Cognitive Absorption: Analyzing and Comparing its Five Dimensions within Virtual Reality and Non-Virtual Reality Rhythm Games

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Preface

Before you lies my thesis "Cognitive Absorption: Analyzing and Comparing its Five Dimensions within Virtual Reality and Non-Virtual Reality Rhythm Games".

I would like to express my gratitude to all who contributed to the realization of this thesis, starting with the participants who filled out the questionnaire used in this study. I also want to thank dr. Maryam Alimardani for her excellent supervision during the process of writing my thesis. I have gained many insights from you on conducting research, which I will be using for the rest of my academic career. It was very pleasant having worked with you. Furthermore, many thanks go out to dr. Wendy Powell, who provided me with valuable feedback on the first version of this thesis. Lastly, I want to thank my fellow student Willeke van der Varst for going through the first steps of the thesis process together, as she also included questions related to her study in our shared online survey, after which our projects parted ways.

Cognitive Absorption: Analyzing and Comparing its Five Dimensions within Virtual Reality and Non-Virtual Reality Rhythm Games

Amy van Bijsterveldt

Virtual reality is becoming increasingly important within a plethora of domains in society. To learn more on human behavior when interacting with virtual reality, as opposed to non-virtual reality technologies, as well as providing new insights for the game development industry, a study was conducted analyzing and comparing the extent to which the five dimensions of cognitive absorption (temporal dissociation, focused immersion, control, curiosity, and heightened enjoyment) occur in three-dimensional versus virtual reality rhythm gaming. Evaluating games and their attributed technologies cross-platform by using cognitive absorption has not been done before. Accordingly, an online survey was distributed within a global community of rhythm gaming enthusiasts. Rhythm gaming is a subcategory within the action games segment that tests the player's sense of rhythm by connecting an in-game action to the beat of the music. Eligible participants were those who had experience playing both a dance pad rhythm game ('In the Groove', 'Dance Dance Revolution', 'Stepmania', 'Pump it up', et cetera), as well as a virtual reality rhythm game ('Beat Saber'). Results collected from the online survey suggest that, in contradiction to expectations, respondents prefer the three-dimensional rhythm games over its virtual reality counterpart for four out of five dimensions of the cognitive absorption construct. Solely the difference in focused immersion within both games was insignificant. This insignificance of focused immersion results might exist because most participants in the rhythm game community are more avid users of three-dimensional dance pad rhythm games as opposed to virtual reality rhythm games. This could be due to several factors: three-dimensional rhythm games have been available for much longer than 'Beat Saber' is; a dance pad is more affordable than a virtual reality headset; or the fact that participants simply view 'being more immersed' as a measure of their general affinity with the game. Due to COVID-19, an experiment setup with novice players could not be performed, which is why this study had to be converted into an online study. However, recruiting novice players might be an interesting topic for future research.

1. Introduction

Over the last decade, virtual reality has quickly become a commonly used technology, as it can be implemented for an incredible wide and diverse range of purposes: businesses use it to train their employees as it saves time and money, schools use it because virtual reality (for children) can help broaden the imagination and stimulate interest in specific topics – virtual reality has even been adopted by governmental bodies like the military to prepare soldiers for the battlefield without having to face the real-world risks. Another application for virtual reality is found in the entertainment industry, more specifically in the game development sector. As virtual reality is fully immersive, engaging, and interactive, users are found to be more likely to play the game again (more on this in the 'Related Work' section of this paper).

This study focuses on how the five dimensions of cognitive absorption play a role in virtual reality games versus three-dimensional, non-virtual reality games. Cognitive absorption, in the context of information technology (IT), is a conceptual construct described in a 2000 paper by Agarwal and Karahanna. Agarwal and Karahanna (2000) developed the measures for cognitive absorption based on reported user experiences with the World Wide Web. Even though Agarwal and Karahanna (2000) were first to translate cognitive absorption into a measure for user experience with IT, the original conceptualization of the construct was a result of the work of many other researchers in the fields of cognitive and social psychology, which is further explained in the 'Related Work' section of this report. Nowadays, however, the theory of cognitive absorption is widely used to put users' reported opinions on software usability, enjoyment, and immersion into perspective, which, together, can be defined as 'overall user experience'. Summarizing the purpose of the cognitive absorption construct: having the ability to evaluate overall user experience and, if possible, enhance it. For a more detailed overview of the five dimensions of cognitive absorption and their application in this study, please refer to 'Related Work' and 'Methods'.

Furthermore, this study is directed at rhythm games specifically. Rhythm (video) games make up a genre within a wide range of action video games, as they are especially focused on testing a player's sense of rhythm. Some rhythm games make use of an input device that is ought to emulate a musical instrument. In this study, however, the focus lies on three-dimensional rhythm games that use dance pads (in which case the player has to step on a certain area of the pad in order to achieve points, usually corresponding to some sort of visual input displayed on a screen in front of the player). Examples of such games are 'In the Groove' (2004)[1], 'Dance Dance Revolution' (1998)[2], 'Stepmania' (2001)[3] and 'Pump It Up' (1999)[4], however, more three-dimensional dance pad rhythm games are available – these are just the most popular ones. Not many virtual reality rhythm games have been developed up to this day. In fact, only one proved suitable to be used as a virtual reality rhythm game counterpart in this study: 'Beat Saber' (2019)[5]. The game 'Beat Saber' is compatible with a wide range of virtual reality headsets and uses two tracked touch controllers that give the player hand presence. For details on the controls and goals of both the virtual reality and non-virtual reality, three-dimensional rhythm game(s), please refer to the 'Methods' section.

Prior to this study, a limited amount of research has been conducted evaluating and comparing the significance of the five cognitive absorption dimensions in video games. Even less studies took rhythm games as the subject of their research, none of them using cognitive absorption as a measure to evaluate and compare the results cross-platform (virtual reality versus non-virtual reality). Cognitive absorption not only measures perceived immersion; it also measures the level of control users experience during gameplay - which is especially relevant for this study, as the manner in which the three-dimensional rhythm game is played differs a lot compared to the way in which the virtual reality game is played on a physical level. Measuring to what extent players feel

1 https://en.wikipedia.org/wiki/In_the_Groove_(video_game)
2 https://en.wikipedia.org/wiki/Dance_Dance_Revolution
3 https://en.wikipedia.org/wiki/StepMania
4 https://en.wikipedia.org/wiki/Pump_It_Up_(video_game_series)
5 https://en.wikipedia.org/wiki/Beat_Saber

the dimensions of cognitive absorption are present during gameplay also contributes to suggesting improvements in order for them to enjoy the game even better, which, in turn, is relevant for the game development industry. Moreover, if it is possible to pinpoint what exactly makes a three-dimensional or virtual reality game attractive and enjoyable for people, we can use that information to provide a methodology for future research into human behavior and how it shapes the way in which they interact with 'regular' three-dimensional technology as compared to virtual reality technology. For rhythm games specifically, this could also prove its relevance for learning purposes. An example: for beginner music students who experience problems from their poor sense of rhythm, and whether they could benefit from playing rhythm games, this study serves as a foundation for the argument that improving sense of rhythm is more useful using a three-dimensional environment as opposed to virtual reality technology – or the other way around.

To find participants for the study, an online questionnaire was distributed into a global community of rhythm game enthusiasts, with the necessary condition that participants had experience playing both a three-dimensional, non-virtual reality rhythm game, as well as a virtual reality rhythm game. Participants were presented with statements that made them reflect on their previous experiences playing the games in the context of cognitive absorption. Results suggested that for four out of five cognitive absorption dimensions, the three-dimensional rhythm game was preferred over its virtual reality rhythm game counterpart, thus surprisingly contradicting the findings of previous studies on human behavior using virtual reality.

2. Related Work

The conceptual construct of cognitive absorption was derived from the findings of Tellegen and Atkinson (1974) on 'absorption' as a human characteristic, a paper by Webster and Ho (1997) that explored cognitive engagement during multimedia presentations, and a manuscript by Csikszentmihalyi 1990, pg. 4, who introduced 'the state of flow' in his work as 'the state in which people are so involved in an activity that nothing else seems to matter'. The theory of cognitive absorption in the context of information technology, based on those three studies, is introduced and defined as 'a state of deep involvement with software' by Agarwal and Karahanna 2000, pg. 665. Utilizing cognitive absorption, they suggest the possibility of evaluating user experiences with information technology using a holistic approach. Agarwal and Karahanna (2000) propose a measure for their theory, which results in a series of statements targeting user experience in general. These statements, which are to be evaluated by users of the software to report the extent to which they feel they agree with them, are subdivided specifically into the five dimensions of cognitive absorption: temporal dissociation, focused immersion, control, curiosity, and heightened enjoyment. An overview of descriptions of each dimension is found in Table 1.

The generalizability of the cognitive absorption theory and appurtenant measurement was confirmed by empirical testing, using the World Wide Web as the target technology. However, this might also be one of the limitations of their study, as they (Agarwal and Karahanna 2000) did not have the opportunity to apply their theory to other information technologies. Also, their experiment concerning the World Wide Web involved a participant pool of students only. Considering that cognitive absorption in their paper - alongside its five dimensions - also involved perceived usefulness (the degree to which the user finds the information technology to make the task at hand easier to accomplish) and perceived ease of use (the degree to which the user finds

Table 1: An overview of the five dimensions of cognitive absorption and their definitions by Agarwal and Karahanna 2000, pg. 673.

CA Dimension	**Definition**
Temporal Dissociation	The inability to register the passage of time while engaged in interaction
Focused Immersion	The experience of total engagement where other attentional demands are, in essence, ignored
Control	The user's perception of being in charge of the interaction
Curiosity	The extent the experience arouses an individual's sensory and cognitive curiosity
Heightened Enjoyment	The pleasurable aspects of the interaction

the information technology to be easy to use), the results of Agarwal and Karahanna (2000) experiment might have been slightly biased, as an average student in the present student population is naturally more proficient and fluent in their interaction with information technology compared to other populations of society - simply because of the era in which they were born and the substantial amount of exposure they already had and continue to have to technology. However, at least one of these concerns has been diminished by further experimental research. Saadé and Bahli (2005) applied cognitive absorption measurement to the adoption of online learning platforms. The researchers asked university students of an undergraduate-level course to use an online learning platform for the duration of the course. Eventually, they were asked to fill out a questionnaire on their experiences with the platform. The results of the questionnaire confirmed the measurement methods of cognitive absorption to be valid, as cognitive absorption proved to be a crucial precursor to perceived usefulness of the online learning platform, however, it was less crucial to perceived ease of use. Whilst Saadé and Bahli (2005) prove that applying cognitive absorption measurements is not limited to the World Wide Web only, they might have faced the same limitation as Agarwal and Karahanna (2000) did in their paper: using a student population only that finds an online learning platform as such naturally easy to use – which likely explains the difference in significance between perceived usefulness and perceived ease of use.

Other research into cognitive absorption in the first decade of this century has mainly focused on the possible limitations of the cognitive absorption theory and how to find antecedents that might influence to which extent humans feel cognitively absorbed when using information technology. A paper by Zhang and Li (2005) studied the importance of perceived affective quality (PAQ) when humans are involved with IT. Research in the field of Human-Computer Interaction (HCI) found that perceived affective quality is important in user acceptance of software: the higher a person's preceding expectations of the software, the better they evaluate 'level of usability' when they eventually interact with it. Zhang, Li, and Sun (2006) later found that perceived affective quality is one of those antecedents with a causal relation to the level of cognitive absorption humans experience.

Cognitive absorption as a measure to examine information technology and user acceptability has been used for a variety of information technology already: Negut, Jurma, and David (2017) have used the theory to test virtual reality-based attention assessment of ADHD. Lin (2009) has used the construct to find out whether the extent to which someone is being cognitively absorbed influences their intentions to join a virtual community. Conrad and Bliemel (2016) explored the extent to which students feel cognitively absorbed using e-learning applications by theorizing a relationship between, amongst other constructs, the construct of cognitive absorption and electroencephalography (EEG) signals.

Cognitive absorption in video games has also been thoroughly explored by several researchers. Sepehr and Head (2011) conclude that competitiveness in video games plays a large role in the extent to which players feel cognitively absorbed. Seah and Cairns (2008) found a correlation between the level of feeling cognitively absorbed and the chances of developing a video game addiction: the bigger the player's feeling of being cognitively absorbed was, the higher their chances of developing a gaming addiction. The causality between cognitive absorption and developing an addiction is not only applicable to video games: other (recent) studies have shown that cognitive absorption can lead to general problematic information technology usage (Jia, Hartke, and Pearson 2007), problematic internet usage (Bozoglan, Demirer, and Sahin 2014) and, in the case of social media, a smartphone addiction (Barnes, Pressey, and Scornavacca 2019).

More recent literature has demonstrated that, even though feeling cognitively absorbed can have downsides for certain susceptible users of information technology, feeling cognitively absorbed when playing action video games can also lead to improvement of one's cognitive abilities, such as learning and attentional control (Green and Bavelier 2012). An exploratory study by Novak and Tassell (2017) builds on the findings by Green and Bavelier (2012) by developing an instrument ('Action Video Game Characteristics') which makes it simpler to distinguish action video games that contribute to a reinforced learning curve for players' cognitive abilities from other action video games without such ability. Kampling (2018) used a qualitative, Grounded Theory approach to establish the 'focused immersion' construct of cognitive absorption being of utmost importance for improving the individual learning process in immersive virtual reality environments.

Feeling immersed and having a perceived sense of interactivity in an environment not only benefits learning processes, it also makes the activity more enjoyable (Jung 2014; Gonzales, Finley, and Duncan 2009). Jang and Park (2019) suggest that this is also the case for fully immersive virtual reality, as they developed a model for user acceptance of virtual reality games. Moreover, physical activity within an immersive, virtual reality environment – which is applicable to 'Beat Saber' as well – improves the psychological advantages and mood benefits of exercise (Plante et al. 2003a,b; Mestre et al. 2011). Furthermore, as virtual reality is deeply engaging, it helps to maintain motivation for maintaining physically active (IJsselsteijn et al. 2004).

Concluding, prior research has demonstrated the efficacy of the cognitive absorption construct for evaluating user experiences with information technology, which has led to more experimental studies on cognitive absorption in virtual reality and (virtual reality) gaming. In line with this theoretical framework, we may expect the outcome of the current study to suggest a strong preference for virtual reality rhythm gaming over three-dimensional rhythm gaming. Hence, the research question and corresponding hypotheses of this study are the following:

RQ: To what extent does the construct of cognitive absorption and its five dimensions play a role in user experience when playing a virtual reality rhythm game compared to a non-virtual reality, three-dimensional rhythm game?

H_0: The extent to which rhythm gamers feel cognitively absorbed in virtual reality rhythm games versus non-virtual reality, three-dimensional rhythm games is similar.

H_1: Rhythm gamers will feel cognitively absorbed to a larger extent when playing a virtual reality rhythm game as opposed to a non-virtual reality, three-dimensional rhythm game.

3. Methods

3.1 Rhythm Game Specifics

The three-dimensional rhythm games that are referred to in this study are games as, for example, 'Stepmania', 'In the Groove', 'Dance Dance Revolution' and 'Pump it Up'. There is a plethora of rhythm games available, out of which these four are best-known among gamers. However, any rhythm game that is played on a dance pad qualifies for this study. An example of an 'arcade dance pad machine' can be seen in Figure 1 [A], however, most dance pads on the market are portable versions of the arcade machines – yet their functionality remains unchanged.

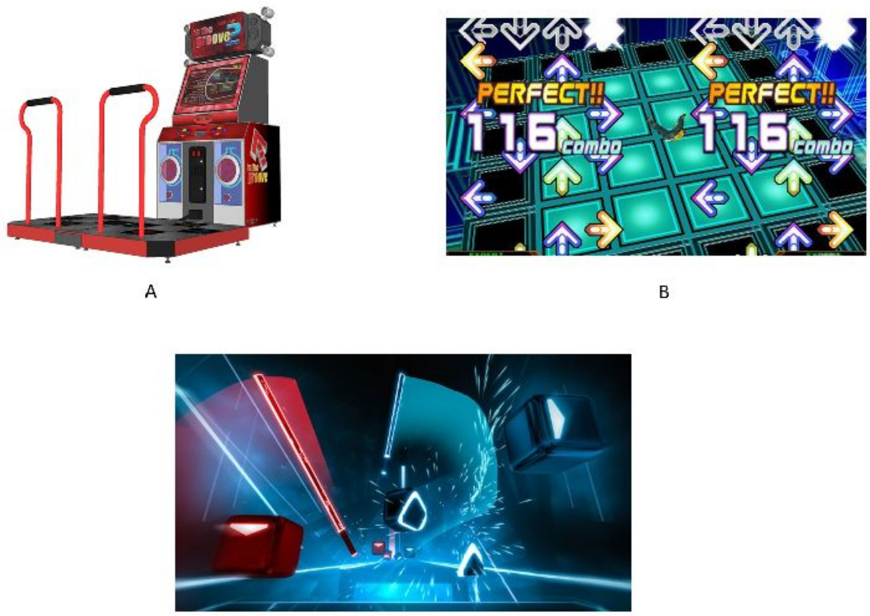
In Figure 1 [B], a still image of such a rhythm game's gameplay illustrates the goal in three-dimensional rhythm games. Arrows appear at the bottom of the screen, facing either up, down, left, or right. The player must step on the corresponding arrow on their dance pad exactly when the on-screen arrow hits the 'arrow template' on top of the screen. The more accurate the player's timing, the higher their score. As it is a rhythm game, the timing of the ascending arrows is subject to the beat of the music.

This is also the case for the game 'Beat Saber'. This is currently the only virtual reality rhythm game eligible for comparing the level of cognitive absorption to three-dimensional rhythm games' level of cognitive absorption. Beat Saber is compatible with a wide range of virtual reality headsets; however, it requires a pair of tracked controllers to play. The goal of 'Beat Saber' is similar to the three-dimensional variants: achieving the highest possible score by using the hands to slash incoming, virtual cubes in the appropriate direction. An arrow, pictured on each cube, informs the player in which way it needs to be cut in half using their hands (which are represented by two light swords). Since 'Beat Saber' is a virtual reality game, the environment in which the gameplay happens is fully immersive, as can be seen in Figure 1 [C].

3.2 Participants and Survey

An online survey was created using Qualtrics, with questions (converted into statements to allow for more profound answers using a Likert scale) drafted from a combination of other, existing questionnaires: the Game Engagement Questionnaire by Brockmyer et al. (2009), the Discrete Emotions Questionnaire (Harmon-Jones, Bastian, and Harmon-Jones 2016), but primarily from the Cognitive Absorption Questionnaire (Agarwal and Karahanna 2000). As the Cognitive Absorption Questionnaire was developed in 2000, when virtual reality was not yet used for gaming purposes by the wider public, some statements in that questionnaire were irrelevant for the current study and had to be updated to suit the purpose of this study. The Game Engagement Ques-

Figure 1: [A] An arcade machine for playing three-dimensional rhythm games such as ‘In the Groove’, ‘Stepmania’, ‘Dance Dance Revolution’ and ‘Pump it Up’. [B] A still image of rhythm gameplay from games such as ‘In the Groove’, ‘Stepmania’, ‘Dance Dance Revolution’ and ‘Pump it Up’. [C] A still image of rhythm gameplay from the game ‘Beat Saber’.



A B

C

tionnaire and Discrete Emotions Questionnaire, both developed more recently than the questionnaire by Agarwal and Karahanna (2000), provided options to accomplish these alterations.

Each statement was attributed to specifically one (out of the five) cognitive absorption dimension(s). A seven-point Likert scale was used to assess the level to which participants agreed with the statements, with the lowest number (‘one’) equaling ‘I don’t agree at all’ and the highest number (‘seven’) equaling ‘I completely agree’. The questionnaire, as well as its statements, did not include any information on the five dimensions of cognitive absorption, nor the construct in general. This would not be of additional value to the participants and could only make it more confusing for them whilst filling out the survey. A copy of the questionnaire used can be found in Appendix A.

Participants were drafted by distributing the online survey into a global community of rhythm game players. One important requirement for being able to participate in this research is having experience in playing both a three-dimensional dance pad rhythm game (‘Stepmania’, ‘In the Groove’, ‘Dance Dance Revolution’, ‘Pump it Up’, et cetera) as well as its virtual reality counterpart (‘Beat Saber’). A digital consent form was presented to the participants which stated their right to withdraw from participation in the study at any given moment. The participants were made aware of the fact that the collected data was anonymized to ensure privacy protection. After answering several questions concerning demographic information (age, gender, ethnicity, home country, and educational level) as well as questions targeting each participant's levels of experience in three-dimensional and virtual reality rhythm gaming, participants had the option to watch a short video which showed a demonstrator playing Beat Saber. The purpose of the video was to remind participants what it is like to play the game and to possibly evoke the emotional state the participants would have found themselves in if it were them playing the game – or at least help them reflect on their experiences with the game more effectively and in-depth. Next, participants were asked to fill out the modified Cognitive Absorption questionnaire for the game Beat Saber. Subsequently, the same thing was done for the three-dimensional rhythm game. Following a short video containing a demonstration, participants had to fill out the exact same questionnaire for the three-dimensional rhythm game – after which the survey ended.

4. Results

4.1 Demographics and Experience

After distributing the survey, seventy-eight responses were returned of which some were incomplete. Eventually, sixty-three responses were used for this study, which included forty-nine males, twelve females and two respondents who do not identify as either male or female. The mode in respondent age is twenty-six to thirty years old. A complete overview of age distribution can be seen in Figure 2 (a). Furthermore, in Figure 2, more information is also depicted on participants' ethnicities (b), home locations (c), as well as their educational levels (d).

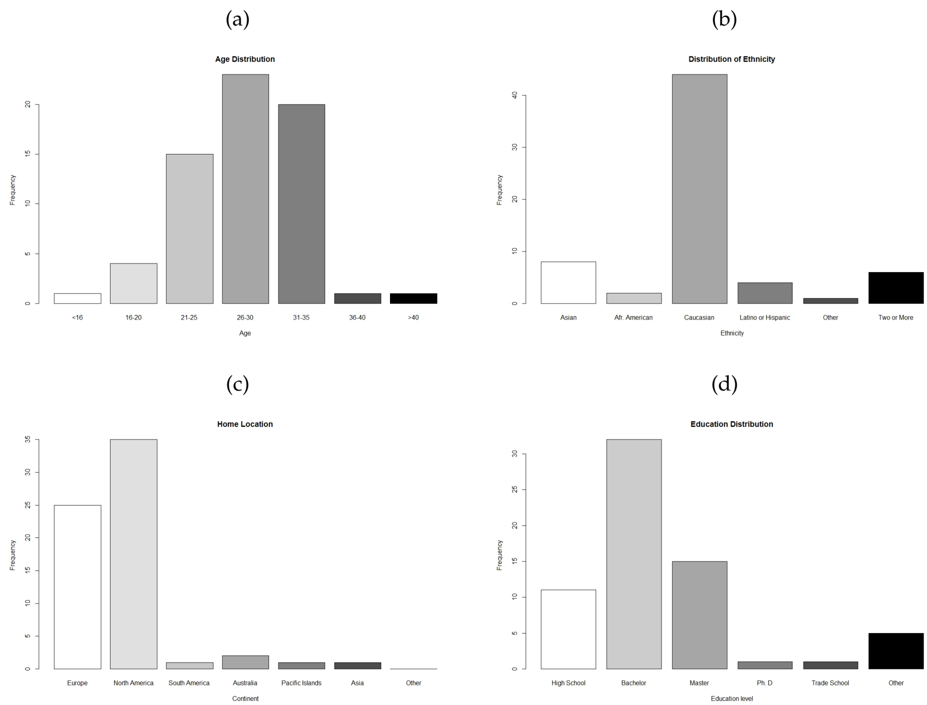
As participants' level of experience was measured using a seven-point Likert scale ('one' meaning 'almost no experience' and 'seven' equaling 'extremely experienced'), the maximum score is seven. Participants' mean experience with three-dimensional rhythm gaming was 5.952 (SD = 1.3), whereas participants reported their experience with 'Beat Saber' to be much lower (M = 2.635, SD = 1.451).

4.2 Comparing cognitive absorption scores between both game types

To answer whether players are more cognitively absorbed in either three-dimensional rhythm games or virtual reality rhythm games, the scores per cognitive absorption dimension were subjected to a t-test for analysis. In case of non-normally distributed data, a Wilcoxon signed-rank test was used. In order to establish whether data was either normally or non-normally distributed, a Shapiro-Wilk test was performed. In the following section, the questionnaire scores of each cognitive absorption dimension and appurtenant results will be reported individually. Multiple boxplots, illustrating participant scores per cognitive absorption dimension for each platform (virtual reality and three-dimensional, non-virtual reality) are given in Figure 3.

4.2.1 Temporal Dissociation. As the temporal dissociation scores were non-normally distributed, a Wilcoxon signed-rank test was performed. This test indicated that the difference in feeling temporally dissociated between a dance pad rhythm game and a virtual reality rhythm game was significant (Z = -5.153, p < .001), with participants feeling temporally dissociated to a larger extent when playing a three-dimensional rhythm game as opposed to a virtual reality rhythm game.

Figure 2: Participant distribution of (a) age, (b) ethnicity, (c) home location and (d) educational level.

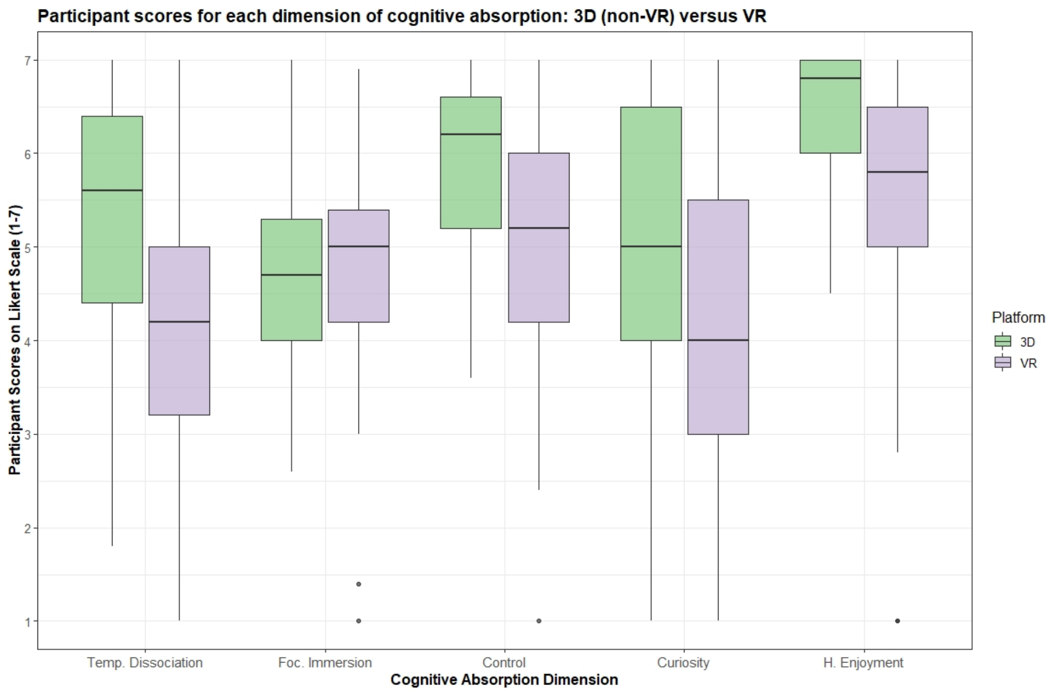


4.2.2 Focused Immersion. The focused immersion scores proved non-normally distributed. Therefore, a Wilcoxon signed-rank test was performed. The difference in focused immersion between both game variants turned out to be insignificant (Z = -0.544, $p > .05$).

4.2.3 Control. A Wilcoxon signed-rank test was performed on the control scores, which indicated that the difference in control the participants feel when playing a dance pad rhythm game compared to a virtual reality rhythm game is significant (Z = -5.163, $p < .001$). Participants felt more in control playing a non-virtual reality rhythm game as opposed to a virtual reality rhythm game.

4.2.4 Curiosity. As the data was once again non-normally distributed, the data was subjected to a Wilcoxon signed-rank test. It proved to be the case that the difference in participants feeling curious about both game variants was significant (Z = -2.968, $p < .01$). The extent to which participants felt curious was larger for dance pad rhythm games than it was for the virtual reality rhythm game.

Figure 3: Multiple boxplots illustrating participant scores per cognitive absorption dimension for each platform (virtual reality and non-virtual reality, three-dimensional).



4.2.5 Heightened Enjoyment. The scores for the heightened enjoyment dimension of cognitive absorption were normally distributed. Therefore, a paired samples t-test was conducted. The results of the t-test showed that the difference in heightened enjoyment for both game types was significant ($t(64) = 4.937$, $p < .001$, 95% CI = [2.13, 5.01]) with participants enjoying three-dimensional rhythm games ($M = 25.69$, $SD = 2.88$) better than a virtual reality rhythm game ($M = 22.12$, $SD = 5.45$).

5. Discussion

This study aimed to establish to what extent the five dimensions of the cognitive absorption construct (Agarwal and Karahanna 2000) are experienced in three-dimensional game pad rhythm games versus virtual reality rhythm games, in order to provide more insights on overall user experience for the game development industry, as well as further knowledge into human behavior when interacting with information technology.

5.1 Three-dimensional rhythm gaming preference over virtual reality rhythm gaming

The scores for each dimension of cognitive absorption for the three-dimensional rhythm games and virtual reality rhythm game separately suggest that, disregarding few outliers, participants seem satisfied with their overall user experience in both games. However, when comparing the scores for both games per cognitive absorption dimension, it can be deemed quite remarkable that participants preferred the ‘traditional’ dance pad rhythm games over ‘Beat Saber’ for four out of five cognitive absorption dimensions -

considering that virtual reality with its three main characteristics (immersion, presence, and interactivity) is practically always preferred over information technologies with the same purpose, but without the possession of these characteristics (Mütterlein 2018). Nonetheless, H_0, as stated in the section 'Related Work', can be rejected. However, the expected outcome - based on previous studies and other literature - that participants would feel cognitively absorbed to a larger extent in the virtual reality modality as opposed to the non-virtual reality modality (as described in H_1), proves incorrect for rhythm games. In the following part of the 'Discussion' section of this report, possible explanations for this surprising outcome will be outlined.

5.1.1 Participant age. As mentioned before in the 'Results' section, the most frequent participant age group in this study is twenty-six to thirty years old. Even though the concept of virtual reality was already invented by Morton Heilig in 1957, the first commercial virtual reality headset prototype (Oculus Rift) became available only ten years ago, in 2010 (Poetker 2019). This could explain why this age group prefers non-virtual reality rhythm games over virtual reality rhythm gaming: they did not grow up with virtual reality as a common technology, however, they did grow up with three-dimensional rhythm games, as those were available worldwide in 1998 already.

5.1.2 Release date. As three-dimensional dance pad rhythm games have been on the market substantially longer than 'Beat Saber' (2019) is, it is only logical that participants generally have less experience playing 'Beat Saber' than they have playing three-dimensional rhythm games, which was also confirmed by the results of the survey. The difference in release date might therefore account for (part of) the participants' preference for dance pad rhythm games over 'Beat Saber'.

5.1.3 Technology affordability. In line with the reported experience scores for both games, another factor that should be considered in accounting for the preferential difference is technology affordability. As virtual reality headsets are relatively expensive compared to dance pads, it is possible that participants hardly had a chance to play 'Beat Saber', as they might not be able to afford a virtual reality headset themselves, and therefore, prefer dance pad rhythm gaming over its virtual reality counterpart. This would also be in line with the reported experience scores.

5.1.4 Community size. As three-dimensional rhythm gaming exists substantially longer than virtual reality rhythm gaming, its community is also much larger than the 'Beat Saber' community is. The preferential difference might be due to gamers' desire to join a large(r) community.

5.2 Focused immersion: insignificant results

Another unexpected outcome was the insignificance of the focused immersion dimension between three-dimensional rhythm gaming and virtual reality gaming. Participants did not feel any more immersed in the virtual reality game as they did in the non-virtual reality game, even though, according to previous experimental studies (also mentioned in the 'Related work' section of this report), participants almost always felt more immersed in a virtual reality environment as opposed to a non-virtual reality environment. Some factors that could account for the insignificant focused immersion results are listed below.

5.2.1 Misinterpretation. It is possible that participants have misinterpreted the statements attributed to 'focused immersion' when filling out the survey and confused or associated the statements related to this concept with the amount of (physical) effort they put in when playing either of the games. Unfortunately, there is no option to check whether this was truly a factor for the insignificant focused immersion results. Moreover, there was little that could have been done to prevent any possible misinterpretations from occurring, as this was a survey conducted online and not in-person. An in-person survey and experiment would have given participants the opportunity to confirm whether they understood all questions and statements sufficiently, however, this was unfortunately not possible due to COVID-19 (please refer to 'COVID-19' in this section).

5.2.2 Physical activity. Another possible influence on the insignificance of immersion results could be the participants' differences in experience on a physical level. A three-dimensional dance pad rhythm game is far more physically demanding, as it requires the player to use their entire body because of the foot movement involved, as opposed to just moving the arms in 'Beat Saber'. Perhaps, onerous physical activity is an antecedent of feeling more immersed automatically. This would make an interesting topic for future research into virtual reality (gaming) involving physical activity.

5.3 Limitations and shortcomings

The current study design has some limitations and shortcomings which should be acknowledged.

First of all, as the survey was conducted online, there is no possibility to confirm whether all respondents actually have experience playing both a three-dimensional dance pad rhythm game and the virtual reality rhythm game counterpart. This is a shortcoming that, unfortunately, cannot be resolved.

Secondly, one limitation of the study design is that it relies on past experiences of rhythm game enthusiasts. However, if the questionnaire had been administered directly after participants played both games, results would most likely prove slightly different from what they are now, since the study would not rely on replicating participants' emotional state right after playing rhythm games, but instead, it would be fresh in their memory.

Finally, another limitation of the study is caused because of a lack of virtual reality rhythm games that more accurately resemble three-dimensional rhythm games on a physical level. 'Beat Saber' is controlled by hand movement, which is fundamentally different from the way in which dance pad rhythm games are played. This is a possible confounder in the results which is unaccounted for at this time. If a virtual reality rhythm game is developed which is also controlled using foot movement, it would be possible to exclude this limitation in a future study.

5.4 COVID-19

The original study design, described in the next paragraph, was considerably different from the current study design, but unfortunately, could not be carried out because of the COVID-19 pandemic. However, for future research, it would be an interesting setup which may result in an even deeper understanding of human behavior when interacting with virtual reality.

The study would not have taken place online, but instead, would have involved recruiting a first group of participants who had little to no experience playing rhythm games and another group that have plenty of experience with both three-dimensional and virtual reality rhythm games. All two participant groups would have had to play both a dance pad rhythm game as well as 'Beat Saber' (a within-subject design) and fill out the cognitive absorption questionnaire directly afterwards. The content of the cognitive absorption questionnaire would not have been different from its current form. Another topic of interest would have been the influence of the 'background music' (on which both rhythm games are played) on participants' performance.

6. Conclusion

By using the theory of cognitive absorption as a measure to evaluate user experience with three-dimensional rhythm games and virtual reality rhythm games, it can be concluded that experienced players of these games tend to prefer the three-dimensional variant over its virtual reality counterpart. This result opens many doors for follow-up research questions; however, it might also be seen as somewhat worrying for the game development industry. Perhaps virtual reality has no future in the gaming industry in its current form as players are not absorbed sufficiently. Perchance, this could be the case for rhythm games only, which could be determined by performing a double study comparing levels of cognitive absorption between video game genres.

These findings also prove its value to further research into human behavior when interacting with information technology. More specifically, this study contributes to the existing knowledge in the field of Human-Computer Interaction. Based on the outcomes of this research – the difference in scores for the 'focused immersion' dimension was insignificant between three-dimensional and virtual reality rhythm games – it could be the case that virtual reality is not 'sufficiently immersive' for people anymore – maybe more or other stimuli are needed to captivate humans during their interaction with technology, even though virtual reality is already extraordinary immersive.

7. Self-reflection

This 'Self-reflection' section of the report is divided into three subsections to reflect more accurately on each stage with regards to the predefined learning goals of the bachelor thesis.

7.0.1 Constituting a research proposal. As I already have some experience in doing research and writing reports, it did not come as a surprise to me that the hardest part of the entire process of writing this thesis was coming up with a good research question. It truly helped that I could focus on just the Human-Computer Interaction domain after being allocated dr. Maryam Alimardani as my supervisor. However, within this broad field, it is still remarkably difficult to construct a good research question that also impacts both the cognitive science and artificial intelligence domains.

After establishing that I was going to focus on cognitive absorption in virtual reality versus non-virtual reality, I really enjoyed doing a thorough literature review of the subject. Still, as I considered all literature that I found interesting, I really had to learn how to exclude the literature that was only remotely connected to my research topic.

Eventually, I drafted the research proposal which described the original study design. Unfortunately, this study design was changed a couple of weeks later due to the COVID-19 pandemic and the adapted study design could not be included in the research proposal anymore.

7.0.2 Drafting the survey and collecting data. The second step in the process was drafting the online survey that was eventually distributed into a global community of rhythm game players. This is what I found to be one of the easier steps in the process. Constructing a survey that has to be complete (as you can only distribute the survey link once) and without any ambiguity (as respondents cannot just ask a question whenever they feel like it) took some time, but it ended up being a well thought out survey.

After distributing the survey link, it was simply waiting for the results to come in. Since I did not know the amount of responses to expect, I was surprised that as much as seventy-eight responses were recorded.

7.0.3 Analyzing data and writing the report. Writing the 'R' code for the statistical analysis of the data proved fairly straightforward. Writing the report, however, was more difficult than I thought it would be. It took me quite some time to be satisfied with my writing. I learned that it takes time to write a structured thesis and that time management is extremely important.

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Appendix A: Questionnaire

1.1 Temporal Dissociation

TD1: Time appears to go by very quickly when I am playing the game.
TD2: Sometimes I lose track of time when I am playing the game.
TD3: Time flies when I am playing the game.
TD4: Most times when I start playing the game, I end up spending more time than I had planned originally.
TD5: Most times when I play the game, I do not want to stop.

1.2 Focused Immersion

FI1: While playing the game, I am able to block out most other distractions.
FI2: While playing the game, I am absorbed in what I am doing.
FI3: While playing the game, I feel immersed in the environment.
FI4: While playing the game, I do not get distracted by other attentions very easily.
FI5: While playing the game, my attention does not get diverted very easily.
FI6: While playing the game, I can't tell if I am getting tired.
FI7: While playing the game, I lose track of where I am.
FI8: While playing the game, things seem to happen automatically.
FI9: While playing the game, I really get invested into the game.

1.3 Control

CO1: When playing the game, I feel in control.
CO2: The controls of the game feel easy to grasp.
CO3: The controls of the game feel natural.
CO4: Playing seems automatic.
CO5: I feel competent playing the game.

1.4 Curiosity

CU1: Playing the game excites my curiosity.
CU2: Playing the game arouses my imagination.

1.5 Heightened Enjoyment

HE1: I have fun playing the game.
HE2: I enjoy playing the game.
HE3: I would like to play this game again.
HE4: I would like to play this game more often than I do now.