two versions of the game. Furthermore, the questionnaire was designed using leisure tasks with low physical activity and its validity for highly physical activities is unknown. This fits well with the task that has to be performed in the game created for this study. While the questionnaire was originally created for a medical context, it was tested and created using simple video games which guarantees the validity of the use-case required in this study. The questions are grouped in three categories, each corresponding to one of three major factors, namely "sense of control of the task", "experience of positive emotion", and "experience of absorption by concentrating on a task"
The questionnaire was made up out of the following 14 questions (Note: The actual

survey was conducted in German. The German questions used can be found in the appendix A.) Each question was answered on a scale between one and seven distributed as 1 Strongly disagree, 4 Undecided, and 7 Strongly agree.

Sense of Control

1. I had a sense of great control over everything I was doing
2. I felt that I could deal with whatever might happen next
3. I was aware of how well the task was going
4. I knew clearly what I wanted to do or what I should do at every moment
5. I knew how well I was dealing with the task
6. My abilities matched the challenge of what I was doing

Positive Emotional Epxerience

7. I had a meaningful time
8. I really enjoyed what I was doing
9. I wanted to do it again
10. The task was really boring

Absorption by Concentrating

11. I lost track of time while doing the task
12. I lost myself in doing the task
13. It felt like time passed quickly
14. It was easy to concentrate on what I was doing

In total 12 players participated in the survey, with one of them not completely filling out the questionnaire. Therefore, the following results are presented with n=11 participants. Note that all questions are worded in a positive way with 7 being the best and 1 being the worst answer in regards to flow. This includes question ten "The task was really boring" which is most likely due to the fact that boredom is the opposite of anxiety with anxiety being much worse than boredom for the flow experience. Since the participants were choosing the first version with which they would start at random, the distribution ended up to be eight players starting with the adaptive version to only three players starting with the non-adaptive version of the game. The full answers for the questionnaire after playing the adaptive version of the game can be seen in table 4.1 and the answers for the non-adaptive version of the game can be seen in table 4.2.

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Par. 1	5	5	7	5	7	6	4	5	3	2	1	1	3	6
Par. 2	5	5	5	5	3	5	3	2	2	6	3	2	3	6
Par. 3	3	2	5	2	5	4	1	5	7	6	3	5	6	5
Par. 4	4	4	6	4	6	6	3	6	6	2	2	2	4	5
Par. 5	6	7	7	6	7	6	1	2	1	4	1	1	4	7
Par. 6	5	6	5	7	6	4	5	5	7	3	5	5	4	4
Par. 7	6	5	7	7	5	6	5	5	6	2	6	4	7	7
Par. 8	6	6	6	3	3	7	4	5	6	2	4	4	4	6
Par. 9	3	3	7	7	6	3	3	6	6	2	7	7	7	7
Par. 10	4	5	3	6	4	5	6	6	5	3	5	2	7	7
Par. 11	4	5	6	2	6	5	2	2	2	6	2	2	2	5
Average	4,6	4,8	5,8	4,9	5,3	5,2	3,4	4,5	4,6	3,5	3,6	3,2	4,6	5,9

Table 4.1.: Results of the Adaptive Version

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Par. 1	4	5	6	7	6	6	4	5	2	2	2	2	5	5
Par. 2	3	2	5	3	3	4	1	1	1	6	3	2	2	6
Par. 3	6	7	7	4	7	5	6	6	7	3	5	5	6	6
Par. 4	3	2	6	5	6	3	3	4	6	3	2	2	4	6
Par. 5	6	5	7	3	7	7	1	3	2	4	1	1	4	7
Par. 6	5	4	5	7	6	5	5	6	6	2	5	5	3	5
Par. 7	5	4	6	7	7	6	5	6	7	1	5	4	7	7
Par. 8	5	5	5	6	5	5	6	6	5	2	4	4	5	6
Par. 9	2	1	6	6	7	4	2	5	5	3	4	6	4	6
Par. 10	2	4	3	7	4	4	5	7	5	3	5	1	6	6
Par. 11	3	2	5	4	6	3	1	1	1	7	1	1	1	4
Average	4,0	3,7	5,6	5,4	5,8	4,7	3,6	4,6	4,3	3,3	3,4	3,0	4,3	5,8

Table 4.2.: Results of the Non-Adaptive Version

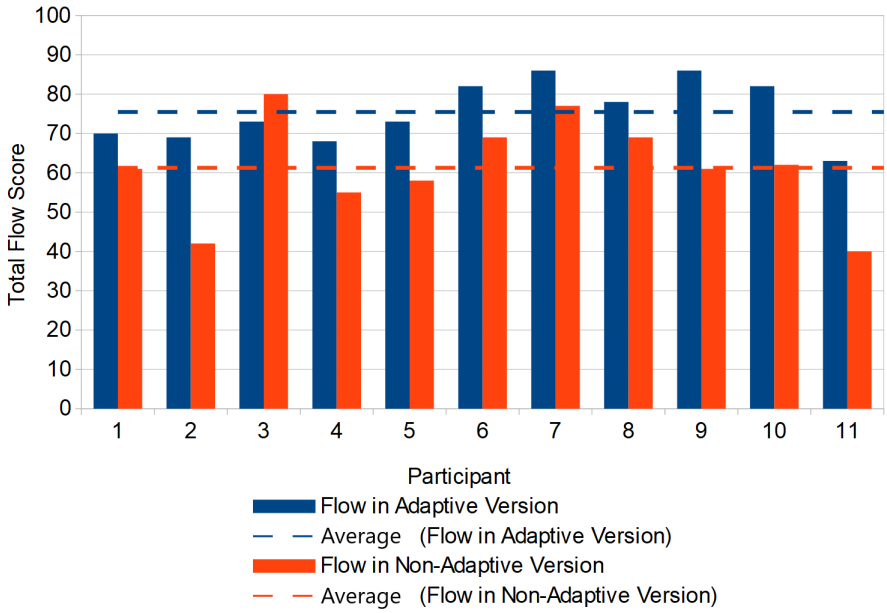

Figure 4.1.: Flow of each participant

4.2. Evaluation

To see the impact of adaptive difficulty on the flow experience of the participants there are different approaches. The most simple approach is, to sum up all answers and compare the results of each participant's questionnaire as seen in figure 4.1. The flow score refers to that sum. When adding all answers evenly weighted, all participants except participant three did reach a higher flow score in the adaptive version in the game than they did in the non-adaptive version of the game. Of course, as a consequence, the average flow score also increased by 14.2 from 61.3 to 75.5. When comparing the individual questions it can be seen that ten out of the fourteen questions had a higher average in the adaptive version of the game, while the remaining four (4,5,7,8) questions where lower. Especially for question number four "I knew clearly what I wanted to do or what I should do at every moment" this was most likely caused because significantly more participants chose to play the adaptive version first and therefore knew better what to do when they were playing the same game again without the adaptability afterward. For question five "I knew how well I was dealing with the task" the reason might be similar. The participants had a high score to compare their new score with from their first playthrough, leading to higher answers to this question.

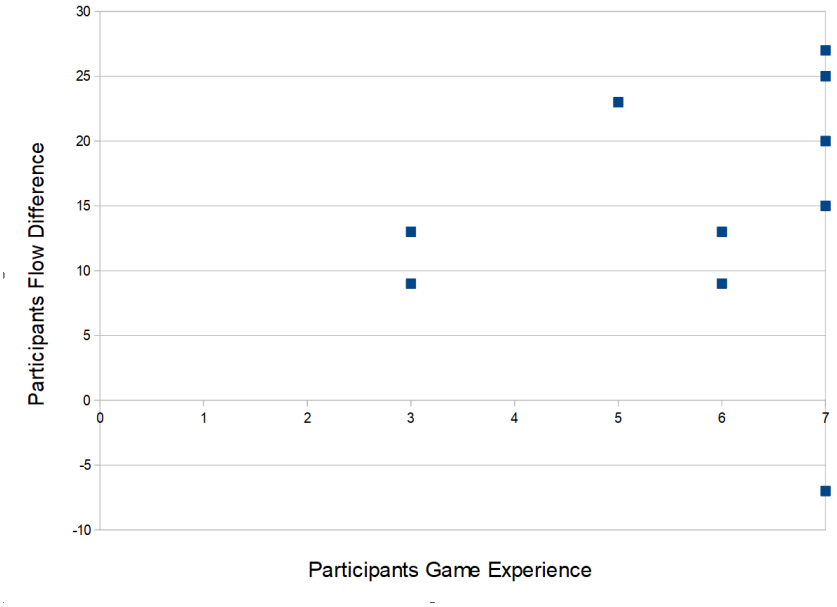

Figure 4.2.: Experience to Flow Difference

I would expect that the difference between those two values would be less if the study was taken by more participants and the distribution of which version is played first becomes more balanced towards 50/50. The difference for question numbers seven and eight is 0.2 and 0.1 respectively. I consider this insignificant since this difference could likely be caused by natural variation. The biggest difference shows for question number two "I felt that I could deal with whatever might happen next" with an average difference of 1.1. This complies with the expectation because this is one major focus of the adaptability of the game.

Figure 4.2 shows the difference in flow in relation to the participants' game experience. I expected that players with less game experience would feel a stronger difference in flow between the versions. This effect cannot be seen, in fact, it seems like the difference in flow is stronger for players with more game experience. However, this is a very vague statement due to the fact that only two participants of the study thought of themselves as inexperienced and is likely caused by the problem that there are not enough participants to answer this question representatively.

Besides the total flow score, the data can also be separated into the three major factors

Factor	Sense of Control	Positive emotional experience	Absorption by concentrating
Adaptive	0.73	0.58	0.61
Non-adaptive	0.70	0.57	0.58

Table 4.3.: Normalized and Weighted Factors

"Sense of control", "Positive emotional experience", and "Absorption by concentrating". Kazuki Yoshida et al.[Yos+13] also calculated a factor loading for each question in regards to these factors. To better understand the results I calculated the weighted average of each factor and normalized it. The values can be seen in 4.3. It can again be seen that each factor of flow improved in the adaptive version. The factor for "Positive emotional experience" improved only slightly, while the factors for "Sense of control" and "Absorption by concentrating" increased more. The adaptability of the game focused mainly on the first factor but the other two factors also increased as a consequence of a better flow experience.

Finally, it can be said that some expectations were met while other expectations cannot be proven with this study. When interpreting the data from this study, it always has to be considered that the participants are not representative for every group and a larger scale study would most likely offer more interesting insights and more reliable data.

5. Discussion

5.1. Experience of the Game

The general feedback suggests, that playing the game was a pleasant experience and most users felt some form of flow as can be seen in the evaluation section. Of course, I also talked with some of the players about their personal experience. A common complaint was, that the orange and the yellow lights were a bit hard to distinguish at first but after playing for a few minutes the players remembered which shade of the light was related to which color or mapped the positioning of the light to the according color. One player criticized that the art style was distracting him or her from the game experience while some other players stated that the art style added to the generally enjoyable experience of the game. When asked specifically about the adaptability of the game, most players said that they felt a difference mostly in the speed but they were not able to estimate the implementation of the algorithms, i.e. they did not know what was causing the circle to slow down. Since usually, a player does not change his or her skill level drastically while playing, the adaptive version of the game also behaved similarly each time the same player played it. Furthermore, the non-adaptive version of the game was set to a difficulty setting of a skilled player, therefore if a skilled player plays both versions he or she might not notice any major differences in the time available to him or her.
Contrary to my expectations, it seems that a bad player can achieve more points and a higher high score in the non-adaptive version of the game while a skilled player can achieve a better high score in the adaptive version of the game. The expectation was, that both players would perform better in the adaptive version of the game. However, because the scaling of points was proportional to the speed the unskilled players would end up with only very few points per completed task since the circle never sped up. On the other hand, in the non-adaptive version, the fast speed of the circle still granted many points, that could easily be more than ten times as many as the slow circle in the adaptive version of the game granted. While more tasks could be completed in the adaptive version, the high score was higher in the non-adaptive version of the game. This caused dissatisfaction for some players, because their competitive character lead them to play the non-adaptive version of the game, even though they thought that the adaptive version of the game was more fun (and also caused more flow according to

their questionnaire answers). For skilled players the scoring system worked as intended since the linear scaling of the points meant that once a certain speed of the circle was reached, a small increase in difficulty (i.e. speed) caused the task to reward only a few more points. Therefore completing more tasks on a high difficulty rewards more points than completing fewer tasks on a slightly higher difficulty e.g. if the speed = 0.5 increases by 5 to speed = 5.5 multiplies score times 11 while speed = 50 to speed = 55 multiplies score by 1.1. In hindsight, a square root function of the speed would most likely lead to a more fairly distributed score. In conclusion, it can be said that some minor improvements can be done to the game to improve the player experience. Nevertheless, the game definitely fulfilled the requirements that were necessary for this study by being able to cause flow for the players and be adaptive to a degree that is noticeable by most players.

5.2. Impact of Adaptive Difficulty on Flow

The key result of the study is the impact of the adaptive difficulty on the flow experience of the user. As can be seen, an appropriate challenge is one of the most important factors for engagement and flow and as a consequence of that, it is also one of the most important factors for fun or learning. Under the criteria of how good a game feels, flow is also the key factor for a game to be evaluated as a good game. The reason why this problem is historically hard to solve is, that different players have different skill levels and it is difficult for a game to provide the same experience to players of all skill level groups. Adaptable difficulty tries to solve this problem by offering a challenge appropriate to each individual player.
At the beginning the main question was defined as follows: "Can the flow state be achieved for every simple task and for every user by adapting the difficulty to the player's skill?" As to answer that question arguments will be presented that support the positive answer to this question as well as arguments that suggest the contrary. Firstly, you have to be aware that the flow state is not a discrete concept i.e. it is difficult to say whether a person is in the flow state or not because there is no clear borderline and players can be in between the flow state and normality and a player might also be "more" in the flow than another or experience the flow state differently. The results of the study show, that not every player reached the flow state as defined by M. Csíkszentmihályi due to some participants answering questions about some of M. Csíkszentmihályi key concepts with "strongly disagree" e.g. participant 1 answered question 11 "I lost track of time while doing the task" with "1 strongly disagree". However, it has to be considered that the task in the game is not necessarily representative because a player might not properly engage with the task and only complete it to participate in the study instead

of engaging with the task and focus his or her concentration on it. While not every player reached the flow state, the study shows that most players are leaning more towards the flow state in the adaptive version of the game. If discrete boundaries would have been set for certain answers to count as "being in the flow state" some players would have shifted from not being in the flow state towards being in the flow state by adding the adaptive difficulty. For the asked question it also has to be considered that it would prove to be difficult for every small task to add appropriate difficult adjustment and performance evaluation, especially if the task is not performed on a computer but instead is a real-life generic simple task. Finally, the difficulty is only one of the multiple factors for flow and a player certainly can be blocked from entering the flow state or have his or her experience altered through other external factors of all kinds. To answer the question, it can be said that adaptive difficulty is generally helpful to reach the flow state and to optimize a player's experience but it can not be used as the only factor to guarantee reaching the flow state.

5.3. Learning through Flow

Flow can increase learning efficiency and is a great tool for learning because it can also motivate a learner. In the work of Juho Hamaria et al. [Ham+15] it can be seen that the level of engagement of a player in the learning game is strongly related to the learning outcome. Furthermore, he or she found out that one major factor for the engagement of a player is the challenge of a task. If a task is challenging for the player, the player will be engaged in the task leading to a better learning outcome. This supports the evaluation of the study of this thesis. With the results of the study of this thesis, it can be suggested that the right difficulty of the learning task is very important for the flow experience of the learner. This results in the conclusion, that flow is a key factor for the efficiency of the learning process which is also supported by the results of the aforementioned paper [Ham+15].
The results imply that the difficulty of any learning process should carefully be adjusted to the skill of a learner to increase the learning effect. This implication is especially valid for serious games, where the difficulty of the learning task can often be adapted. Using automated performance evaluation algorithms and adjustable tasks or a repertoire of tasks with different difficulties, the player of a serious game can easier be set into the flow state to improve his or her learning and to optimize his or her experience with the game.

5.4. Accessability

The adaptive difficulty is a very important topic when talking about the accessibility of games. For commercial games, the target group of a game is often very specific and hugely impacts the game design as well as the difficulty of the game. As the results of the study show, it is possible to increase the flow for players with different skill levels. This implies that by using adaptive difficulty the range of players can be increased. Of course, different difficulty settings for different players are not a new concept but by taking away the responsibility from the player to be able to accurately evaluate their own performance many benefits arise. Proud players who do not want to play the game on an easy difficulty might not be able to enjoy a game with traditional difficulty selections because they might choose an inappropriately high setting. Other players simply might not know what the right difficulty for them is, especially if there are many difficulty settings to choose from. Having adaptive difficulty settings allows the player to have a more fine-grained adaption and even adapt different difficulty aspects of the game independently according to each individual player. Finally, the adaptive difficulty can also be useful at both ends of the player skill level spectrum. Depending on the game and the implementation, adaptive difficulty can be without boundaries for maximum or minimum skill. This can keep a very skilled and talented player satisfied but also help people with special needs due to physical or cognitive disabilities to enjoy the game experience at a level that fits their individual capabilities.

5.5. Addiction to Games

Addiction to video games is an important topic when thinking about the mental health of video game players. M. Csíkszentmihályi says that flow is pure happiness and the way to happiness is becoming an autotelic personality that constantly reaches the flow state [Csí02]. However, video game addicts, similar to gambling addicts, often say that they are experiencing the flow state and that the goal of their actions is to reach the flow state. Contrary to M. Csíkszentmihályis idea the people that are living out their addiction are not happy even though they are often reaching the flow state. Research by Ting-Jui Chou et al. [CT04] in that area suggests that flow is the main reason for addiction to video games or gambling and happiness is often only involved in the process to the addiction, but once a person has been addicted the happiness decreases and playing a video game helps the addict to reach the flow state but does not make him or her happy. Research by Damien C. Hull et al. [HWG13] even suggests, that addiction and happiness are inversely correlated i.e. the more addicted a person gets the less happy he or she is while playing games. It is important to distinguish between

happiness and flow for that reason. When creating a game that is only focused on the flow of the player e.g. by using adaptability in various ways but that is not considering the happiness of the player, the players of that game could be prone to addiction. The awareness of this issue should be raised so that more players can evaluate their own situation and in case of addiction consult a professional or receive other forms of help. Evaluation of happiness and flow are possible to a certain degree. It could be interesting to see if a game could accurately evaluate the flow and the happiness of a player because by doing this the game could detect low levels of happiness and therefore inform the player about a possible addiction to the game. However, this might be in conflict with the interests of the company behind such a game, since economically the addiction of a player is profitable for the company.

6. Conclusion

This thesis does not offer new research results compared to already existing scientific papers. Nevertheless, the study conducted for this thesis is a powerful demonstration of the effect of adaptable difficulty on the player's perception of the game and the flow state. The isolation of the single factor of adaptable difficulty for flow experience successfully showed expected results. It can clearly be seen, that adaptability of difficulty is a key factor for the flow state and therefore is very relevant for many other areas including accessibility, gaming addiction as well as general player experience. Making a game fun for every type of player is still a long shot but adaptive difficulty is a key factor for it. The study also showed that even though the adaptive difficulty is important it is not the only factor and it should not be the only factor that is considered when trying to set up a flow experience in a task whether that is in a game or any other task.

6.1. Future Work

The flow state is a very broad topic and research can be done in various areas depending on their interests and proficiency. Of course, the baseline is the flow state and how to reach it consistently for different people. Creating a similar study but instead of adapting the difficulty having other factors of flow adapting could potentially hold very interesting results which could eventually lead to games that can consistently bring people into the flow state, no matter who is playing the game. Combining flow research interdisciplinary, especially with psychology, is also a great setup for many new insights that could change our understanding of day to day life and especially education since flow is an important tool for efficient learning. Since every person spends years of their life, if not their entire life learning, optimizing the process could be very valuable. Using adaptability for accessibility is also very interesting. On the one hand to be inclusive towards people who could not play regular games otherwise and on the other hand to simply increase the target group of a game which can also be valuable for video game companies. Finally, the analysis of the flow experience of players could open up a path to software that tracks the addiction of the player. By carefully considering the impact of different game features and altering them the game could even adapt in a way that could help to prevent getting addicted in the first place.

Of course, there are more areas where flow research could be conducted since it is a common human state that everybody encounters in his or her life.

A. German Translation of the Questionnaire

The questionnaire used the scale "1 Stimme überhaut nicht zu" to "7 Stimme voll zu". Note that question number seven was written in both languages, since there is no accurate translation and this was the best approach to keep the integrity of the original questionnaire.

1. Ich hatte das Gefühl, dass ich zu jeder Zeit alles unter Kontrolle hatte.
2. Ich hatte das Gefühl, ich werde mit allem fertig was passieren könnte.
3. Mir war bewusst wie gut die Aufgabe voran ging.
4. Ich wusste zu jeder zeit genau was ich machen sollte.
5. Mir war bewusst wie gut ich die Aufgabe bewältige.
6. Meine Fähigkeiten entsprachen den Herausforderungen, die ich tat.
7. Ich hatte eine bedeutungsvolle Zeit. (I had a meaningful time)
8. Ich hatte Spaß, während ich die Aufgabe bewältigte.
9. Ich wollte es noch einmal machen.
10. Die Aufgabe war sehr langweilig.
11. Ich habe die Zeit vergessen, während ich die Aufgabe bewältigte.
12. Ich habe mich selbst vergessen, während ich die Aufgabe bewältigte.
13. Ich hatte das Gefühl, dass die Zeit schnell vergeht.
14. Es war leicht, mich auf das zu konzentrieren, was ich tat.

List of Figures

List of Tables

Bibliography

[19] *Blizzard entschuldigt sich für Hongkong-Kontroverse*. 2019. URL: https://www.sueddeutsche.de/sport/sport-blizzard-entschuldigt-sich-fuer-hongkong-kontroverse-dpa.urn-newsml-dpa-com-20090101-191102-99-547304.

[Csí02] M. Csíkszentmihályi. *Flow: The classic work to achieve happiness*. 2002.

[Csí90] M. Csíkszentmihályi. *Die Grundbedingungen für flow*. 15th ed. English title: The basic requirements for flow. 1990, p. 103.

[CT04] T.-J. Chou and C.-C. Ting. "The Role of Flow Experience in Cyber-Game Addiction." In: (2004).

[Ham+15] J. Hamaria, D. J. Shernoffb, E. Rowec, B. Collerd, J. Asbell-Clarkec, and T. Edwards. "Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning." In: (2015).

[Hun05] R. Hunicke. "The Case for Dynamic Difficulty Adjustment in Games." In: (2005).

[HWG13] D. C. Hull, G. A. Williams, and M. D. Griffiths. "Video game characteristics, happiness and flow as predictors of addiction among video game players: A pilot study." In: (2013).

[Juu11] J. Juul. "Fear of Failing? The Many Meanings of Difficulty in Video Games." In: (2011).

[Sch08] J. Schell. *The Art of Game Design*. 2008.

[SP18] J. D. Sites and R. F. Potter. "Everything Merges with the Game: A Generative Music System Embedded in a Videogame Increases Flow." In: (2018).

[SW05] P. Sweetser and P. Wyeth. "GameFlow: A Model for Evaluating Player Enjoyment in Games." In: (2005).

[Yee16] N. Yee. *Game Genre Map: The Cognitive Threshold in Strategy Games*. 2016. URL: https://quanticfoundry.com/2016/01/20/game-genre-map-the-cognitive-threshold-in-strategy-games/.

[Yos+13] K. Yoshida, K. Asakawa, T. Yamauchi, S. Sakuraba, D. Sawamura, Y. Murakami, and S. Sakai. "The Flow State Scale for Occupational Tasks:Development, Reliability, and Validity." In: (2013).