FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Aleksi Penttilä

Increasing User Motivation of Neurological Occupational Therapy in Virtual Reality Using Gamification

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ABSTRACT

Neurological rehabilitation is a long process which requires a lot of work and motivation from the patient to be effective. Though patients might be motivated to partake in rehabilitation just to improve their own ability to live a more fulfilling life, it is beneficial for all parties involved to enhance patient motivation by other means as well. Gamification aims to increase user motivation with the introduction of game-like elements in a non-game context. In this study, the effectiveness of gamification techniques, common in fields such as education and life-style applications, are investigated on a virtual reality-based neurological rehabilitation software.

In this study a user study was conducted to evaluate the motivational aspect of gamification. Ten test subjects (six male and four female) aged 22-34 participated in two settings in a random predetermined order: a gamified environment and a simplified environment. After each play session, the participants filled a questionnaire and partook in a short semi-structured interview relating to the experience.

Mixed methods analysis was conducted, meaning results were analyzed both quantitatively and qualitatively. In quantitative analysis, the results showed that participants' intrinsic motivation was greater during the gamified play session as opposed to the simplified one. Additionally, participant amotivation was somewhat higher in the simplified version. Qualitative analysis showed that the aesthetic elements combined with scoring system increased interest and motivation in the gamified environment. Though which independent elements contributed how much remained inconclusive.

Follow-up studies with larger sample sizes could confirm the findings in this study and even go as far as to compare different gamification methods to further improve the usefulness of gamification in rehabilitation context.

Keywords: motivation, gamification, neurological rehabilitation, virtual reality (VR)

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TIIVISTELMÄ

Neurologinen kuntoutus on pitkä prosessi, joka vaatii paljon työtä ja motivaatiota potilaalta vaikuttaakseen tehokkaasti. Vaikka potilaat voivat olla motivoituneita kuntoututumaan parantaakseen elämänlaatuaan ja toimintakykyään, on hyödyllistä tukea motivaatiota myös toisin keinoin. Tässä tutkimuksessa tutkittiin pelillistämisen, jota on käytetty muun muassa koulutus- ja elämäntapasovelluksissa, hyötyjä virtuaalitodellisuudessa järjestettävässä neurologisessa kuntoutussovelluksessa.

Kymmenen koehenkilöä (kuusi miestä ja neljä naista) iältään 22-34 ottivat osaa tutkimukseen, jossa he kokeilivat kahta satunnaisessa järjestyksessä valittua virtuaalitodellisuusympäristöä: pelillistettyä, sekä yksinkertaistettua. Molemman pelisession jälkeen osallistujat täyttivät kyselylomakkeen ja osallistuivat lyhyeen haastatteluun.

Tulokset analysoitiin monimenetelmä analyysillä, tarkoittaen että tulokset analysoitiin kvantitatiivisesti ja kvalitatiivisesti. Kvantitatiivisessa analyysissä tulokset osoittivat osallistujien kokeneen enemmän sisäistä motivaatiota pelillistetyssä ympäristössä kuin yksinkertaistetussa. Lisäksi koehenkilöt kokivat jokseenkin enemmän motivaation puutetta yksinkertaisessa versiossa ympäristöstä. Kvalitatiivinen analyysi osoitti, että esteettiset elementit sekä pisteiden lasku lisäsivät kiinnostusta ja motivaatiota pelillistettyyn version. Kuitenkin epäselväksi jäi, kuinka paljon yksittäiset elementit vaikuttivat tähän tuntemukseen.

Jatkotutkimukset suuremmalla osallistujamäärällä voisivat vahvistaa tämän tutkimuksen löytöjä. Lisäksi olisi mahdollista vertailla eri pelillistämismenetelmiä ja niiden hyötyjä neurologisessa kuntoutuksessa.

Avainsanat: motivaatio, pelillistäminen, neurologinen kuntoutus, virtuaalitodellisuus (VR)

TABLE OF CONTENTS

ABSTRACT
TIIVISTELMÄ
TABLE OF CONTENTS
FOREWORD
ABBREVIATIONS
1. INTRODUCTION 7
    1.1. Method and research question 7
    1.2. Author's contribution 7
2. LITERATURE REVIEW 9
    2.1. Motivation 9
        2.1.1. Intrinsic and extrinsic motivation 9
        2.1.2. Self-determination theory 10
        2.1.3. Achievement oriented theories 13
        2.1.4. Reward oriented theories 14
    2.2. Gamification 15
        2.2.1. Gamification and motivation 16
        2.2.2. Design of gamification 17
    2.3. Virtual reality 19
        2.3.1. The technology behind the immersion 19
        2.3.2. User interface in virtual reality 20
    2.4. What does immersion bring to gamification? 22
3. VIRTUAL REALITY ENVIRONMENT 24
    3.1. Simplified Environment 24
    3.2. Gamified Environment 25
4. STUDY SETUP 28
    4.1. Participants 28
    4.2. Material 28
5. RESULTS 31
    5.1. Analysis Methods 31
    5.2. Quantitative data 31
    5.3. Qualitative data 33
6. DISCUSSION 35
    6.1. SIMS 35
    6.2. Basic Psychological Needs 36
    6.3. Gameplay vs. Aesthetics 36
    6.4. Future Work 37
    6.5. Limitations 37
7. CONCLUSION 39
8. REFERENCES 40

FOREWORD

This thesis was done with the request of Peili Vision, and it serves as the Master's Thesis for my Biomedical Engineering Master's degree. First and foremost, I would like to thank my thesis supervisor Paula Alavesa (University of Oulu), without whom I could not have done as good of a job. I own her my sincerest thanks as she was a crucial help in finding information upon the subject, guiding me through the overall process, and being generally interested in the whole thesis. I would also like to thank Peili Vision and my supervisor Mikko Kontio (Peili Vision) as they were able to introduce me to an interesting thesis topic and give me paid time to write my thesis. I would not have been able to finish my thesis in this time had I not the extra time to do so. I also have my family and friends to thank who supported me during the stressful times and shared my joy when things went as planned. Special thanks go to a dear friend of mine Ville Hassinen, who recommended *Mendeley* as the citation software. It certainly helped immensely and increased my ever growing and devout loathing towards *RefWorks*. I thank the people who willingly gave their time to participate in my study, without them I would quite literally not have been able to complete my thesis. And lastly, I want to thank for my time in the University of Oulu and all the friends I made along the way. I will cherish these memories forever.

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Aleksi Penttilä

ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
AM	Amotivation
ANOVA	Analysis of variance
AUTO	Autonomy
BPNT	Basic psychological needs theory
CET	Cognitive evaluation theory
COMP	Competence
COT	Causality orientations theory
DOF	Degrees of freedom
EM	External motivation
EVT	Expectancy value theory
FOV	Field of view
GCT	Goal contents theory
HCI	Human computer interfaces
HMD	Head mounted display
IM	Intrinsic motivation
IMU	Inertial measurement unit
IR	Identified regulation
MMORPG	Massively multiplayer online role-playing game
NPC	Non-player character
OIT	Organismic integration theory
PIT	Personal investment theory
RELA	Relatedness
RMT	Relationships motivation theory
SDT	Self-determination theory
SIMS	Situational motivation scale
UI	User interface
UX	User experience
VR	Virtual reality
κ	Cohen's Kappa

1. INTRODUCTION

Rehabilitation is a time-consuming process which requires a lot of work. Therefore, motivation is a crucial aspect to maintain for a successful rehabilitation. Peili Vision, commissioner of the thesis study, develops virtual reality environments designed for neurological rehabilitation. This is why there is a great interest to increase patient motivation within the software. Gamification aims to do just that: increase motivation using borrowed elements from games.

My motivation to investigate such subject spawns from a personal interest in games and game design concepts. I find it highly fascinating, how games induce great emotions in players and how they keep motivating and going as far as to drive the players through sometimes close to insurmountable tasks. Latter is even more apparent in achievement-oriented gaming subcultures such as speedrunning (completing games as fast as possible) or esports (commercial competitive video game scene). This interest also applies to other applications which seek to enhance themselves with concepts familiar from games. I sought to understand the function of gamification and more specifically how game elements are used in non-game products and services.

Peili Vision provided me with the opportunity to study just that. I got an opportunity to study how gamification elements affect users' motivation with the added benefit of being a part of medical/healthcare technology application to satisfy my degree goal in biomedical engineering.

1.1. Method and research topic

This study investigates the motivational impact of gamification elements in a therapy oriented virtual reality environment. A user study was conducted to evaluate the motivational effects of gamification in a virtual reality environment. Both quantitative and qualitative methods were utilized. The quantitative parts consisted of a survey which was done for both simplified and gamified environments. Two-factor one way ANOVA and Kruskal-Wallis test were used to determine statistically meaningful variables between the two experiences [1, 2]. Qualitative methods included two interviews from which interview transcriptions were made and analyzed focusing on motivational schematics [3]. An agreement testing was applied to the qualitative analysis [4, pp. 57–71].

1.2. Author's contribution

The base therapy environment used for the study was "Shoot the Targets" game provided by Peili Vision, where the user shoots 3D objects by looking at them. Two versions of the game scene were used: gamified and simplified version. Both games were manually set to have same object generations and durations to better compare the two.

I modified the gamified version by adding a simple scoring system to make the experience more game like. The graphical elements were already implemented by Peili Vision and did not need further improvements. In the simplified version, I stripped all unnecessary visual enhancements and removed the game object rotation. In addition,

the scoring was not implemented in the simple version. The study setup and result analysis were designed and implemented by me.

Game analytics were collected by default, but they did not play a big role in the analysis. This was due to them being mostly geared towards identifying neuroatypical behavior and debugging the actual scene. Since the participants did not have impacting neuroatypical disorders, the game analytics data did not produce meaningful results. To add even further, since all random or variable elements that are present in the actual product (element spawn locations, number of targets etc.) are normalized for the study, they could have not been meaningfully compared between the groups.

2. LITERATURE REVIEW

The literature review will dive into concepts of different motivation theories, ways of affecting the motivation, gamification, and virtual reality (VR). All these concepts are explained in a context suitable for gamified therapy product. For example, some motivation theories are quickly mentioned but not focused on as they are not suitable for the specific context. And because motivation as a concept is very convoluted and the theories explaining it often overlap, the incoming chapters are laid out in a fashion that is easy to read and understand.

2.1. Motivation

Motivation is a desire to do something – a theoretical concept of providing humans with the need or reason, to react and fulfil those needs. It is a complicated concept, with multiple theories from which Self-determination theory (SDT) is the most widely used. Generally, motivation can be categorized to three basic subcategories: intrinsic motivation, extrinsic motivation, and amotivation [5]. Intrinsic and extrinsic motivation can be further split into autonomous and controlled motivation [6]. Different motivation theories can be used to describe how humans behave and focus their energy on different situations and tasks. For instance, SDT further evolves the concepts of intrinsic and extrinsic motivations [5].

Motivation can also be affected by outside sources. These so-called motivational affordances comprise of objects which determine if the object guides the person's motivational needs in a positive or negative fashion [7]. It should be noted that motivation is often associated with positive motivation, which describes the revival of positive energy for a specific action. However, motivation can also be described to have the opposite effect. Negative motivation illustrates a situation, where the goal of an action is shrouded by expectations and fear of not being able to achieve the desired outcome [5].

This chapter will briefly explain the concepts of different motivation theories most suitable for the topic of gamification as explaining the motivation theories and concepts in full detail would be impossible within the scope of this thesis. Not only that, but we will focus on motivation theories which focus on the individual rather than social theories such as Social comparison theory [8]. As the product evaluated in this thesis is aimed at rehabilitation, it would be counterintuitive to introduce elements which promote comparisons between others since the process of rehabilitation is always unique to the individual.

2.1.1. Intrinsic and extrinsic motivation

Intrinsic motivation describes a motivational factor, where an action the person takes is enjoyable, fun, or interesting. This leads to a behavior where the person is self-determined to perform a task autonomically. This phenomenon is also known as autonomous motivation and it describes the volition to choose whether to perform the task or not [6].

Intrinsic motivation exists within individuals naturally, and actions driven by it are not affected by extraneous rewards or incentives. This natural motivation is present from childhood onwards and is shaped continuously as the individual gather's new experiences, gains knowledge and improves their skills. Although intrinsic motivation exists within the individual, it can also be described to have a relation between individuals and activities. Therefore people are intrinsically motivated by different things and not everyone is intrinsically motivated by the same thing [9].

Studies show that autonomy-supportive tasks and environments (e.g., classroom experiences which encourage choice and self-direction in contrast to outside control) enhance intrinsic motivation, curiosity and desire for challenge [9]. It is important to note that achieving autonomous motivation requires satisfying basic psychological needs described in Self-determination theory: autonomy, competence and relatedness [6].

Extrinsic motivation depicts motivation driven by external actions such as a reward, compulsion, and punishment. Therefore individual is extrinsically motivated if they receive any rewards or pressure from outside [5]. This is also described as controlled motivation [6].

Though it would be easy to assume that all extrinsic motivation is nonautonomous and the opposite of intrinsic motivation where individuals' actions are merely done for the enjoyment of the activity itself and not for an external reward or pressure, SDT states that extrinsic motivation can vary greatly in the degree it is autonomous [9]. For example, a person can study hard for a test because they find it important to learn the subject, not only for their grade, but also for knowledge in their dream employment. In this case the individual is extrinsically motivated to study to get a good grade, but intrinsically motivated to better themselves, thus the level of autonomy the individual feels may vary in seemingly nonautonomous tasks and motivators.

Extrinsic motivation is a strong motivator, but it has been proven in several studies that giving any sort of reward or high pressure for an intrinsically motivated task, does in fact undermine the intrinsic motivation [9]. However, it can still be a necessary tool to improve intrinsic motivation in the long term. Motivation can be cultivated extrinsically in the beginning which will later translate to intrinsic motivation when the individual has gained skill or knowledge on the subject [5]. Not only that, but rewards may even promote the sense of autonomy and self-determination as shown by a study conducted by Eisenberger et al. [10], where college students who were given a task to identify subtle differences between two cartoon images were more motivated to surpass a performance limit when motivated by an extrinsic reward. Maybe even more importantly, they were also more interested in the task itself even after withdrawing the reward [10].

If individual lacks interest or joy in a task and is not rewarded nor pressured for doing the task, the individual has a complete lack of motivation for the task and therefore will not accomplish it. In other words: lack of intrinsic and extrinsic motivation results to amotivation [5].

2.1.2. Self-determination theory

SDT represents a broader array of meta-theories which build upon intrinsic and extrinsic motivations, and basic psychological needs of autonomy, competence, and relatedness. SDT contains six sub-theories each describing a specific facet of

motivation or personality functioning [11]. Though Cognitive evaluation theory and Organismic integration theory are the oldest sub-theories in SDT [5] (and often introduced in such order), for the sake of clearer understanding of the concepts, they are explained in the paper after the basic psychological needs of autonomy, competence, and relatedness.

Basic psychological needs theory (BPNT) states that in order to maintain optimal function and well-being, humans have an intrinsic psychological need for autonomy, competence and relatedness [11]. Autonomy is described as a need for freedom of choice and volition to perform activities which are meaningful and in line with personal goals. Competence is the experience of success or the feeling of accomplishment in doing tasks which result in gaining mastery within the environment. Finally, relatedness is the need to feel connected or belongingness in the given environment [6]. Relatedness is important in enhancing the individuals' performance and motivation in a given context such as academia or therapy [5].

Cognitive evaluation theory (CET) is the first sub-theory of SDT, which describes the effects of external consequences on internal motivation [5]. CET draws attention to the importance of competence and autonomy in support of intrinsic motivation. It highlights the social contexts on intrinsic motivation, or how other external sources such as rewards or external control affect the internal motivation and interest. It is a very impactful factor on environments such as education, arts, sports and other domains [11]. However, CET specifically states that the feeling of competence alone does not increase intrinsic motivation unless it is paired with a sense of autonomy. Therefore for the motivation to be enhanced and maintained, the satisfaction for the basic psychological needs of competence and autonomy must both be present [9].

Second sub-theory is Organismic integration theory (OIT). In the theory, extrinsic motivation has different states of autonomy. In other words, OIT describes the extrinsic motivation as behavior that is varied in internalization and integration of the value of the activity itself. Internalization is how well the value of an activity is felt while integration explains the process of transformation from external regulation to individual's own self-regulation [12]. Therefore, the more internalized the extrinsic motivation is, the more autonomous the individual will be in their enacting behavior [11]. The concept of motivation having different stages of perceived degree of self-emanating properties is illustrated in the *Figure 1* starting from least self-determined (a complete lack of motivation) on the left to most self-determined (internal motivation) on the right. As an example of different levels of autonomy in extrinsic motivation, a child performing a school assignment given by a teacher (externally regulated activity) will have internalization occur when they see the value and importance of the assignment itself. The integration in the situation is relative to the degree to which the child perceives the completion of the assignment as their own choice [12].

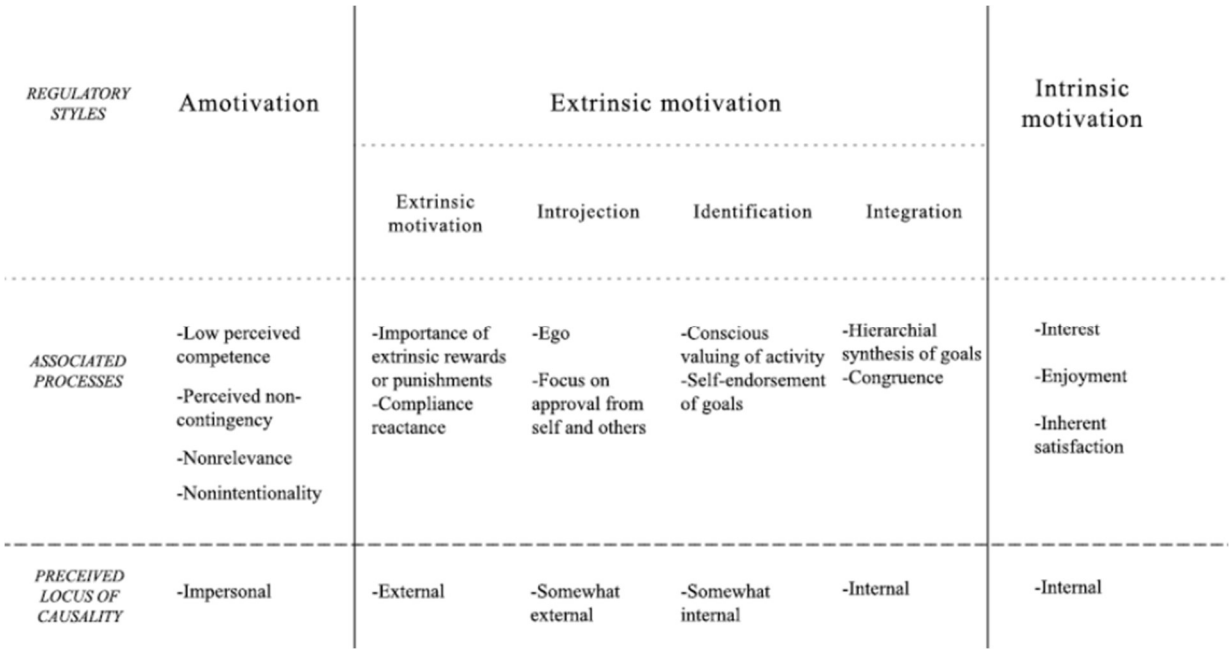


Figure 1. Perceived degrees of motivation. *Recreated Image (c) Aleksi Penttilä based on work by M. Ryan and E. Deci* [13].

Next theory is the Causality orientations theory (COT), which describes the tendency to orient toward social or environmental inputs. These inputs can be divided into three categories: autonomous (acting out of interest), controlling (acting out of seeking rewards or avoiding punishment), and impersonal (no personal meaning, belief of being unable to control outcomes) [11, 14]. COT therefore describes the behavior in situations requiring social or environmental interaction and the willingness of acting in such situations [14].

Goal contents theory (GCT) highlights the relationship between basic need for satisfaction and well-being based on intrinsic and extrinsic goals [5]. Humans portray their need for satisfaction in their well-being which is affected by the nature of the goals set by or to the individual. In other words, the feeling of satisfaction is related to the type of goals the individual has. These goals are either intrinsic such as personal growth or relationships with other people, or extrinsic such as financial success, appearance, and fame. Intrinsic goals are often more satisfying and reflect on better well-being compared to extrinsic goals [11].

Finally, Relationships motivation theory (RMT) explains that relationships with other people is not only desirable, but essential as they satisfy the basic psychological need for relatedness. Not only is the satisfaction of relatedness important in good relationships, but also the needs for competence and autonomy. In a high-quality relationship, all of the basic psychological needs are supported by both parties of the relationship [11].

It should be noted, that SDT provides a very comprehensive view on intrinsic and extrinsic motivation as it tries to explain the aforementioned motivations, the states, and transitions between them. It also provides solid explanations for different video game related motivational engagement factors such as fulfilling basic psychological needs [15]. Though comprehensive, SDT is far from the only theory covering motivation topics found in video games.

2.1.3. Achievement oriented theories

Achieving a non-essential goal is often considered an extraneous desire, an act that is not necessary for survival but is still sought after as self-improvement and growth. Indeed, desire for higher self-fulfillment was theorized by Abraham Maslow in his paper from 1949 "A theory of Human Motivation"[16] later dubbed as Maslow's Hierarchy of Needs.

Maslow's Hierarchy of Needs describes the human motivation as a hierarchy of varying levels of needs that need to be at least moderately satisfied in order to advance in self-betterment. The hierarchy consists of deficiency needs such as basic needs (food, rest, security) and psychological needs (relationships, friends, prestige), and at the top lies self-actualization, which illustrates the desire to better oneself [17].

Deficiency needs drive individuals' motivation not of act of seeking fulfillment but rather the act of not being denied of these needs. In other words, the deficiency needs are motivating the individual to for example deny hunger and lessen loneliness, and furthermore the motivation to do such things is increased as the denial of these needs grow larger (i.e., hunger only grows as time from last meal increases) [17].

After basic needs are satisfied to a certain extent, the motivation changes from decreasing when needs are met, to increasing as needs are met. Self-actualization provides positive goals and incentives to motivate individual to act accordingly. These goals vary between individuals own interests. One person might be striving to be the greatest musician in their respective musical genre, while another could have a dream of becoming a successful mother of four children. Therefore as the individual achieves milestones and gains competence in their field of interests, they are increasingly more motivated to better themselves in them [17].

The idea of self-actualization and basic psychological need of competence is the basis for aiming actions towards an achievement and a goal. Achievement motivation theory aims to explain individuals' motivation to accomplish a task in varying degrees of difficulty, desire of attaining success with a standard of excellence, master a specific complex task, and the need to surpass others in said field [18]. Individuals with such affinity for the need of achievements seek to accomplish realistic yet challenging goals. In other words when individuals' motive to achieve success is greater than their avoidance for failure, they have a high need for achievement. They seek tasks which are moderate in difficulty which leads to positive motivation to be the strongest. If persons' motivation is avoidant (being individuals' motivation to avoid tasks is high compared to the need for achievement in the field), they possess high avoidance of failure and thus experience motivation to avoid such tasks. They prefer either very easy or very hard tasks [19]. Indeed, the two motivations are separate as they determine which tasks and maybe more importantly how they affect the level of task difficulty individual chooses to undertake [8, p. 26].

Goal setting theory is closely related to achievement theory, and it claims that difficult, specific, and immediate context-appropriate goals motivate to achieve said goals more than long-term goals. Their purpose is to assist individual to focus their attention and increase one's perseverance towards the achievement – the end goal [8, p. 27]. The goals are more effective at improving task completion and motivation for an individual who is sufficiently skilled to perform the task, when the difficulty is appropriate (according to achievement motivation theory when probability of success is 50% for a positively motivated person [19]), they are specific, the actual progress is

shown by some feedback mechanic, and attaining the end result will be rewarded and accepted by the individual [8, p. 27].

Both goal setting and achievement motivation encourage individual to accomplish moderately difficult tasks still within the scope of one's ability. As these tasks are performed the individual gains skill and continues to increase one's ability to complete aforementioned tasks as long as the task difficulty stays appropriately challenging throughout the process. This important motivational construct for a phenomenon called self-efficacy [8, p. 27]. Self-efficacy is the self-perceived expectation that the individual can successfully execute the behavior which will result in a desired outcome. Though closely related, it is important to differentiate the outcome expectancy and efficacy expectations since an individual can be sure that a certain action will lead to a certain outcome, but if they doubt their capability of accomplishing the actions required for the outcome, it will inevitably lead to a situation where the efficacy of the actions does not matter in their actual behavior [20]. When a person has a high self-efficacy, they have the power to choose and perform more challenging tasks. As the individual invests more effort on a task, they will persist in the face of obstacles and aversive experiences [8, p. 27]. In addition, the stronger the perceived self-efficacy, the more active are the efforts. Those who persist through a difficult activity, will gain corrective experiences enforcing their self-efficacy even further and eventually even eliminate defensive behavior altogether [20]. Further, judgements of self-efficacy are based on four types of experience: own performance accomplishments, secondhand experience of observing others' performances, verbal persuasion, and social influences. Performance accomplishments prove to be most influential, since achieving success heightens perceived self-efficacy, while repeated failures lower it [8, p. 27; 20].

Personal investment theory (PIT) claims that the meaning of different situations is comprised of three components. These are personal incentives, sense of self, and perceived options [21]. The meaning of an activity the individual feels is created in form of personal beliefs, perceptions, feelings, purposes, and goals and in return the sense of meaning motivates behavior [8]. Personal incentives refer to the motivational focus of a task or activity. Sense of self refers to one's sense of competence, self-reliance (as in sense of personal control), goal directedness (personal willingness to assign and work towards goals), and social identity (perception of association with certain groups or people). Finally, perceived options refer to the behavioral opportunities and alternatives for action in different situations [21].

2.1.4. Reward oriented theories

As discussed in an earlier section, rewards – those in the nature of promoting extrinsic motivation – are a very powerful way of motivating an individual to a certain extent [5, 9].

Expectancy value theory (EVT) is a concept which tries to explain how individuals' choice, perseverance, and performance vary in relation to how well they believe they can perform the activity and how much they value the activity. EVT contains a complicated multi-layered expectancy-value model which details different factors such as cultural influence, social constructs, individuals' perception of environment and self, interpretations, and memories of different experiences (own or related), affective memories, goals, and expectations. Not only are the constructs influencing our choices and actions vast, but expectancy-value model also tries to explain the

relations and influences of the constructs [22]. However, the EVT may be condensed to a thought that expectancies and values influence individuals' choices, persistence, effort, and performance, and in turn the individual is affected by beliefs related to the task. These influences are goals, ones' ability, perceived difficulty, previous experiences, and external social factors or influences [8].

EVT factors internal versus external control. It refers to whether the reinforcement or the outcome of actions is due to own effort or other personal characteristics versus uncontrollable or unpredictable factors such as chance or luck. Reinforcement on preceding behavior is dependent on whether or not the individual thinks their own control led to the reward [8]. Therefore, it is not surprising that people find rewards more motivating when they are given to the individual when they have a self-perceived feeling of high-performance on the task. Such is the idea behind general interest theory [10].

General interest theory states that intrinsic motivation can be positively affected by rewards in addition to a possibility of having a negative impact or no impact at all. The content and context of tasks increase intrinsic motivation when they convey that task performance helps satisfy needs, wants or desires. The effect is opposite when these needs and wants are not met. Importantly, both are true with the inclusion of rewards, which either increase or decrease motivation depending on how the task must be completed to obtain the rewards. Therefore, rewards that are obtained by showing aptitude and competence, and which symbolically identify the task giver's judgement on the task, increase motivation [10].

Lastly, Skinner's principle of partial reinforcement claims that continuous reinforcement establishes a quick and effective probability for wanted behavior but fades away quickly after removing the reinforcement (such as a reward). On the other hand, a partial reinforcement such as a reward given at random intervals leads to a greater persistence. According to Skinner, rewards at a variable schedule are more effective and yield more consistent wanted behavior than rewards given at fixed schedules. This is apparent in gambling which reward based on a variable ratio and are highly addicting [8].

2.2. Gamification

Gamification is a term associated with borrowing elements from games to a product or service not inherently designed to be entertaining as a priority. Gamification as described by Deterding et al. can be condensed as "*the use of game design elements in non-game contexts*", though it is an umbrella term defining many different methods and focal points on designing a product to benefit from game-like elements [23]. Interestingly, the term gamification originated a decade earlier from 2002 by Nick Pelling but gained no popularity at the time [24]. Gamification is used for the intention of making the product or service feel more entertaining or motivating for the user. Therefore, it does not come as a surprise that education and learning are the most common contexts for gamification implementations [25]. Gamification can often be confused to serious games, which provide a full game experience while serving a non-entertainment purpose. While gamification has similarities in providing a different design vision for non-entertainment purposes similarly to serious games, importantly gamification only uses elements of game design instead of applying a full game to a product or purpose [23].

Gamification contains multiple layers of elements each of which target a part of the overall design and purpose of the product. These can be roughly separated as: the overall gamified design components, the way how the design elements affect the motivational aspects of the user, and the behavioral psychology behind the concept [23, 25, 26]. The main goal is to implement game-like elements to increase fun, engagement and compliance, in addition to accomplishing the activity which is sought after (in this case behavioral neurotherapy) [26]. The psychological aspects which affect our behavior are called motivational affordances [25].

2.2.1. Gamification and motivation

Purpose of gamification is to provide meaningful ways to motivate, promote certain wanted behavior, and increase user compliance in an fun and engaging fashion while accomplishing the primary goals such as healthcare or educational activities [26]. As discussed earlier, promoting individuals' intrinsic motivation to achieve a certain goal is ideal and very effective in retaining interest to do a specific task and to pursue a goal. It is no wonder that SDT is well studied and used theory for gaming and gamification contexts. Indeed, gamified products do try to satisfy the basic psychological needs of competence, autonomy and relatedness [27]. That said, it is helpful to understand a well-studied topic of motivation in video games.

One of the goals of gamification is to invoke similar emotions which are seen in games and to include similar affordances that are present in games [25]. The same kind of appeal that is found in video games is sought after for a purpose outside gaming itself. This appeal is the emotions and experiences the game provides to the player. Players seek experiences in gaming which accommodate the needs of competence, autonomy, and relatedness. Satisfying these needs results in inherent satisfaction: fun [15].

Gamification systems can and should include elements which promote the satisfaction of basic psychological needs. These systems can vary and are virtually only limited by imagination. However, it is beneficial to provide few concrete examples of such practices. Like games, gamified experiences tap into player's autonomy by giving sense of freedom of play [28]. Feeling of agency, or how significantly the player can interact with and manipulate the world in games, is one of the methods to bring such autonomy for player. The degree of agency can vary drastically from a simple sense of control in decision making to altering entire game world and its inhabitants based on the actions of player [29]. Virtual reality by definition indicates that the player can navigate and interact with the environment in real-time and as such should provide the player with a sense agency even at base level [30]. Other methods for autonomy include elements such as profiles and avatars, alternative activities, and configurable interface [31].

Feeling of competence comes from a display of skill and the pursuit of mastery. A game where the player can accomplish goals set by the game or player themself based on their player's performance enhance the feeling of competence. This is apparent in game progression [28]. Even the earliest successful video games provide this sensation. Arcade games such as *Donkey Kong* and *Pac-Man* provide a sense of progress with level progression. The levels are designed to have an increasing difficulty to challenge players. Therefore, completing levels require ever increasing amount of skill to match level specific skill floor thus providing a sense of progress and competence. In addition, old video games (such as aforementioned *Donkey Kong*

and *Pac-Man*) often incorporate a point system which functions as an easily understandable and comparable numerical value for skill. This number can then be compared to individual's previous accomplishments as well as between other players in in-game high scores. Though these games were very simplistic in design, most of the newer more sophisticated games also rely on these two ways of progression as they provide a clear and understandable way of perceiving progression. Though simple, it should be noted that if the progression is too difficult it may cause frustration, and on the flip side if the progression is too easy it causes boredom [15]. Games can also accommodate badges, achievements etc. systems to give feedback to the player. The key takeaway is providing enough feedback to the user about their progress and providing just enough challenge to engage users [32].

Relatedness in video games stems from interactions within the game world and other players in a multiplayer scenario. This interaction with others and the world around the player provides feelings of connectedness and relation. Massive multiplayer online roleplaying games (MMORPGs for short) such as *World of Warcraft* or *RuneScape* are most notable examples of games built on the idea of a larger connected world using the benefits of internet-based technologies [15]. However, while it is quite intuitive that other players provide a sense of belongingness and relation, sensation of relatedness can also be built on a rich world and interactable non-player characters, NPCs. This feeling can be enhanced with an engaging story and worldbuilding, NPC companions, and by giving player a sense of agency. Indeed, autonomy can be an effective method of also increasing relatedness in players. This is important in games which cannot provide the scale nor the depth of a massive world. This can be done by giving player a relatable avatar to represent them inside the game [6]. Emotions can further enhance this effect. Though emotional experiences vary between people, different types of aesthetic emotional qualities promote different kinds of relatedness towards characters in games which further proves that non-player characters and concepts can induce emotions of relatedness [33]. Relatedness is crucial to accepting any task as player's own which is especially important in gamified products aiming to guide player's behavior to a preferable outcome [6].

2.2.2. Design of gamification

Making a gamified product implies, as is the definition, designing elements which mimic game elements in non-game contexts. Gamification puts emphasis on the human interaction. This means adding fun, interactive, and compelling game elements in real-world scenarios or activities which promote wanted behavior [26]. There are several ways of approaching this conundrum and as such it is well studied and analyzed subject. One method is to divide into four different main elements as described by Palmer et al. [34]. These elements are progress paths, feedback and reward, social connection, and lastly interface and user experience. These elements are focused, but purposefully ambiguous in function so that they may be implemented in a plethora of different ways and scenarios. The important part however is that the game mechanics and elements are not observed and implemented haphazardly in isolation, but in relation to other pre-existing material and concepts of making a gamified product [34].

Progress path describes the goal of increasing game completion by gradually increasing difficulty while the player improves in the game. This is done to keep the tasks easy enough to succeed in but hard enough to keep interest in the tasks. It is important that the progress path is transparent for the player. If player has no clarity

over the progress, they may not be inclined to complete the experience [26]. Effectivity of progress paths can be amplified with multiple ways: introducing brand new challenges, narrative changes or by rewarding progression, though rewards are not necessarily part of the progress path itself but rather the feedback and reward system [34].

Feedback and reward systems are unique to games as they provide instantaneous rapid indications of success. In real-life, tasks may not product any sort of feedback or tangible rewards. Games have the advantage, and perhaps the requirement, to add well timed rewards to different actions in order to keep player engaged and motivate the user to progress further. Feedbacks and rewards are ambiguous in a way since their quality may vary vastly based on the actions and design. Feedback can be any sort of small indicator or sound effect given as a response to an action or event. It could also be a more direct reward such as in-game points, monetary based rewards or unlocks [34]. Rewards can function as a goal-setting device as they signal completion of goals and therefore progression [8]. It should be noted that people are motivated by different things. While some users are motivated by more tangible rewards such as badges or currency, others are more motivated by the feeling of mastery and competence [34].

Social connection uses social networks to encourage either competition or cooperation. Depending on the gamification context, inducing competition can be done either directly by challenging player against opponents or via leaderboards like completing exercises and gaining points accordingly in the gamified language learning app *Duolingo* [34]. Though some people might find competition highly motivating, it is likely that in return some people completely disengage with the gamified product due to competitive elements [8]. The social connectiveness can be however used cooperatively like in the daily activity management application role-playing game *Habitica*, where players complete productive daily activities to benefit their group in game. Social elements encourage having conversations about the game and in-game engagements with others increase the interaction and engagement with the app itself [34].

User interface (UI) and user experience (UX) are factors that include visual representation and overall product usability in order to enhance users behaviors, attitudes and feelings towards it [35]. Though the interface, which plays an integral role in the user experience, is easily perceivable and tangible part of the gamified application, the designing process provides challenges which may make or break the overall success of a product. Poor interface induces frustration and dissatisfaction in the user experience which is easily detectible and unavoidable. Therefore functional and aesthetically pleasing UI is integral to a good user experience [36]. Elements of a good interface include being easy to learn and understand, being attractive, closely interacting with user, and conveying information clearly [37]. Visual representation is also present in the form of graphics. A part of making a gamified experience in addition to game mechanics, is making the product game-like in aesthetics [38]. Graphical elements can improve the attractiveness of an environment, increase legibility, and provide a more game-like experience hence a more gamified product [39]. Further, graphical elements and visual cohesion can be seen as an integral part for a gamified application to succeed [40].

As gamification is human-focused (as opposed to function-focused) in design, gathering constant user output is critical in maintaining the benefits of gamification. Incorporating the knowledge from user feedback should be a part of the design consideration [26]. In addition, it is beneficial to focus the design elements to

specifically target different basic psychological needs to boost the effectiveness of gamification. This can be done, for example, by using badges as rewards to accommodate user's need of competence [6].

2.3. Virtual reality

Virtual reality (VR) as defined by the professor in the Faculty of Information Technology and Electrical Engineering at the University of Oulu and the former head scientist of Oculus VR Steven LaValle in his book *Virtual Reality:* "inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference" [41, p. 1]. Though any sensory interaction with artificially created content on a 2D display could be included in the definition, the modern use of the term VR is often reserved for fully immersive and interactable environments [42]. With this note, the main purpose of VR is therefore to be as immersive as possible. VR systems excel at displaying audiovisual information but are also capable of providing haptic feedback with handheld controllers [43]. Another crucial component for immersion is interactivity. The ability for user to interact within the virtual world provides a sense of realism not achieved with other mediums such as television [41, p. 6].

2.3.1. The technology behind the immersion

As stated in the previous section, immersion is a key element to a believable VR environment. Immersion as Mel Slater defines it, is *"an objective description of what any particular system does provide".* Therefore, immersion can be seen as an objective attribute of a system. To add, Slater defines the perceived sense of being inside a virtual world as *presence*. [44] As, immersion is often used to describe this sense of presence, the same is also done in the thesis for simplification. To help understand what makes the immersion work, it is good to understand the basic technology behind VR equipment. This chapter will quickly elaborate on the basics of this technology.

VR systems use technology as a means to produce an audio-visual sensation of a virtual world. This means that most common systems use visual displays as their main source of sensory stimulation [43]. The immersion level may vary between different technologies, but most modern uses of the term often imply the fully immersive experience. This is commercially accomplished with head-mounted displays (HMD) which have two displays, one of each eye, to mimic stereoscopic vision by horizontally displacing the images slightly [43, 45]. HMDs can play audio as well usually by either using headphones or by having a separate sound system such as Dolby 7.1 Surround Sound. While surround sound gives a full and realistic stereo depth and is world-fixed in function, most often headphones (user-fixed) are the more feasible commercial option. When the audio playback is user-fixed, VR environment needs to accommodate the stereo field orientation to the user orientation accordingly as the sound needs to originate from the virtual world and not just the headphone's stereo field [41, p. 42]. Another important aspect in making VR system work as an immersive and comfortable experience is to match the movement of user to the VR environment. This means that the HMD needs to track the motions of the user [41, p. 37].

The possible movement of an object in 3D space can be referred as the number of degrees of freedom (DOF) the object possesses. VR headsets generally use these DOFs

to refer to how many ways of motional tracking they have implemented [46]. All VR headsets track the head movements in 3 dimensions around the x, y and z axis often referred as pitch, yaw, and roll respectively. The hardware used to calculate orientation is usually an inertial measurement unit (IMU). IMU is a component containing several different measurement tools, but as a simplification its main component responsible for orientational tracking is a gyroscope [41, p. 45]. As an example, *Oculus* VR accomplishes 3 DOFs with a gyroscope [47]. Many modern devices also track movement in 3D environment granting additional 3 degrees of freedom with being able to move forwards, backwards, laterally and vertically [46]. The methods for motion tracking vary between different manufacturers but are usually either optical or magnetic. In optical tracking, the HMD uses either visible light or infrared (IR) cameras to track motion and position of wearable VR devices. Now older devices as *Oculus Rift* and *HTC Vive* did this by having external sensors to measure player position via infrared optics. More recently, devices such as *Oculus Quest* use inbuilt cameras with machine vision algorithms to track the position of player. While very accurate, optical methods have their downsides such as occlusion and homogenous reflective or transparent surfaces which in worst scenario completely lose track of the device [48]. Magnetic tracking does not suffer from same optical limitations as they use electromagnetic fields and transmitters to analyze the position of the player. However due to the nature of the technology, it is affected by other electromagnetic fields in the playing area and even materials such as metal [49]. Whichever is the technical implementation, having 6 DOFs is essential for tracking users' motions in a more realistic way.

2.3.2. User interface and experience

Because virtual reality immerses users' whole surrounding environment, it is important to pay attention to the user interface and the area of comfortable use. On a more conventional device such as computer, the screen only occupies a portion of users' field of view (FOV). Even if 2D displays have their own preferred areas for different information, these guidelines are not quite usable for a VR environment [50, p. 36]. Due to the nature of stereoscopic VR environment, the UI elements need to exist within the 3D environment. Analogous to holding a phone in your hand, it is noticeably more comfortable to hold it out arm's reach away from your face instead of right in front of your eyes. Therefore, different manufacturers (depending on the HMD technical aspects) have their recommended minimum distance for a comfortable viewing experience. For *Oculus* this distance is around a meter though it is a good general estimate for most consumer VR headsets [50, p. 36; 51]. Around 1-10 meters the effect of depth perception is the strongest, while the effect lessens gradually after 10 meters until the stereo effect disappears completely around 20 meters [50, p. 37].

Because UI elements should be accessible with minimum effort, a comfortable viewing angle must be considered. Comfortable viewing angles for reading text approximate a transverse rotation (turning head) angle of 30° and a downwards sagittal rotation (nodding head) angle of 40° [52]. These are of course approximations for desktop worker ergonomics but provide a good guideline for UI placement in VR. Though due to HMD field of view, user can comfortably see elements 77° to each side. Not only that, but the fact that users can move their head more than the comfortable angle results in a maximum viewing angle of 102° to each side. Use of this peripheral

area of course strains the neck and should be left only for occasional use [50, p. 38]. Therefore putting the most important UI elements near the quarter sphere around the minimum comfortable viewing distance and aforementioned comfortable viewing angles is recommended [50, p. 46]. Of course, virtual environment covers the whole world around the player. This means there lies another area behind both peripheral zones dubbed as the curiosity zone by the senior interaction designer of Google, Mike Alger [50, p. 49]. This aptly named area is only accessible if the user is curious enough to turn their physical body alongside with their head and thus is mostly left unused. The different viewing zones are illustrated in *Figure 2*.

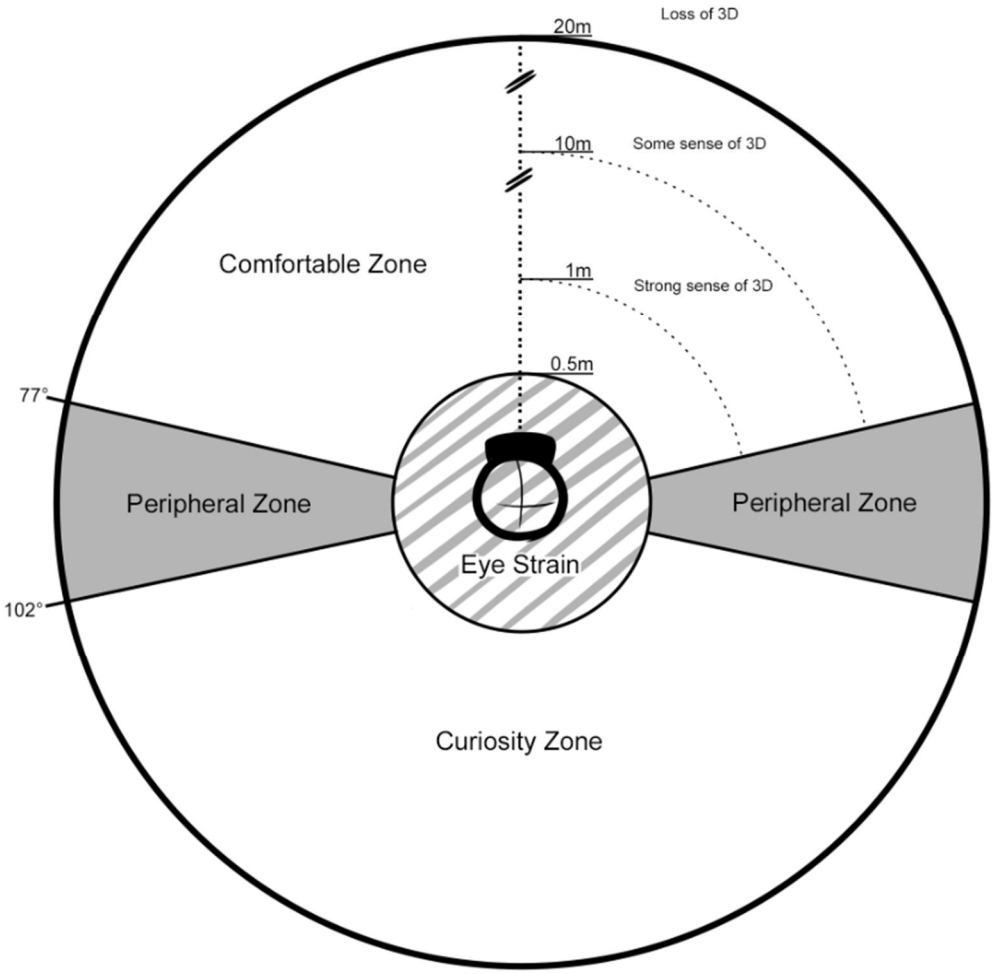


Figure 2. Different zones user can see inside VR. *Recreated Image (c) Aleksi Penttilä based on the book 'Virtual Reality' by S. LaValle* [41].

Because of VR equipment and full immersiveness, the common methods of interaction, such as keyboard and mouse, or touchscreen controls, are not suitable for VR. As demonstrated over 30 years ago by Rolf Molich and Jakob Nielsen in their work on coining ten separate usability heuristics for human computer interfaces (HCI), an interface should "speak the user's language" or to put in other words be intuitive to understand by the user [53]. Because of how VR environments differ from more commonly used HCI experiences, the user is tasked to not only adjust to fully

immersive environment but to learn how to operate the new environment. To interact with the environment and the UI, the user needs some sort of input device to do so. Almost all manufacturers include handheld controllers which are used to simulate hand movements and different actions via buttons or gestures [41, p. 300]. Though these types of motion controllers are inconvenient for actions such as typing text [50, p. 23] they provide benefits traditional HCI may not be able to provide. Handheld motion controllers provide a natural and easily understandable way of interacting with UI or the environment. For instance moving a 3D object in a space by holding a button and using hands to rotate and move the item does not require instructions as it is already an intuitive way of interacting with real life objects [54]. Some devices provide a way to track hand motions. These techniques include either a glove-like tracking devices such as *Leap Motion* [55] or machine vision algorithms such as *Oculus Quest* [56]. This natural way of interacting with HCI is called natural interaction. Natural interaction is defined as the user being able to interact with technology as if they were interacting with something in the real world like evolution and education has taught them to do [57]. To achieve this in VR interaction, interactivity must 1) react to natural commands, 2) provide immediate feedback, and 3) provide natural expected feedback [58]. Natural interfaces try to lessen the cognitive load and thus simplify experience for the user. Since VR environments are already overwhelming sensorily it is for the best interest of simplifying the interfaces anyway [57].

2.4. What does immersion bring to gamification?

As discussed in an earlier chapter, gamification aims to satisfy basic psychological needs and thus motivate the user to manifest wanted behavior. We quickly discussed how gamification can motivate the user [15]. However, what we didn't do was to answer the question: *what does immersion bring to gamification*?

The level of immersion is subjective, but it can be measured. For example, findings suggest that immersion can be measured objectively in traditional non-VR games with eye movements or task completion time [59]. Immersion inducing elements in video games (such as narrative structures, personal avatar, or customization) have properties which give player self-directiveness, freedom of choice, and produce stronger feelings of autonomy [60]. The addition of VR is also significant, as it provides a possibility for an increased egocentric immersion, which is shown to increase task performance [44]. As discussed earlier, STD defines basic psychological needs as competence, relatedness, and autonomy, and therefore immersion in game elements satisfy the need for autonomy and motivate the player [27, 60]. As a gamified product wants to tap into these motivating aspects of games, it is reasonable to derive that immersion is indeed an important part of gamification. Therefore, instead of asking what immersion brings to gamification, we should be asking: *how to immerse users in a gamified product*?

As gamified applications try to implement game design elements to motivate users, it can borrow such elements from games. Often times this is done by having customization options such as profiles or avatars to enhance their personal preferences and traits. Another way, and the most frequently used in online education, is to include storytelling or narrative elements in the system and/or in the progress path. Having an environment where the users can interact with their surroundings and where the activities performed have an additional meaning outside the activity itself are found enjoyable [61]. However, though some gamification elements such as customization

are useful and often relatively easy to implement, sometimes these elements risk the possibility of leading users to off-task behavior due to excessive time spent using aforementioned mechanics [62]. The enhanced realism of VR provides a great ground level for immersion [63]. Even if VR is already greatly more immersive than other formats of displaying audiovisual material, the created environment should still respect the same guidelines as more traditional video games do. For example, adding unnecessary and obstructive UI elements or breaking aesthetic or functional consistency of the world should be avoided, though depending on the context this might be unavoidable to some extent [64]. This is, as stated before, because the goal of gamification is to enhance the motivation and engagement towards wanted behavior and not distract user. Therefore, sometimes it's justifiable to break the immersion to a certain degree in order to maintain the main functionality of a product. A balance should be struck with enough immersion to maintain focus and engagement, but not too much to distract the user. One way of immersing user is to design the UI as non-intrusive and non-distracting as possible [63]. This can be done by embedding the UI elements or menus in the virtual world itself. Not only is it more immersive to read text from a virtual noticeboard, it is also more intuitive to the user as we do not have to deal with floating user interfaces in the real world either [41, p. 347]. Therefore, immersion can also make the gamified product easier to use due to being more intuitive.

3. VIRTUAL REALITY ENVIRONMENT

The thesis study consists of two virtual environments. Both environments are based on a real neurological evaluation and rehabilitation exercise developed by Peili Vision dubbed as *Shoot the Targets*. The purpose of this exercise is to evaluate and rehabilitate people with hemispatial neglect. Both environments are games, where the player is placed on a platform in an open space. In front of the player there is a board with a simple 3D shape (such as a diamond or octagon) which determines correct targets. Different amount of randomly selected simple 3D shapes spawn around the field of view of the player, some shapes same as in the board and some different. Player is instructed to shoot the targets by focusing their view on an object for 0.2 seconds. This is indicated by a crosshair with filling circle. Hits are then registered either as correct or incorrect. The game lasts for a predetermined amount of time and afterwards the results are displayed to the user.

The two experiences are functionally the same as they share same settings and predetermined functionality apart from the random elements of which shapes spawn as targets or decoys. The main differences lie in the aesthetics and other additional content. The simplified version is stripped from any extra visual effects, sounds, or environmental detail. The amount of simplification is discussed in more depth in the next chapter. The enhanced version (or the gamified version so to speak) contains animations, sound effects, environmental details, and a scoring system which is not present in the simplified version.

Before either of the games start, the user is seated and instructed to wear *Pico G2* VR headset. The scene was preselected (either simplified or gamified) and the participant can look around and get accustomed to the environment before the actual game begins. Before the game, the study organizer also explains how the game works and what actions the participant can take inside the game. After the participant has understood the instructions and accustomed to the environment, the game then begins.

3.1. Simplified Environment

The simplified version of the game contains all necessary elements for a functional exercise: a platform to stand on, instructions on how to play, correct targets, and the spawning targets. Everything else is reduced to a minimum.

The player stands on a simple dark grey platform in an open space with completely grey skybox. Instruction text is shown on screen accompanied with two test targets and one example shape representing the correct target on a board (one of the two test targets). The user may practice the controls in this pre-game lobby. After shooting both targets at least once, the game can be started by the therapist or in this case the test organizer. The game is set to end by either when timer runs out, or when maximum object count is reached. In this scenario, the maximum object count is selected, as it provides more control on how many shapes spawn and the ratio of how many are correct targets spawn throughout the game. Timed mode creates objects completely at random, so the user might face a situation where 20 correct targets spawn in one game, and 7 in another. We want to make the two different scenarios as close to each other functionally, which dictates the game mode selected. A total of 40 objects spawn throughout the game, where 20 of them are classified as correct targets. Accounting

spawn times and despawn times, the game lasts approximately 60 seconds and during this time random shapes spawn in front of the player within a set field of view (in this case 80°). During the game, the bottom panel indicates correct targets that the player needs to shoot. Every 30 seconds the correct targets are swapped for new ones and the game continues until the last remaining shape has spawned and finally despawns either by shooting or timeout.

Shooting targets is done by pointing the head towards the middle of a target (indicated by a reticle) for 0.3 seconds. After the delay, the target is then destroyed, and the hit is determined as either correct or incorrect. This delay is implemented as a way to prevent accidental hits by glancing over a target. Targets spawn inside a box collider with predefined settings as to where, how many, or what kinds to spawn. To add challenge for the test players, the game is set to have the maximum number of different spawnable objects. The simple environment consists of a completely grey skybox, accompanied with a small black platform to stand on. In addition, necessary game-elements such as the canvas for the correct target, and the instruction texts are kept in the game. An example screenshot of the simple environment is illustrated in *Figure 3*.

Figure 3. Simplified exercise during practice. The user can see instructions on how to shoot the targets. Diamond (left target) is incorrect while the octagon (right target) is the correct target as show on the canvas bellow (grey octagon). *Image (c) Aleksi Penttilä.*

3.2. Gamified Environment

The gamified version of the environment has the same basic principle as the simplified version: the targets and shapes are similar, the player can always see the correct target, and the player is based on a platform. However, a lot more is added and modified to enhance the experience further.

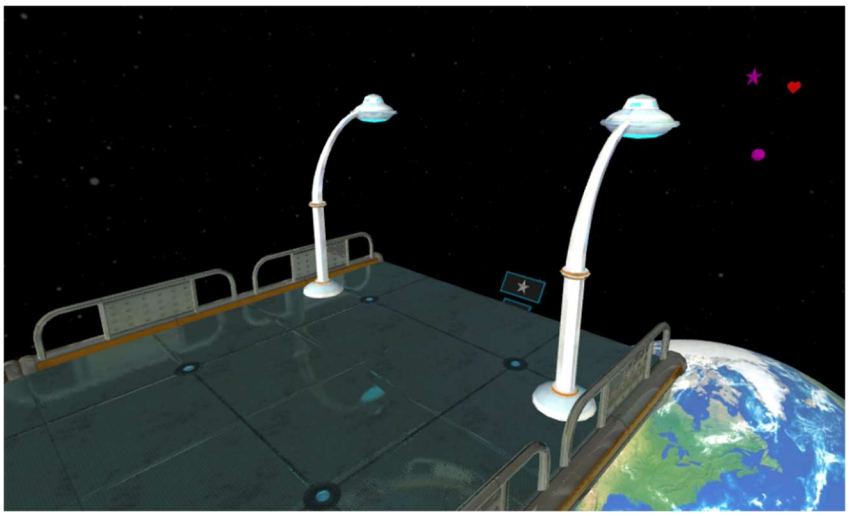
The environment is no longer just a grey skybox, but instead players are greeted by a view down to Earth from space as seen in *Figure 4* and *Figure 5*. In addition to the correct target box, there is a canvas for score which we will come back to later. The player is placed on top of a science fiction inspired platform with metal floor and railings and two futuristic lamp post props similar to streetlamps. The space environment was chosen as a way to integrate the actual game mechanics of finding the objects in front of the player more to the world. Though abstract in a sense (why is there a floating platform in the middle of space?), this was done to optimize performance for the VR headset in general and so that there are no extra obstructions in the way of the shootable objects. Since objects could spawn below the plane where player stands, the platform cannot continue past a certain point. Not only that but placing the ledge next to the player also makes it possible to place UI elements on a spherical viewing angle below the plane.

Figure 4. Gamified environment during gameplay. Skybox includes a view of the Earth from space. A correct objects has been shot as seen from the shrapnel animation. An additional in-game score is included, which has no ties in the actual data score used to calculate performance percentage. *Image (c) Aleksi Penttilä.*

The improved game also provides additional effects. Shooting is not depicted as instantaneous but instead when right target is selected, the player shoots a beam which destroys the object on collision. On impact, the pieces of the shape can be seen floating to random directions until they vanish after a short period. This effect is accompanied with matching sound effects. Selecting a wrong target behaves the same as in the simplified version of the game. The animations do not affect the gameplay, as the right

target is chosen at the same time as previously. Only an animation is added following the selection.

Figure 5. The gamified environment seen from another angle. *Image (c) Aleksi Penttilä.*



After the game concludes, the player is presented a rectangular results window (seen in *Figure 6*). The window presents each hit, missed, and incorrectly shot target as a dot. The position of shot targets is also tracked, which means the results window also displays where the target was shot. The results window also displays percentage of correct targets shot divided by all the correct targets regardless of if they are hit or not and the wrong targets shot.

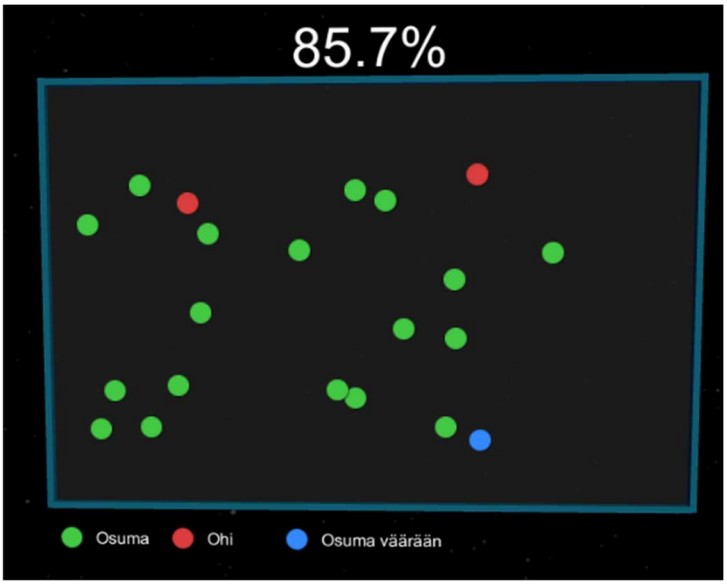


Figure 6. Results screen seen after the gamified session concludes. Correctly shot targets are shown as green dots, missed objects as red, and incorrectly shot targets as blue. *Image (c) Aleksi Penttilä.*

4. STUDY SETUP

This chapter focuses on the study setup i.e., how the participants were recruited, how the study setup was arranged, and what data was gathered from participants. Participants were also asked if they agreed to get their pictures taken for the study, some of which will be shown in this chapter.

4.1. Participants

The participants were recruited via email and student group chats. A brief email was sent where the study purpose was described, and possible participants were asked to reserve a half an hour-long session from *Doodle* and to fill a demography survey hosted at *Google Forms*. An informed consent was also obtained from everyone involved. Participants were also advised to only participate if they had previously used VR in order to minimize a possible novelty effect from the study setup. In addition, the selection was done to reduce the chance for unforeseen simulation sickness due not being accustomed to a VR experience. All participants were given a 5€ voucher for university cafeteria.

A total of 13 participants filled the forms and out of those 13 people, 10 were able to join the actual study held at Oulu University. According to the demography survey, participants consisted of 60% (6) male and 40% (4) female aged 22-34 (M=26,3; SD=3,7). Participants' highest educational degree was a master's degree, while the lowest was high school graduation. None of the participants had any affective qualities asked in the survey such as photosensitivity or migraine susceptibility.

4.2. Material

Between-subjects study design was used. This meant that the participants were randomly selected to either A or B group and both groups tested the simple and gamified environments, but the order depends on the group. A group starts with the gamified environment and after a fillable survey and an interview they move on to the simple environment and repeat the beforementioned questionnaires. B group is similar, though they begin with the simplified environment and move to the gamified one afterwards. Some additional questions are asked at the end of the test often phrased comparing the two tests.

There were three types of data collected: in-game analytics, a survey, and an interview. This meant, that since both quantitative (survey and in-game analytics) and qualitative (interview) data were gathered, a mixed method analysis was needed.

A survey (see appendix 1) was created to gather quantitative data based on users' motivation and satisfaction on the game experience. The answers the questions based on how relatable the question is to the user's experience of the test. For example, 12 of the questions in the survey have a base question of "*What are your feelings about the activity?"*, then there are claims such as "*I am satisfied with the aesthetics"* which the user then answers by selecting an option between 1-7 where 1 is *does not correspond at all* and 7 equals to *corresponds exactly.*

The survey had in total 20 questions. 8 of the questions are based on The Situational Motivation Scale (SIMS) [65] which is a validated survey measure for intrinsic and extrinsic motivation. The situational motivation refers to the motivation individuals

experience during an activity which is measured by the survey questions right after the test. The 8 survey questions (Q) from appendix 1 are separated (without the knowledge of the user) into 4 categories: intrinsic motivation (Q1 and Q5), identified regulation (the extrinsic motivation to perform an activity by own volition as a means to an end – Q2 and Q6), external motivation (the motivation of doing something because someone asks you to do it – Q3 and Q7), and amotivation (Q4 and Q8). Therefore, all of the categories have 2 separate questions which are then complied as one category when analyzing the data. The last 12 questions measure user satisfaction and immersive tendencies. Some questions were based on the Immersive Tendencies Questionnaire [66] but since these were mostly used for measuring user satisfaction, no validated analysis methods could be utilized and as such each of the questions were analyzed separately. Figure 7 shows a participant filling out the survey.

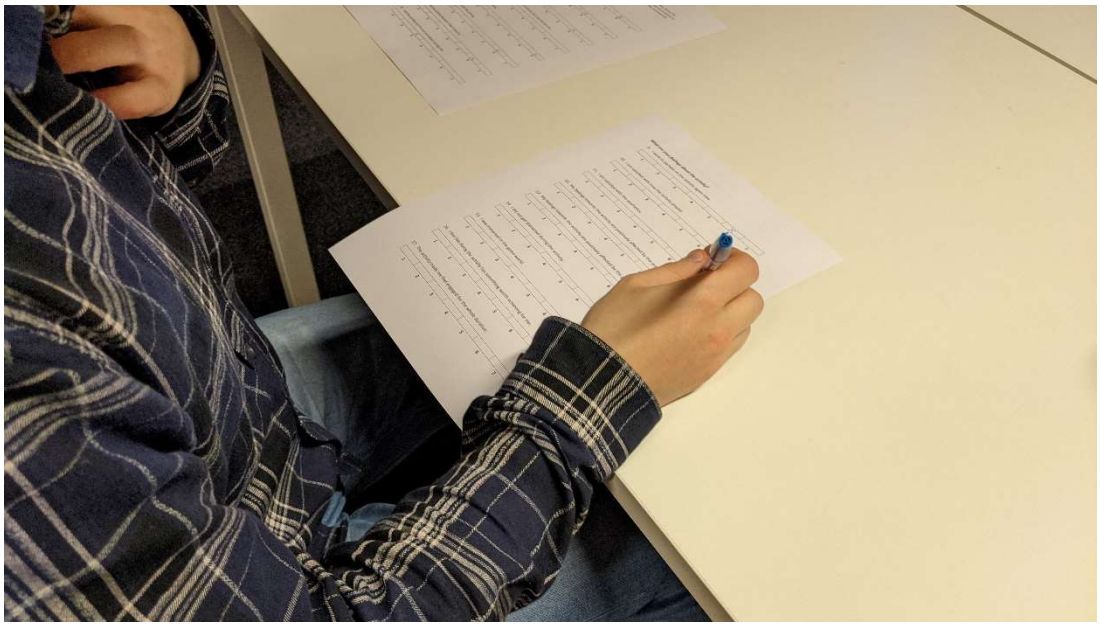


Figure 7. Participant filling out the survey (Appendix 1). *Image (c) Aleksi Penttilä.*

Due to the small sample, the interview was conducted as a means to further analyze what motivational and user satisfaction properties were present. The interview had a semi-free structure meaning that an interview structure (appendix 2) was used to get some main points of interest through and to add more consistency between users in their answers for analysis. The nature of semi-free structure allowed for extra questions and the possibility to skew away from the structured questions if, for instance, the user is already familiar with the rehabilitative context of the test software, the question can be swapped to inquire opinions about the test software if it was meant to be a fun game instead. Most of the questions were asked after the tests, but a few additional questions were left at the end of the whole testing procedure to determine thoughts comparing the two tests.

The software gathers data during gameplay. This data consists of the HMD (and controller, which was not used) position logs, game score (hits, misses, wrong targets shot, where and when the targets were shot, etc.) and game duration. Both game

analytics data were recorded for each participant. However, since the test setup was made to be as uniform as possible between users and tests, the game duration and number of targets does not vary between tests. This meant that the only meaningful data could be either HMD position logs or the score which the player gets. As the users are unlikely to be (and in this case indeed they were not) neuroatypical in regard to the intended use of the software, the score is does not portray any meaningful statistic between users and groups. The position logs, or to be more precise, the calculated average head movements were used to see if the users had any meaningful difference in their behavior during the tests.

Figure 8. Participant using the software. *Image (c) Aleksi Penttilä.*

5. RESULTS

This chapter will consist of the results of the study and statistical analyses conducted to the gathered data.

5.1. Analysis Methods

Because of the quantitative and qualitative nature of the study, a mixed method analysis was needed. For the quantitative data a two-factor one way ANOVA [1] was used to determine statistically meaningful variables between the tests. Kruskal-Wallis test [2] was also included, since the *n* (n=10) was relatively small. For the qualitative portion of the analysis, a thematic analysis of the interview transcripts was used [3]. Schematics for this analysis were selected to be the SIMS motivational qualities (intrinsic motivation, identified regulation, external motivation, and amotivation) and BPNT (autonomy, competence, and relatedness). Agreement testing was applied to the aforementioned coding schematics [4, pp. 57–71]. In addition, user satisfaction was also used as a schematic, however they were not applied for the agreement testing and were used mostly to analyze the overall satisfaction of each of the tests [67].

5.2. Quantitative data

The validated motivational survey SIMS data was handled as 4 categories intrinsic motivation (IM), identified regulation (IR), external motivation (EM), and amotivation (AM). Average answer values are listed on *Table 1* as well as single factor one-way ANOVA and Kruskal-Wallis test p-values. In addition, since there were two separate groups for the ordering of the two test setups, these groups were also evaluated separately to see if there were any statistically meaningful difference ($p \leq 0,05$) between the groups.

Table 1. Overall SIMS scoring between groups.

	Order	***Mean A***	***Mean B***	***ANOVA Sig.***	***Kruskal-Wallis Test***
IM	ANY	5,25	4,25	0,0267	0,0326
	A THEN B	4,7	3,8	0,1701	0,1124
	B THEN A	5,8	4,7	0,0543	0,0640
IR	ANY	4,55	3,9	0,3622	0,3867
	A THEN B	4,5	3,8	0,5023	0,4497
	B THEN A	4,6	4	0,5653	0,6501
ER	ANY	4,75	5,35	0,3461	0,3720
	A THEN B	4,9	5,3	0,6435	0,5967
	B THEN A	4,6	5,4	0,4206	0,4497
AM	ANY	3,45	4,35	0,0988	0,1517
	A THEN B	3,5	4	0,5286	0,5205
	B THEN A	3,4	4,7	0,0997	0,1988

From all the variables, only statistically significant difference between the gamified environment A and the simple environment B was intrinsic motivation (IM) determined by one-way ANOVA (*F(1;38)=5,312; p=0,0267*). This can also be seen in more detail in *Table 2*. Kruskal-Wallis test provided a p-value of (p_K*=0,0326*) and thus also determined IM to have statistically significant difference between groups.

Table 2. Detailed intrinsic motivation single factor one way ANOVA and Kruskal-Wallis analysis

Source	***SS***	***df***	***MS***	***F***	***P-value***
Between Groups	10	1	10	5,314685	0,0267
Within Groups	71,5	38	1,881579		
Total	81,5	39			
Kruskal-Wallis					0,032601486

Amotivation (AM) did not provide a statistically significant difference between the two groups as determined by ANOVA (*F(1;38)=2,863; p=0,0988*) and Kruskal-Wallis test (p_K*=0,1517*) (as seen in *Table 3*).

Table 3. Detailed amotivation single factor one way ANOVA and Kruskal-Wallis analysis

Source	***SS***	***df***	***MS***	***F***	***P-value***
Between Groups	8,1	1	8,1	2,863255814	0,098809568
Within Groups	107,5	38	2,828947368		
Total	115,6	39			
Kruskal-Wallis					0,15167082

User satisfaction was analyzed with single factor one-way ANOVA and Kruskal-Wallis tests. These survey questions were analyzed individually and by ignoring the order in which the users participated in the test setups (due to small *n*). Since multiple satisfaction survey questions game statistically significant differences between groups, only these categories of questions were listed in the *Table 4*. Out of 12 user satisfaction survey questions, 5 gave statistically significant results (*p≤0,05*). These qualities were gameplay satisfaction (*p=0,02874;* p_K*=0,05878*), aesthetic satisfaction (*p=0,00096;* p_K*=0,00320*), positive user affirmation by gameplay (*p=0,01922;* p_K*=0,02837*), positive user affirmation by aesthetics (*p=0,00257;* p_K*=0,00407*), and game world appreciation (*p=0,00372;* p_K*=0,04125*) , where *p* is the p-value from ANOVA and p_K is the p-value from Kruskal-Wallis test. All of the aforementioned variables had statistically significant difference between groups though only gameplay satisfaction had a p-value of *p≥0,05* from Kruskal-Wallis analysis it is having a value of (*p=0,05878*).

Table 4. User satisfaction ANOVA and Kruskal-Wallis analysis

Category	***ANOVA p-value***	***Kruskal-Wallis p-value***
Will to partake again in the game	0,17688	0,13057
Gameplay satisfaction	0,02874	0,05878
Aesthetic satisfaction	0,00096	0,00320
Positive user affirmation by gameplay	0,01922	0,02837
Positive user affirmation by aesthetics	0,00257	0,00407
Focus on task	0,81171	0,87983
User immersion	0,40603	0,36435
Sense of meaning in the task	0,11052	0,17362
Engagement	0,22571	0,38467
Ease of following instructions	0,22633	0,32575
Loss of track of surroundings	0,24823	0,28992
Game world appreciation	0,00372	0,04125

5.3. Qualitative data

The qualitative analysis was done by analyzing the interview transcriptions with predetermined schematics. The interview answers were then filtered out to only include sentences where a schematic could be applied. As an example, one user said: *"...I can see that the grey (simplified) environment is meant only for rehabilitation, but I cannot see anyone would play it otherwise."*. The sentence is then tagged as one of the schematics. In this example the participant had a total amotivation about the simple environment and therefore the SIMS tag would be AM. All interview answers were filtered separately for SIMS and BPN.

From all 20 interviews, two data tables were constructed. List of all total appearances is seen on *Table 5*.

Table 5. Total schematic observations

	IM	**EM**	**ER**	**AM**	**AUTO.**	**COMP.**	**RELA.**
Researcher	24	32	18	23	4	29	16

A Cohen's Kappa agreement testing was done to validate qualitative results. The resulting matrix consists of both researcher's and second observer's results. All sentences were analyzed by both parties and the results were compared against one another. For example, if both observers tagged the sentence as EM, one appearance would be added to row 2 column 2 (in a 4 by 4 matrix). If the researcher tagged sentence as ER and the second observer as IM, a count would be added to row 1 column 3. Absolute agreement follows a diagonal line through the matrix. SIMS category of schematics can be seen on *Table 6*.

Table 6. SIMS Cohen's Kappa Agreement Matrix

	Researcher				
Second observer	**Schematics**	**IM**	**EM**	**ER**	**AM**
	IM	9	2	1	1
	EM	15	24	7	3
	ER	1	1	6	4
	AM	1	4	3	15

The overall agreement on the observed arguments was 55,67%. The weighted Cohen's Kappa value was also calculated and used to determine agreement of the results. Cohen's Kappa was used instead of regular Kappa value to minimize the factor of guessing [68]. The answers resulted in a weighted Kappa value of $\kappa=0,506$, meaning a moderate agreement was found.

The weighted Cohen's Kappa was also calculated for basic psychological needs categories. The Cohen's Kappa agreement matrix can be seen on *Table 7.*

Table 7. BPNT Cohen's Kappa Agreement Matrix

	Researcher			
Second observer	**Schematics**	**AUTO.**	**COMP.**	**RELA.**
	AUTO.	3	3	22
	COMP.	0	32	2
	RELA.	0	3	2

As before, total observation agreement was 60,66%, and the Cohen's Kappa value was calculated and was determined to be of $\kappa=0,102$, meaning a slight agreement was found.

6. DISCUSSION

The point of the study was to analyse whether gamification elements had an impact on the user's motivation in a virtual reality therapy setting. This was partially done to determine if a company should spend resources on gamifying a therapy environment to motivate patients to rehabilitate themselves better. The elements used for this particular use case were improved graphical environment, and a scoring system.

6.1. SIMS

The quantitative and qualitative analysis indicate that there was evidence of statistically significant difference between the gamified environment (A) and simple environment (B) in user motivation. This was evident in the intrinsic motivation ($p=0,0267$, $p_K=0,0326$) scale seen in Tables 1 and 2. Users generally found more intrinsic enjoyment out of the gamified environment than the simplified one. As one user put it: *"(A) made me feel more hooked in the activity and generally more engaged than the first one (B)."* However, there was one noteworthy opinion from one participant who mentioned that the simplified environment was preferable in some situations: *"I liked the other (simplified) environment because the background was less distracting and therefore it was easier to focus on the goal."* The user added that they would still prefer the gamified version even if the simplified environment had its merits. To add, a free choice between the two would be preferable. Some users would report that they would go as far as to just relax in the environment to stargaze further adding to the effectiveness of a prettier environment. This is also supported by the user satisfaction questionnaire questions *'Aesthetic satisfaction', 'Positive user affirmation by aesthetics'* and *'Game world appreciation'* (seen in *Table 4*).

The amotivation results ($p=0,0988$, $p_K=0,1517$) hinted towards some lack of motivation with (B). However, though not statistically significant, the observations were of importance due to the fact that amotivation is the most important aspect to minimize in a therapy setting. Amotivation results in a failed therapy and possible long-term harm for the patient.

Extrinsic motivation was apparent from the interview answers. Though the SIMS questionnaire category itself showed no statistically significant difference ($p=0,3461$, $p_K=0,3720$), the interview answers showed that the users appreciated the gamified mechanics such as the scoring system. Users felt like having points results in an increased motivation to try to improve. One user said the following about the scoring: *"...yeah (the scoring system) made me feel like I want to improve and aim towards a new high score."* Additionally, some users pointed out that having points works as a baseline to improve upon which motivates even further. It is worth noting that the appreciation for gamified elements which promote competition could also be linked to the user satisfaction survey variables *'Gameplay satisfaction'* and *' Positive user affirmation by gameplay'* (*Table 4*).

One of the reasons a qualitative analysis was conducted in addition to the quantitative, was to compensate the small pool of candidates for the study. In addition, since the perception of the experiences and the relative motivation to do the said tests is very subjective, a qualitative analysis was also crucial to understand the underlying thoughts about the motivational factors.

6.2. Basic Psychological Needs

The quantitative and qualitative analysis suggest statistically significant difference between the gamified environment (A) and simple environment (B) in user motivation. This was evident in the intrinsic motivation ($p=0,0267$, $p_K=0,0326$) scale. Users generally found more intrinsic enjoyment out of the gamified environment than the simplified one. As one user put it: *"(A) made me feel more hooked in the activity and generally more engaged."*

Autonomy, competence, and relatedness were analyzed from the interview schematics and cross-referenced to validate result accuracy. From the analysis, the largest BPN schematic present in the interviews was competence (29 out of 49 total observations). The total agreement was substantial (60,66%) while the calculated Cohen's Kappa on the qualitative analysis was deemed to be slight ($\kappa=0,102$) according to the analysis methods by *Landis* and *Koch* [69]. Though the Cohen's Kappa showed only slight agreement, it is to be noted that competence scoring was not the culprit for the low agreement score. Therefore, for this particular schematic, the total agreement score is more accurate. This is backed up by the users' comments. Most users found the scorekeeping to be a beneficial inclusion. It was felt that points provided a better sense of progress, should the user participate on the activity for extended period of time. Related to the competence: extrinsic motivation was the most prevalent (32 out of 97 instances) from the situational motivation scale. This goes to show that users felt that extrinsic goals, such as points, do indeed motivate the user.

6.3. Gameplay vs. Aesthetics

Both gameplay and aesthetic elements were adjusted between the groups. This leaves a question, which of the changed elements proved to be more impactful? From the user satisfaction survey, a few parallels can be addressed. Between *Positive user affirmation by gameplay* ($p=0,01922$) and *Positive user affirmation by aesthetics* ($p=0,00257$) we can see that the p-value is lower in aesthetic category suggesting a higher impact on the visuals. This conclusion can be drawn from *Gameplay satisfaction* ($p=0,02874$) and *Aesthetic satisfaction* ($p=0,00096$). Therefore, there are indicators that the visual adjustments were more impactful in the perceived satisfaction of the environments than the gameplay adjustments.

On the other hand, the semi-structured survey interview schematics would suggest that feelings of competence (a category more geared towards gameplay), were more prevalent than those of relatedness (a category more suited for aesthetics). Competence had a total of 29 occurrences whereas relatedness had only 16. One participant said that *"I missed* (in the simplified version) *the success percentage and score board"* while another stated *"I felt like I wanted to see how fast I can do it because I think that the speed had something to do with the points and I felt like I kind of want to aim for a high score."*. While these thoughts were fairly common (as can be seen from the competence occurrences), many also stated that they felt like the graphics were an important part of the fun and engagement: *"I think that this was a lot nicer in a way because for example there was a bigger impact* (when a target was destroyed) *and it was more fun and entertaining."*. It is worth noting that competence is more

pronounced as a schematic than relatedness. Whereas competence can be easily defined by being excited about gameplay, success, or difficulty; relatedness on the other hand is a bit more complex to analyze. It can mean appreciation to the game world, interacting with the said game world and its inhabitants (which there were none in this case), or by having a story or a purpose inside the environment itself. This feeling could also be more difficult to express in an interview than feelings of competence.

Nevertheless, gathered data provided no conclusive evidence that one feature would be more important to the increased sense motivation as the survey data seems to point towards the visuals and the interview data towards the gameplay.

6.4. Future Work

The study setup was created to compare two different rehabilitation exercises, one with gamified elements and enhanced visuals, and another with only the gameplay. There was a statistically significant difference in the perceived levels of intrinsic motivation between the two exercises. Further studies could aim to identify which factors were the most crucial in improving intrinsic motivation. Further still, future work could compare different types of gamification elements such as points, leaderboards, narrative game structures, or difficulty curves to compare and identify which methods are most useful in this particular setup.

Based on this work, another view would be to have a longitudinal study to determine how the gamification elements work in a more realistic situation (as real therapy would take way more than one play session). This could help analyze the long-term effects of gamification more accurately and give a more in-depth look into the usefulness of gamification in therapy context. Additionally, aforementioned different gamification elements could be implemented in this future work as well to help identify the best course of action, when gamifying a therapy product.

6.5. Limitations

Due to the 2020-2022 pandemic the study had in total 12 participants 10 of which were able to participate in the actual measurements and interviews. As the number of participants was quite low, it leaves some room for error in the quantitative analysis. This was compensated with Kruskal-Wallis tests and the additional qualitative analysis. Though these compensations were adequate, the scarcity of data is still seen as a limitation.

For the qualitative assessment, a comparative agreement testing was conducted for the SIMS and BPN variables. Overall agreement was substantial, but when analyzed with Cohen’s Kappa, the agreement values dropped dramatically. Even though the Cohen’s Kappa value is quite volatile and aggressive in nature, the differences between some variables was still observable. This was mostly due to differences between the views of certain variables. As an example, user might act upon and put more weight on the visual aspects and feel that the environment is a crucial component to the meaningfulness of the experience. This can then be seen in the analysis (for BPN variables) as either relatedness or autonomy. A solution for this would be to reiterate

on the variables and their definitions and proceed to do the agreement testing again. Though this was not feasible due to time constrains.

In this study, both visual and gameplay elements were modified for both versions. As hindsight, the gameplay modifications (additional scoring features) and visual differences (the graphics and game world appearance) could have been separated to different categories, in order to study which elements were affecting how much as mentioned in chapter 6.4. Due to resource and time limitations, the visuals were dumbed down (for the simple environment) instead of improved even further (for the gamified environment). Though aesthetics is an important part of gamification, the selected solution might not have been ideal.

The time constrain was also culprit for some other limitations, such as the low sample size, only having a single play session for each participant, and the inability to arrange a longitudinal study as it would be more akin to a real-life situation.

7. CONCLUSION

This study focused on investigating the motivational effects of gamification in a virtual reality environment designed for neurological rehabilitation. Two different environments with similar gameplay were used. One of them had gamified elements such as scoring and upgraded visuals, while the other version was significantly simplified. The participants used both versions and expressed their opinions quantitatively by filling out a survey, and qualitatively by partaking in a semi-free structured interview. The data showed a statistically significant difference in intrinsic motivation between the two experiences favoring gamification, thus showing that gamification does in-fact increase motivation. Reversely, the simplified version did seem to induce more feelings of amotivation than the gamified version did, though not quite at the statistically significant levels as the former result was.

Follow-up studies with larger sample sizes are needed to further confirm these results, especially on the side of amotivation, and to add a more detailed level of understanding towards which gamification elements prove to be most effective in a virtual reality based neurological rehabilitation environment.

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Appendices

Appendix 1. Motivation and Satisfaction Survey

Appendix 2. Interview Framework

Appendix 1. Motivation and Satisfaction Survey

Motivational Survey

Imagine that you are instructed to complete the exercise every day for two weeks. Answer the following questions by selecting one of the following for each question: *1) Does not correspond at all, 2) Corresponds very little, 3) Corresponds little, 4) Corresponds moderately, 5) Corresponds enough, 6) Corresponds a lot, 7) Corresponds exactly.*

Why are you engaging with this activity for the duration?

1. Because the activity is interesting.

1	**2**	**3**	**4**	**5**	**6**	**7**

2. Because it is for my own benefit.

1	**2**	**3**	**4**	**5**	**6**	**7**

3. Because I am instructed to do so.

1	**2**	**3**	**4**	**5**	**6**	**7**

4. There may be good reasons to do so, but I do not see any.

1	**2**	**3**	**4**	**5**	**6**	**7**

5. I like doing the activity.

1	**2**	**3**	**4**	**5**	**6**	**7**

6. I choose to do the activity.

1	**2**	**3**	**4**	**5**	**6**	**7**

7. I do the activity because I feel I need to.

1	**2**	**3**	**4**	**5**	**6**	**7**

8. I do the activity but I’m not sure what it brings me

1	**2**	**3**	**4**	**5**	**6**	**7**

What are your feelings about the activity?

9. I want to partake on the activity again now.

1	**2**	**3**	**4**	**5**	**6**	**7**

10. I am satisfied with how the activity played.

1	**2**	**3**	**4**	**5**	**6**	**7**

11. I am satisfied with the aesthetics.

1	**2**	**3**	**4**	**5**	**6**	**7**

12. My feelings towards the activity are positively affected by the present gameplay.

1	**2**	**3**	**4**	**5**	**6**	**7**

13. My feelings towards the activity are positively affected by the present aesthetics.

1	**2**	**3**	**4**	**5**	**6**	**7**

14. I did not get distracted during the activity.

1	**2**	**3**	**4**	**5**	**6**	**7**

15. I was immersed in the game world.

1	**2**	**3**	**4**	**5**	**6**	**7**

16. I feel like doing the activity has something worth achieving for me.

1	**2**	**3**	**4**	**5**	**6**	**7**

17. The activity made me feel engaged for the whole duration.

1	**2**	**3**	**4**	**5**	**6**	**7**

18. It was easy to focus on the activity as instructed.

1	**2**	**3**	**4**	**5**	**6**	**7**

19. The activity made me lose track of real world around me.

1	**2**	**3**	**4**	**5**	**6**	**7**

20. The environment felt like a real place.

1	**2**	**3**	**4**	**5**	**6**	**7**

Appendix 2. Interview Framework

What did you think about the activity?

- *Was it engaging?*
- *Was it pleasing?*
- *Was it difficult?*
- *Was it unpleasant?*

How did you feel about the activity?

- *Did you like it?*
- *Did you dislike it?*
- *Was it unpleasant?*

How would you feel about having to do the same activity every day for two weeks?

- *Why?*
- *Is there anything that would change your opinion?*
- *Is it tedious?*
- *Did you experience nausea?*
- *Anything that would make you excited to do it?*

What did you like about the activity?

- *Gameplay/visuals?*
- *Was it fun or engaging?*

What did you not like about the activity?

- *Did it have issues that you didn't like?*
- *Was it boring or uninteractive?*
- *Did it cause nausea?*

Leave at the end:

How does your opinion change (if at all) if you were told to do it for rehabilitation purposes?

- *Does it change your view of the activity?*
- *Are the activity's flaws overshadowed by the goal or vice versa?*

Which activity would you rather partake in for two weeks?

Why?