Ben Schouten · Stephen Fedtke
Tilde Bekker · Marlies Schijven
Alex Gekker *Editors*

Games for Health

Proceedings of the 3rd european conference on gaming and playful interaction in health care

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Preface

The Third European Games for Health Conference 2013 (GFHEU 2013) brings together researchers, medical professionals and game developers to share information about the impact of games, playful interaction and game technologies on health, health care and health policy. Over two days, more than 400 attendees will participate, here in Amsterdam, in over 60 sessions provided by an international array of 80+ speakers, cutting across a wide range of activities in health and well-being. Conference topics include exergaming, physical therapy, disease management, health behaviour change, biofeedback, scientific validation, rehab, epidemiology, training, cognitive health, nutrition and education.

As we are aiming for innovation and further integration of Research and Game development in Health Care, this year we decided to add an extra Academic Track to the conference. These proceedings are the outcome of that integration and contain 26 full papers presented at the conference in the form of oral presentations or posters and structured around 12 major themes, which are reflected in the program of the conference. The Academic Track is interwoven into the conference's broader structure to further promote dialog between academics and practitioners working within the fields of Game & Play Studies, Design Research, Game development and the Medical Community, exploring and innovating within the greater area of Health. This track is labelled (A) in you're conference program.

Games have been played in many settings and in all times. No matter if the subject was jousting in medieval times by knights, or in the local playground by children playing football, it was always a combination of joy, skill mastery and social setting. With the new digital games this remains the same as they can be played in many contexts, being autotelic or applied. However, one thing should be noted, as the digital variant of games has grown to present even stronger possibilities due to the large groups that can share them and the 'always on' quality of mobile devices and networked game consoles. Moreover, digital games allow players to use advanced computational power, (haptic) devices, consoles, wearables, visualization, persuasive technology, social design and crowd computing, among many others, to empower the (cognitive) skills of the player. It is this power that makes contemporary games and play so successful especially in Health Care. Or as Jane McGonigal phrases it: "Gaming can make a better world."

The talks and presentations in this third conference are subdivided into several tracks such as: Game Design, Gamification & Behaviour Change, Business, Validation, Public Health, Medicine Adherence, and Professional Education. These proceedings follow the same subdivision as the conference. The major trends in contemporary game development are reflected in these tracks: the attention for public health for instance underlines the further wide spread adoption of medical apps and games in areas such as cancer prevention and HIV. Another recurring topic is the battle against Chronic Diseases (such as Obesity or Alzheimer) being the subject for new games, where patients and practitioners join together (in many cases, literally, in imaginary or hybrid game worlds). We see games for rehabilitation as part of a therapy shift from the hospital to a more natural (home) environment for the patient. Many games aim at prevention and participation of patients and as such contribute to effective cost reduction of health care.

Off the shelf consoles and controllers (like the iPad or Kinect) utilized in health games allow for further integration in existing e-health applications and will drive the industry to new solutions. From silver games (for the elderly) to toddle-apps, these applications allow further integration into daily life as well as in health care settings. In the future, games will integrate improved models of the human body and new advanced feedback mechanisms (e.g. interactive mirrors or spoken feedback).

The theory of games for health and the validation of games in health care settings is also gaining traction, which is important for commercial adoption and the implementation of new and alternative business models. Games such as 'Re-Mission' aiming to help battle cancer are now thoroughly validated in larger trials. Furthermore games are not only regarded as products (applications) but also as services for a longstanding relationship between patients, doctors, relatives and care providers or between medical doctors and students, to learn the practice of medicine.

In view of this all, the GFHEU 2013 proceedings can be considered as a timely document that provides many new results and insights in the new field of Games for Health. We would like to thank all members of the Program Committee for their most valuable and highly appreciated contribution to the conference by reading submissions, writing reviews, and participating in the discussion phase. We hope to provide you with many pleasant and fruitful reading hours.

July 2013 Ben Schouten, Chair Program Committee

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A Serious Game to Inform about HIV Prevention: HInVaders, a Case Study

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Abstract

The aim of this research is exploring the possibility of using Serious Games in order to educate the general public, in particular young people, about HIV prevention. We have developed a Facebook-based online game called "HInVaders" as a case study for our research. In the HInVaders game, the player is a HIV virus molecule and his aim is infecting as many people as possible. When the game starts, the molecule has already infected a person and is located inside the infected body. During the gameplay, the player encounters treatments (e.g. antiretroviral therapy) represented using the pill metaphor, and the human immune system (e.g. white blood cells). The player has to avoid the treatments and to attack the immune system in order to increase his score (called viral load). As a side effect (from the virus point of view), the viral load increase cause a decrease in the infected person's health level (as highlighted in the game interface). If the molecule/player goes through the same body too long, he will die with the infected person. Therefore, it is important for the player to explore the possibilities to escape from the infected body by infecting other persons exploiting some events, which occur during the gameplay. We have conducted some preliminary tests to assess the game didactical effectiveness on a small group of adults. The paper presents the game design and some preliminary results from experiment with real users.

Keywords

Serious games, HIV, virus, education, health

1 Introduction

The Serious Game term is used to define games which provide a mental contest and are played with a computer in accordance with specific rules for government or corporate training, education, health, public policy, and strategic communication [1, 3]. Serious games are not meant to replace traditional learning methods, they rather aim at integrating them and allowing users to learn and have fun at the

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same time [4]. Traditionally, videogames are considered a mere form of entertainment. Even though the role of play is acknowledged as fundamental in the first years of life, it is often undervalued in formal education [2]. While playing games children do not even realize that they are learning, and this makes the learning activity more natural. In addition, Serious Games can contribute to the player’s level of motivation [5]. In particular, Serious Games for health can be defined as games that have the purpose of teaching how to live in a healthy way by avoiding unhealthy habits [6]. In this paper, we will discuss a videogame developed to disseminate information about HIV virus transmission modalities among young people. In particular, the main target of the game is high school students. By playing this game, the user should learn what behaviours involve a risk of HIV contagion and what behaviours are safe. In other words, the aim of the game is to modify people's habits in order to fight the spreading of AIDS. The game has been developed using Adobe Flash technology, which provides a set of very powerful tools to create online games. In order to make the game as easily accessible as possible we published it on the Facebook social network.

2 Related Work

Serious Games for heath have been successfully used in the field of pain management [7]. In fact, the concentration required to play a game can contribute to alleviate the feeling of pain felt by patients [8]. Getting patients to play can have positive effects on their blood pressure and their feeling of nausea [9]. Beyond the use of Serious Games to support therapy, another field is focused on enhancing the information and education of the public about healthcare related topics. The Andalusian Patient Safety Observatory has developed a videogame to promote, among both healthcare professionals and common people, the correct hand hygiene practices [10]. In the field of HIV research, the work [11] discusses about the design process of “The HIV Game”. Similar to our aim, the focus of that game is to inform young people living in Yucatan about the HIV topic. In order to exploit their culture, the designers have chosen to situate the game in a Mayan environment and the player is a Mayan hero. In 2008 the American videogame software house Virtual Heroes developed the “Pamoja Mtaani” game, aimed at educating youths living in the African country of Kenya on HIV prevention habits [12, 13]. In the two games about HIV discussed above the main characters are human meanwhile in our game the main character is the virus itself. We have chosen to make the HIV the main character in order to let the player concentrate on the virus and on its behavior.

3 The HInVaders Game

The following subsections describe the idea behind the game, who the main character is and what the player has to do in the game.

3.1 Virus, antiretroviral and white blood cells

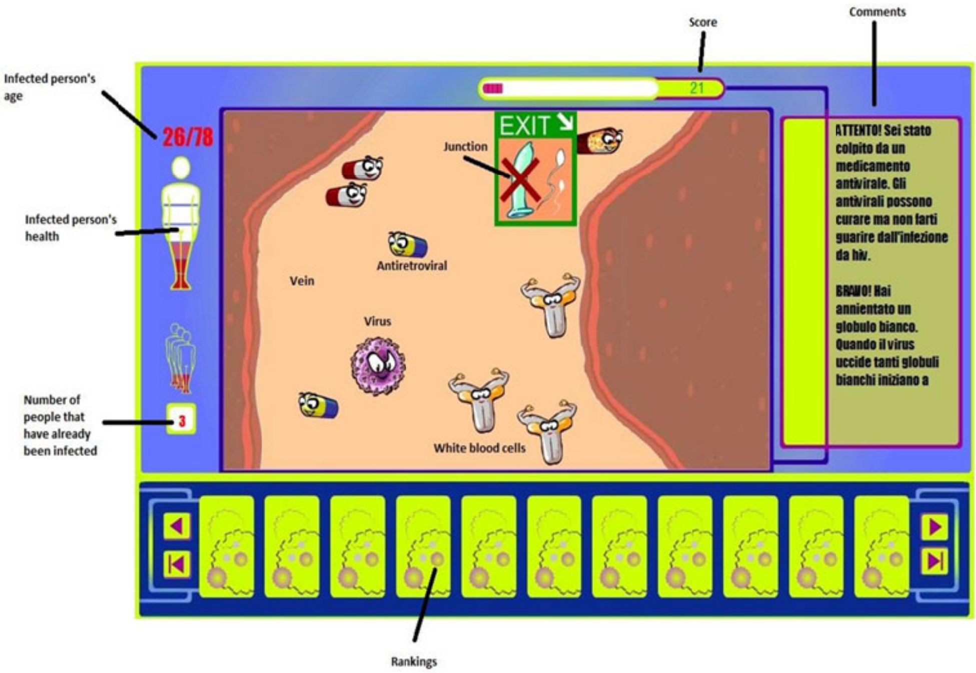

Fig 1: HinVanders game interface

The main character of the game is the HIV virus. The player controls a molecule using the directional keys of the computer keyboard. When the game starts, the virus has already infected a person and the player is located inside a vein of the infected body. During the gameplay, the molecule controlled by the player encounters treatments (e.g. antiretroviral therapy) represented using the pill metaphor, and the human immune system (e.g. white blood cells) coming down the screen. The player has to avoid the treatments and to attack the immune system in order to increase his score (called viral load). When the virus kills a white blood cell its viral power increases, and the person's health decreases, meanwhile when the virus hits an antiretroviral its viral power decreases and the person's health increases. The infected person's health level is indicated by a specific widget on the game GUI. If the molecule/player goes through the same body too long, he will die with the infected person. Therefore, it is important for the player to explore the possibilities to escape from the infected body by infecting other persons exploiting some events, which occur during the gameplay. Figure 1 shows the interface of the game highlighting the main features.

3.2 The events

The events represent the transmission modalities with different degrees of success probability. The player can encounter events with a high risk (e.g. unprotected sexual intercourses), medium risk (e.g. a rescue of an injured person) and low risk (e.g. a mosquito bite) of contagion. These events become available during the gameplay. For example, a syringe is a channel to infect another body, and it becomes available when a healthy person uses the same syringe that was previously used by the currently infected person. Another channel is the insect sting. This opportunity of contagion becomes available when an insect that has previously stung the infected body stings a person. Each event is represented by an image. When an event occurs, the corresponding image comes down on the right side of the screen and the player has to hit that image in order to try the channel. These events and channel are called junctions in the game. Some events involve a high risk of contagion, some involve a medium risk and others involve almost no risk of infection at all. For example, the use of a syringe previously used by an infected person causes a high risk of contagion; meanwhile touching the sweat of an infected person can't cause the HIV to spread. In collaboration with HIV experts, we have identified 16 main contagion channels, catalogued according their risk of infection in three main categories (A-no risk; B-medium risk; C-high risk). The events that can be found in category A are an insect sting and the exchange of body fluids between two persons, like saliva (e.g. sharing a glass), urine (e.g. using a public baths) and sweat (e.g. sharing the same tools in a gym). Category C includes the exchange of milk between mother and son during breastfeeding, the exchange of high quantity of blood (e.g. in a big injury or during the share of a syringe), the exchange of seminal fluids (e.g. in a non-protected sexual intercourse). Table 1 shows all the events that can happen in the game. If the molecule/player decides to exploit an event, his attempt of infection can be successful or unsuccessful. If the infection attempt is successful, the molecule will be in a newly infected body and the game will go on, otherwise the molecule dies and the game ends. In this way, to get high scores the player has to learn which channels and behaviours are more likely to cause a contagion and which aren't.

Table 1: The list of game events

Event	Description	Type	Risk Level	Image
Breast Feeding	An infected mother feeds her child through her breast	C	High	
Big Injury	A healthy person touches an infected person's blood	C	High	
Syringe	A healthy person uses a syringe which was previously used by an infected person	C	High	
Non Protected Sexual Intercourse	Two people have sex without using a condom and one of them is infected	C	High	
Small Injury	A healthy person touches an infected person's blood	B	Low	
Saliva	Two people kiss and one of them is infected	B	Low	
Protected Sexual Intercourse	Two people have sex using a condom and one of them is infected	B	Low	
Insect Sting	A healthy person is stung by an insect that has previously stung an infected person	A	Very Low	
Mucus	An infected person coughs in front of another person	A	Very Low	
Sweat	A healthy person touches an infected person's sweat	A	Very Low	

Event	Description	Type	Risk Level	Image
Urine	A healthy person touches an infected person's urine	A	Very Low	
Vomit	A healthy person touches an infected person's vomit	A	Very Low	
Contraceptive	Two people have sex and the woman takes a contraceptive pill	C	High	
Oral Sexual Relationship	Two people have an oral sexual relationship	B	Low	
Protected Homosexual Intercourse	A homosexual couple has a protected sexual intercourse	B	Low	
Non Protected Homosexual Intercourse	A homosexual couple has a non protected sexual intercourse	C	High	

3.3 After the event

When the player hits a junction, a video clip starts showing the event that is happening. Near the video clip, a text is displayed asking the player whether he want to try the contagion exploiting this event or not. Before deciding what to do, the player has to answer a multi-choice quiz, we use this trick in order to assess the level of knowledge of the user about HIV contagion during the gameplay. Figure 2 shows in detail what happens after the events.

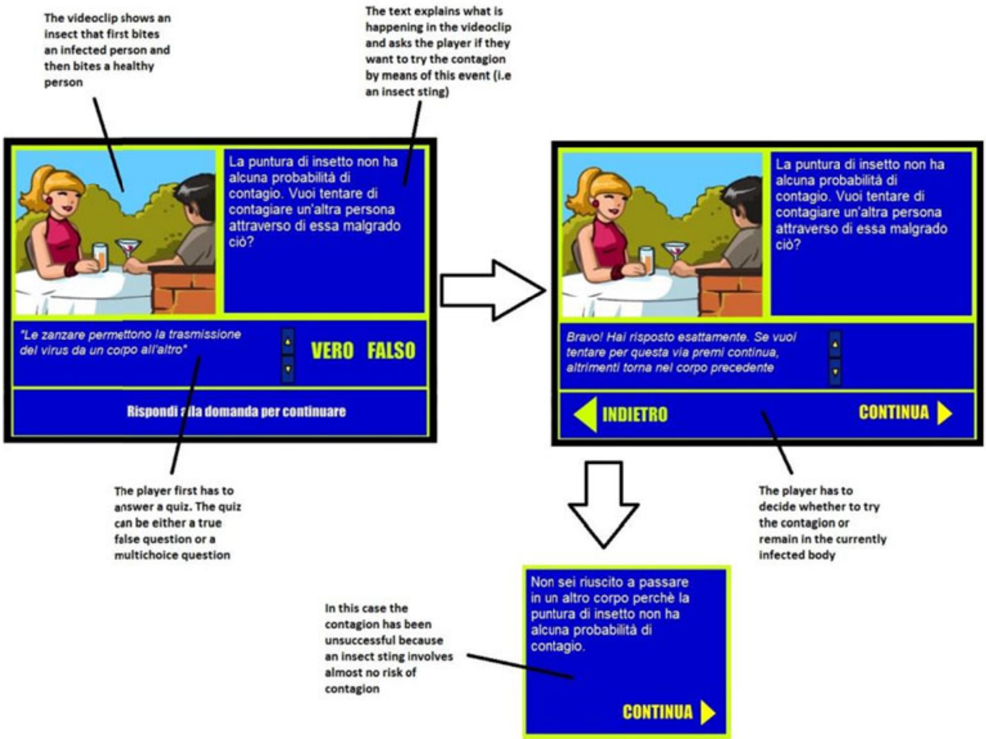

Figure 2: When the player hits a channel, the games explain what happens

The player, using his facebook account, can compare his score with the scores of his friends in order to improve the motivation.

4 Tests

One of the main issue in Serious Games research is the difficulty to prove the efficacy, effectiveness and usability of games. We are now starting a trial with real users to test the effectiveness of the game, by making it available on Facebook. A set preliminary lab tests involving a small group of students shows some encouraging results.

Seventeen university students participated in the experiment. The students were from a varied educational background but all had completed High School studies. All the students involved were more than 20 years old and didn't have a specific medical education.

During the test, first, the students were asked to complete a questionnaire of seven items about HIV. Then they play a 30 minutes session with the HInVaders game individually and in a quiet room. After the playing session, they are asked to complete a second questionnaire with seven items (multiple choice questions) about HIV (different from the first seven). For each student, the questionnaires was composed selecting randomly the questions from a pool of 14 items about HIV, in order to avoid bias in the result due to difference in the difficulty of the questions. The questions were aimed at measuring the level of knowledge about the HIV infection. Finally, the subject were asked to fill a questionnaire with four items about the perceived quality (in terms of fun) of the game. The expectation was that the final knowledge (measured from the second questionnaire) has to be higher than the initial knowledge (measured from the first questionnaire), if the game is effective.

5 Results

The two following subsections present the initial results gained from the experiment.

5.1 Questions about HIV

In order to assess the effectiveness of the game, we have compared the number of correct answers given by each player before playing the game with the number of correct answers given by the same player after playing the game. The results are shown in Table 2.

Table 2: The results of the test

Groups	Number of People	Correct Answers	Average	Variance
Pre	17	101	5,94	0,68
Post	17	108	6,35	0,49

After playing the game, the players have answered correctly a greater number of questions than before playing. Nevertheless, an ANOVA test shows that the improvement is not statistically significant, because P=.12 >.05.The higher scores gained after the test are encouraging, but the results cannot be used to conclude that the game is effective, because the statistical test fails. However, the result may be due to the fact that the initial knowledge of the selected subjects was already quite high, so there was little room for improvements. Actually, we tried to exclude from the statistical analysis all users (4) that answered correctly to all initial questions. In that case, the ANOVA test shows a significant difference which is an encouraging result. Moreover, the playing session, lasting only half an hour, may have been too short for the game to have effects. For this reasons, in the future we plan to conduct more extensive tests. The new tests will involve a higher number of subjects, selected among high school students (a more suited target for the game) and with a longer game play period.

5.2 Perceived game pleasantness

The questions about the game were aimed at assessing both the players' comprehension and the players' acceptance of the game.

Comprehension. The first question was about who is the main character of the game: the virus, the doctor or the patient. 16 out of 17 answered correctly to this question. Only one person didn't understand that the main character of the game is the virus. The second question asked whether the purpose of the game is killing the infected person or infecting as many people as possible. 16 out of 17 understood that the aim of the virus is infecting as many people as possible. So, we can conclude that the settings of the game is correctly understood by users.

Acceptance. The third question about the game asks how pleasant the game is. Two people answered that the game is very pleasant, eleven answered that the game is pleasant. For three people the game is unpleasant and for one it's unpleasant.

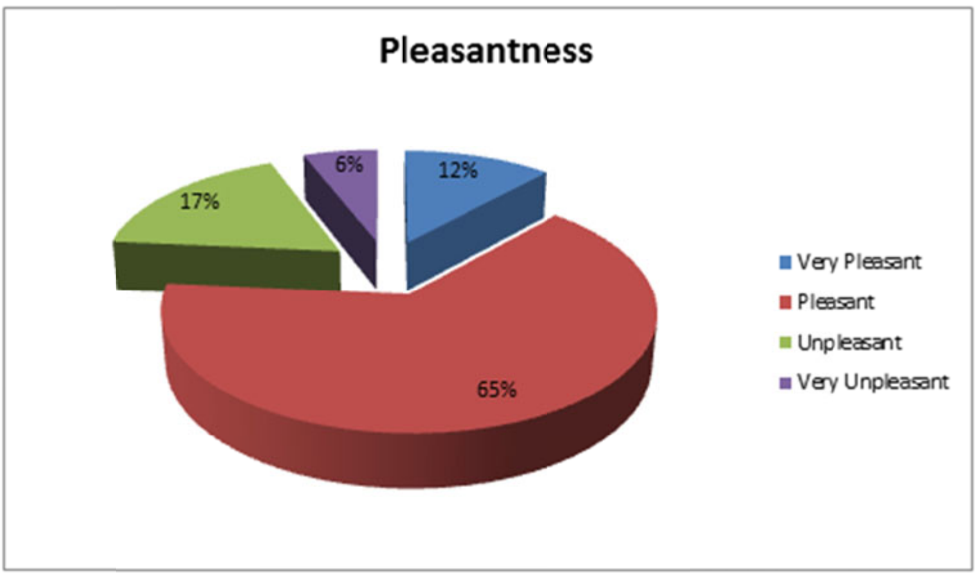

Figure 3: Perceives pleasantness of the game

The fourth question is about the game's usefulness. Seven people considered the game very useful, ten considered it useful. Nobody considered the game useless.

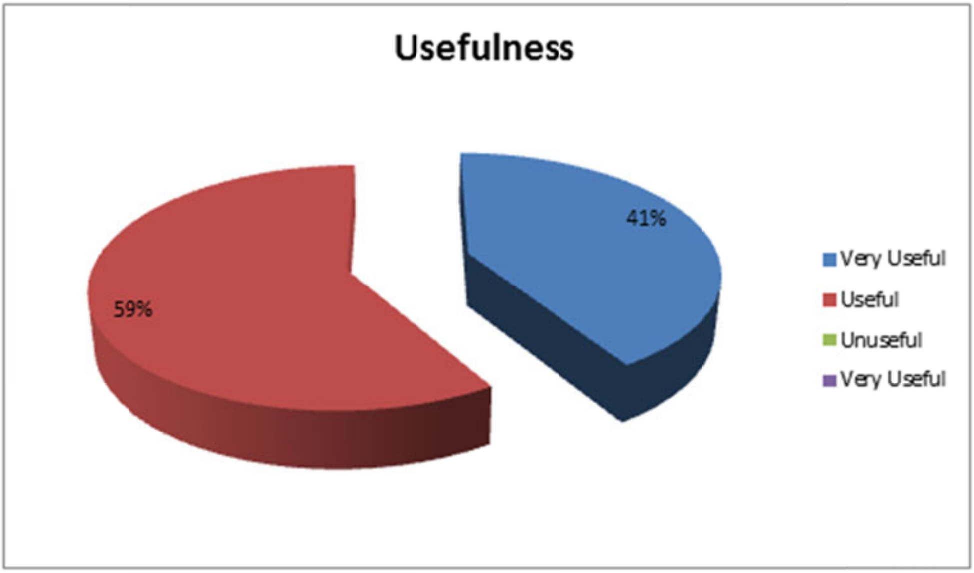

Figure 4: Perceived usefulness of the game

6 Conclusions

The purpose of this research is to explore the possibility of using Serious Games in order to teach how HIV spreads and how it is possible prevent its contagion. We have developed a game about HIV and tested its effectiveness. In this game, called HInVaders, the main character is the virus and its aim is to infect as many people as possible by choosing the right channels. The tests have been conducted on 17 adults with no medical background. The game has proven to be comprehensible and well accepted but the didactically effectiveness cannot be concluded, at least for adults. The population we tested had probably a too high level of initial knowledge that it is been impossible for the game to provide a significant improvement. For this reason, in the future, the game will be tested on a younger and wider population.

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From Kinect™ to anatomically-correct motion modelling: Preliminary results for human application.

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Abstract

The Kinect™ sensors can be used as cost effective and easy to use Markerless Motion Capture devices. Therefore a wide range of new potential applications are possible. Unfortunately, right now, the stick model skeleton provided by the Kinect™ is only composed of 20 points located approximately at the joint level of the subject which movements are being captured by the camera. This relatively limited amount of key points is limiting the use of such devices to relatively crude motion assessment. The field of motion analysis however is requesting more key points in order to represent motion according to clinical conventions based on so-called anatomical planes. To extend the possibility of the Kinect™ supplementary data must be added to the available standard skeleton. This paper presents a new Model-Based Approach (MBA) that has been specially developed for Kinect™ input based on previous validated anatomical and biomechanical studies performed by the authors. This approach allows real 3D motion analysis of complex movements respecting conventions expected in biomechanics and clinical motion analysis.

1 Introduction

Human motion tracking is widely used for movement analysis and biomechanical representation of the musculoskeletal system. Currently, most movement analysis laboratories are using Marker Based Systems (MBS) [1]. Although precision of this kind of device is high, practical problems still occur in daily practice: such systems are cumbersome and expensive, setting of the markers used on the subject is time-consuming and result validation is still an issue in the literature (reproducibility and accuracy issues). This can be explained by several factors. At first, markers need to be placed carefully on the subject's skin overlying some anatomical reliefs located underneath the skin surface, for example some bony tuberosities [2]. Errors during placement of the markers will induce errors during motion representation (i.e., based on the marker placement), and therefore result will show relatively low

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reproducibility [3]. Motion artifacts caused by skin deformations can also reduce the measurement precision [4]. MarkerLess System (MLS) are developed for nearly twenty years and could represent alternatives for MBS [5-7]. MLS shows interesting perspectives for biomechanical applications: fast subject preparation because no marker placement, reduced reproducibility error due to the absence of marker placement. However, despite these promising advantages, MLS does not seem to have broad success in the motion analysis field. This lack of interest may be due to the fact that, in people's mind, MLS offers less precision than MBS. Let's note that MBS also show limitations: for example it is recognized that some skeleton motions (e.g., longitudinal rotations) are inducing limited skin displacements; marker displacements are therefore minimal. [8]. On the other hand, precision of MLS depends on the number of cameras used (single camera [9] to multiple cameras system [10]), types of algorithms (annealed particle filtering [11], stochastic propagation [12], silhouette contour [13], silhouette based techniques [14] …), estimation of whole body or only specific region.

The recent availability of the Kinect™ sensor - PrimeSense technology (Tel Aviv, Israel) [15-17] - a cost-effective, portable and single camera MLS, shows interesting perspectives in the revalidation and motion analysis field. Due to the high potential of the Kinect™ in various fields (e.g. motion assessment, rehabilitation, ergonomics…) research is being performed to estimate the precision and validity of this device for environment estimation [18], posture assessment [19] or full body analysis [20]. Currently, based on these studies, is appears that the Kinect™ can be used to assess some kind of motion in well-defined situations [21]. However these studies only focused on the validation of the crude stick model skeleton provided by the Kinect™ (with SDK) composed by 20 points. These 20 points are gross estimations of the center of the major joints of the human body (Figure 1). This kind of model however only allows simple motion assessment (e.g., vector angle between 3 points for knee or elbow flexion, simple geometric approach to estimate elbow abduction between shoulder and elbow…) with limited precision. Furthermore this skeleton is a planar representation of the human anatomy, and therefore does not really represent the human skeleton in 3 dimensions (3D). It must be stressed that in order to be used in clinics for the evaluation and the follow-up of patients, the standard provided skeleton must be improved to include anatomical knowledge to meet anatomical conventions. This paper presents a novel paradigm in motion analysis using a single Kinect™ sensor as MLS to collect raw data that are optimized thanks to Model Based Approached using past experimental data and knowledge collected by the authors.

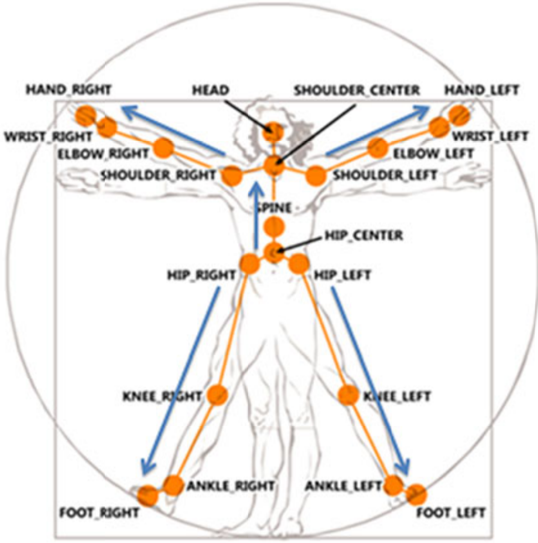

Figure 1: Stick model skeleton obtained with Kinect™ sensors and Kinect for Windows SDK (Source: **http://msdn.microsoft.com/en-us/library /jj131025.aspx)**

2 Methodology

Two main problems are met with the raw skeleton provides by the Kinect™: - the limited number of points available; - and the inconstant length between the successive points making the subject's segments. These inconsistencies lead to non-physiological results (Figure 2). The instability of the points is partly due to the fact that the segment lengths are not fixed during the motion causing important length variations when the subject is moving [22].

In order to tackle these problems, a model-based approach (MBA) was developed to enhance the anatomical accuracy of the standard skeleton obtained from the SDK associated to the Kinect™ input. Results lead to the availability of an enriched skeleton embedding supplementary anatomical data.

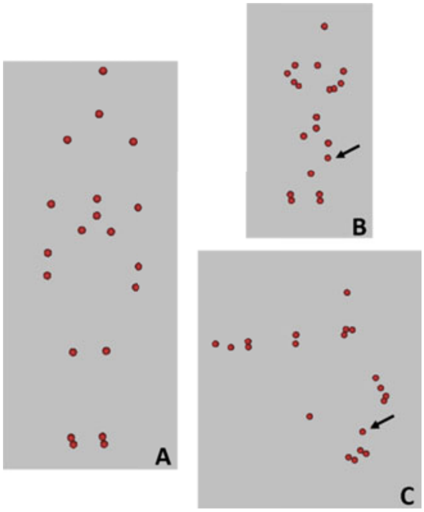

Figure 2: Example of miss tracking with Kinect™ sensor (before optimization). ***A*** Stick model diagram in upright position indicates that joint centres are well recognized (anterior view). ***B*** and ***C***. The subject is performing a deep squat movement (knee flexion), the arrow indicates that the left knee is miss tracked (***B***=anterior view, ***C***= lateral view).

Joint kinematics has been intensively studied these last 15 years in the author's department allowing a better understanding of joint behavior. Both in-vivo (e.g., study on living subject using MBS stereophotogrammetry for motion analysis) and in-vitro (e.g., study on cadaver using pins placed on the bone to record exact motions without soft tissues artifacts) studies were performed. All these knowledge were introduced into the developed MBA procedures in order to optimize the Kinect™ raw skeleton data (Figure 3).

The authors' past work on joint modeling was obtained from various techniques : 3D bones reconstructions obtained from medical imaging (CT scan) [23]; joint kinematic obtained with 6 DoFs instrumented spatial linkage [24], with embedded strain gages [25], with optoelectronic devices [26]; soft tissues information's were obtained from dissection or medical imaging [27].

Kinematic data available for each joint were assembled in one unique MBA pipeline in order to optimize skeletal segments characterized by some spatial poses (i.e., relative spatial orientation of the subject's segments during some movement). The new MBA algorithm is based on a previous double-step registration method developed within our group for the lower limb motion analysis [28].

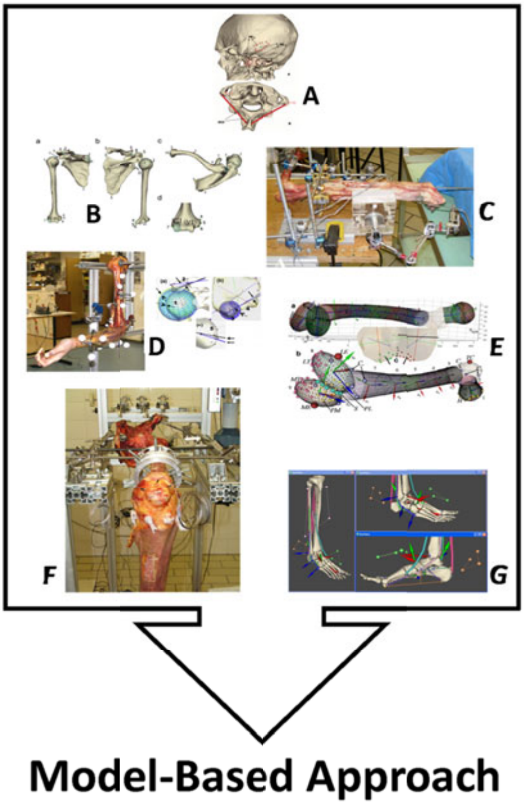

Figure 3: A few examples of biomechanical studies performed in the laboratory and implemented into MBA. ***A*** Musculoskeletal modelling and cervical spine kinematics [26,29]. ***B*** *S*houlder rhythm (shoulder joint behaviour) [30-31]. ***C*** Hand, wrist and fingers biomechanics [32-34]. ***D***. Elbow (including soft tissues modeling) [35]. ***E*** Hip joint and femoral bone morphometry estimation [36]. ***F*** In-vitro knee joint kinematic [37-38]. ***G*** foot and ankle motion (in-vivo and in-vitro) [39].

MBA results are illustrated in Figure 4. MBA allows obtaining an enriched skeleton including supplementary anatomical landmarks that are necessary for motion representation according to anatomical and clinical conventions. The same procedure also rigidifies the subject's segment length. The output enriched skeleton is suitable for conventional motion analysis and further biomechanical analysis (for example, including soft tissue information based on the added anatomical landmarks).

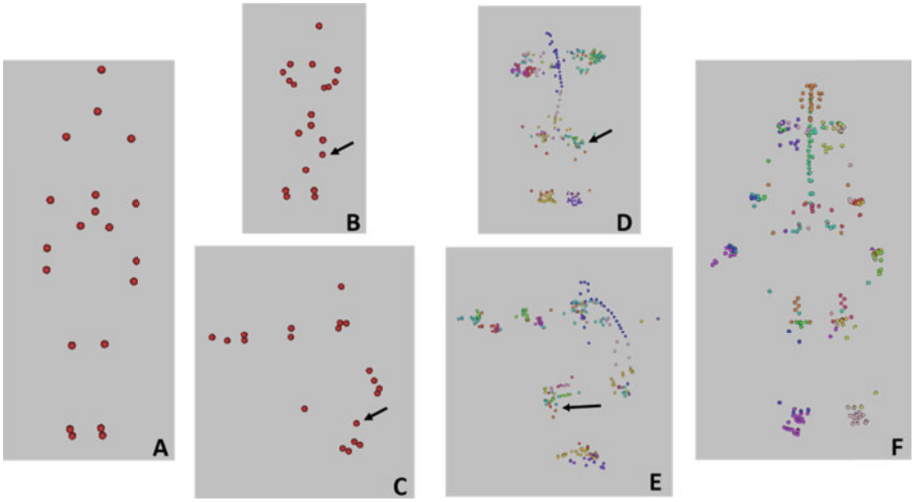

Figure 4: *A, B, C* Raw results (similar to Figure 2). Figures ***D*** and ***E*** show the same squat motion after MBA optimization process, arrows indicates that the left knee is in a more natural position. Figure ***F*** show the optimized skeleton in upright position. Note the supplementary anatomical data has been added to the raw data in order to obtain an enriched skeleton.

The enriched skeleton can then be fused with a generic anatomical skeleton model using data fusion methods based on spatial transformation [40]. Figure 5 is showing the full pipeline for an upper body motion analysis.

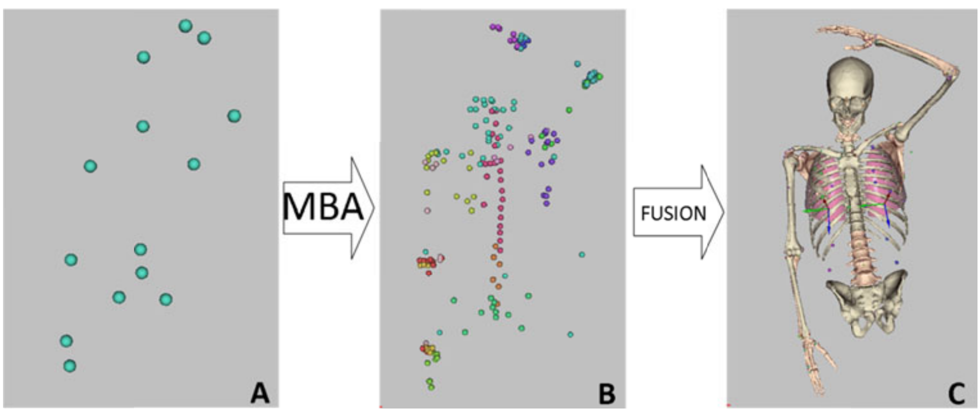

Figure 5: Example of complex 3D motion recorded with the Kinect™ and enriched with the presented MBA algorithm: conventional Hand-to-Head clinical assessment (called the Mallet Score [41]). ***A*:** raw results of the Kinect™ = input signal for MBA. ***B*:** optimized results = MBA output. ***C*:** MBA results fused with generic skeleton. Supplementary anatomical information, such as muscle or ligament information can be added to the skeleton.

3 Results

To assess results of the MBA method, 5 healthy subjects were equipped with reflective markers (Plug in Gait model) and were invited to realize clinical “Hand-to-Head”, “Hand-to-Mouth” and “Hand-to-Back” motions (these motions are used to assess upper limb functions with patient suffering, for example, from obstetrical braxial plexus palsy [41], see Figure 5). Motion data were recorded with the Kinect™ and with a MBS (Vicon, 8MXT40s camera) simultaneously. Both signals were processed using MBA, and Range of Motions (ROM) were compared using Wilcoxon signed-rank test. Results are presented in Table 1

Table 1: Mean (std) ROM for the three studied motions, results are expressed in degrees.

	Hand-to-Head		Hand-to-Mouth		Hand-to-Back	
	Kinect™	MBS	Kinect™	MBS	Kinect™	MBS
Shoulder Flexion	35 (8)	33 (5)	29 (7)	30 (7)	32 (12)	29 (8)
Shoulder Abduction	75 (7)	69 (12)	22 (9)	19 (7)	18 (8)	18 (8)
Shoulder Rotation	60 (9)	53 (8)	19 (8)	14 (7)	35 (14)	29 (10)
Elbow Flexion	92 (9)	95 (11)	102 (20)	109 (18)	49 (16)	48 (14)
Forearm Prono-Supination	50 (12)	55 (16)	42 (14)	47 (20)	46 (16)	47 (19)

No statistical difference was found for both devices after processing the inputs with MBA. The (non-significative) differences were as following: shoulder flexion presented difference values from 3 to 10% depending on the motion, shoulder abduction from 0 to 13%, shoulder rotations from 11 to 26%, elbow flexion from 2 to 7% and forearm prono-supination from 2 to 11%.

4 Discussion

The Kinect™ seems promising not only for games purposes but also in clinics and rehabilitation. Raw skeleton data must however be processed prior to produce motion representation that are meaningful within clinical assessment activities. Research have already been performed allowing live visual feedback for patient correction during rehabilitation exercises [42], to assess the reachable volume with upper limb [43], to correct posture [44]. To the best of knowledge these studies are only using the simple stick model skeleton. Restrictions of the clinical use of the current system, prior to MBA optimization, include:

- The visual feedback is important to correct motion and increase benefits during rehabilitation [45]. One can easily imagine that the avatar used for visual feedback must be as close as possible to the real movement produced by the patient. Currently Kinect™ input can be used to animate avatar or models, but due to the lack of sufficient anatomical landmarks these avatars will not reflect the patient's movements in an accurate way.
- Motion analysis is an important part of the clinical examination of patient suffering from various disorders such as neurological conditions (e.g. stroke, cerebral palsy, etc) or orthopaedic disorders (e.g. low back pain, total knee replacement, etc). This kind of examinations requires precise devices able to record 3D motions because these pathologies lead to complex motions patterns [46]. MLS must be adapted to be able to track such motion pattern.
- The same MBA approach could be used to gear human avatar controlled in gaming applications.

The presented MBA solves some of these problems thanks to various operations such as segment length rigidification, weighted smoothing for each particular joints and physiological joint behaviour based on joint mechanism obtained from experimental data. Precision of the overall skeleton is increased.

The MBA procedure can be used to animate a real skeleton as presented in Figure 5. MLS results were similar that those obtained with a MBS (Table 1). These results indicated that, for those particular motions, the combination of Kinect™ and MBA can be used to quantify complex 3D motion of the upper limb. It is important to note that, due to the important number of parameters of this model, calibration is required in order to have similar results that those provided with gold standard MBS. This calibration is mainly focusing on fine tuning of smoothing parameters, actually each joint can be configured separately. Despite the MBA some motions, in particular shoulder rotations, and the ankle joints, remain difficult to estimate and should be, therefore, carefully interpreted.

The enriched skeleton can also be integrated as Anatomical Optimization Engine within game environments in need of anatomical accuracy.

Further researches are needed to evaluate the possibilities of the Kinect™ for future potential clinical applications. This paper presented a method for fast and easy 3D motion analysis (kinematics evaluation). Currently there is a lack of tool easily available to clinicians to perform clinical motion assessment in a quick and efficient way. Proposed devices are either not precise or reproducible (e.g. goniometer) or expensive and with limited access (electrogoniometer, optoelectronic device). Bringing new and more accessible motion assessment devices could allow increasing the frequency of patient follow-up, and therefore would allow better patient monitoring.

New possibilities are also provided by the use of the skeletal model (Figure 5) obtained after the MBA process and after data fusion. Soft tissues (e.g. muscles, ligaments …) can be added to this model and information related to muscles behaviour during motion (muscle length, lever arm, etc) can be obtained. These new information could bring new insight on pathologies involving musculo-skeletal system such as spasticity [47]. Of course important validation works are required before going so far in the treatment of data obtained with this MBA.

5 Conclusion

Although the Kinect™ is already used for some limited clinical applications including basic motion assessment or live correction during rehabilitation, the underlying skeleton model is too crude for more advanced applications. This paper presents an optimization method that able to enrich the available raw data with supplementary anatomical and biomechanical information which were collected in previous scientific data collections. The optimization of the Kinect™ data with the proposed MBA method allows more accurate 3D motion analysis according to clinical conventions. Since the technology is cost-effective, not time-consuming to use and portable both patients and clinicians could benefit from this kind of developments thanks to an increase availability of motion assessment and better control of rehabilitation exercises. Note that this paper is using the first version of the Kinect™. The release of new Kinect™ hardware is expected to increase the quality of the MBA optimisation thanks to a better production of the raw skeleton.

6 Acknowledgments

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Fear and Happiness in "Re-Mission": Teasing Out Emotional Gaming Events Responsible for Cancer Risk Perception

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Abstract

Improving cancer risk perception among adolescents and young adults is a crucial public health goal that allows the prevention of cancer-initiating behaviors. Digital games can be implemented in health interventions to drive cancer risk perceptions.

This research experimentally examines how a video game called "Re-Mission™" (HopeLab, Redwood City, CA) may create an environment in which perceived threat from virtual cancer cells can lead to emotional involvement and ultimately induce perceived cancer risk among healthy young adults. In "Re-Mission," players control a nano-robot that fights cancer cells inside cancer patients' bodies. After baseline survey completion, participants (n = 118) played "Re-Mission" at low or high conflict (i.e., low, or high level of game challenges). Then, participants completed a post-experience survey.

Results from path analyses show that fear when being attacked by virtual cancer cells and happiness when killing cancer cells mediate pathways between conflict manipulation and change in cancer risk perception. These findings suggest that the study of emotions may aid researchers and designers in the identification of in-game events responsible for health outcomes.

Keywords

Video game, digital game, cancer, emotions, gaming events, features

1 Introduction

Despite the regular implementation of health interventions among youths, healthy young adults continue to suffer from a lack of awareness about cancer risks. The

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transition from adolescence to young adulthood is marked by an increase in cancer-initiating behaviors [1] such as smoking initiation [2] and low physical activity. Such behaviors highlight the need to implement health interventions that are able to make young adults aware of the risk of cancer [3, 4].

Perceived cancer risk (PCR) is a concept of the health belief model that is characterized by two main dimensions. First, *perceived susceptibility* to cancer explains one's beliefs about the odds of being personally at risk of getting cancer. The second dimension of PCR is *perceived severity* of cancer, which explains one's perception of how serious cancer and its consequences are. Previous research has found that individuals' perception of the chances of getting cancer and their beliefs of being vulnerable to cancer may predict healthy behaviors. In fact, perceived susceptibility to and severity of cancer have been shown to be connected to cancer preventive behaviors such as breast self-examination [5, 6], mammography [7], and skin protection [8].

One strategy to drive cancer risk perceptions is to implement interactive interventions. In particular, digital games have the potential to raise awareness about cancer risks. Going beyond exposure to a narrative, digital games allow their users to experience firsthand information related to cancer. Several games such as "Ben’s Game", "Re-Mission", and the "Cancer Game" have been designed for cancer awareness and prevention. Particularly, "Re-Mission" has shown evidence based results among adolescent and young adult patients. "Re-Mission" is a third-person shooter game in which the player goes on missions to fight cancer cells in the virtual bodies of cancer patients. Numerous studies have confirmed the effectiveness of "Re-Mission". Randomized controlled trials have shown that "Re-Mission" can increase knowledge and medication adherence among young cancer patients [9, 10].

While "Re-Mission" was mainly designed to promote medication adherence among patients, recent research has also demonstrated its ability to help healthy young adults perceive cancer risk and encourage them to seek cancer-related information [11]. An experimental study has shown that healthy young adults who played "Re-Mission" at high conflict (i.e., high level of obstacles and challenges in the game) experienced an increase in perceived susceptibility to and severity of cancer as compared to players at low conflict. Also, the more young adults perceived virtual cancer cells in the game to be threatening, the more they experienced an increase in perceived cancer severity and susceptibility [11]. This study suggests that by virtually experiencing the consequences of cancer cell behavior (e.g., cancer cell multiplication and attack of tissues), young adult players of "Re-Mission" increased their perception of cancer risks. The present study will expand on previous research by investigating the mediating role of emotional involvement in "Re-Mission" between perceived threat from virtual cancer cells and cancer risk perception.

The present work is grounded on theoretical perspectives related to experiential learning as an outcome of emotional involvement and a driver of PCR. *Experiential learning* is a product of interactive platforms that stimulates learning through experience. The interactive aspect of digital games offers players a wide range of choices that gives them the opportunity to take certain gaming decisions. Examples of choices may be the embodiment of characters, the manipulation of objects, and the exploration of different scenarios in the game [12]. Such in-game decision making leads to different courses of events that are followed by consequences.

1.3 The Events of Conflict

Conflict is characterized by an interactive, responsive, and purposeful set of obstacles (e.g., invasion by and multiplication of cancer cells) that slow down the players' attempt to reach their goals (e.g., killing virtual cancer cells and saving cancer patients) [13, 14]. In "Re-Mission", conflict with virtual cancer cells is key when making decisions and facing consequences. In addition to difficulty level as set by game designers, three features that describe conflict are considered in "Re-Mission": confrontation of cancer cells (i.e., personally face cancer cells), vulnerability to cancer cells (i.e., loss of energy when attacked by cells), and limited resources to fight cancer cells (i.e., limited ammunition). As a result of high conflict in "Re-Mission", young adults may begin to perceive virtual cancer cells to be threatening.

Knowing that conflict may play an important role in driving risk perception, understanding the events that constitute conflict in "Re-Mission" sheds light on the specific experiential moments that are responsible for the learning experience. As part of a pilot study conducted to identify gaming events that occur during conflict, research has identified four main themes of events that constitute conflict and repetitively occur throughout game play in "Re-Mission": exposure to cancer cells, cancer cell multiplication, cancer cells attacking, and killing cancer cells. Such events may form the experience of conflict with virtual cancer cells, resulting in experiential play.

1.4 From Game Play to Emotional Involvement

Emotions have a chief role during experiential play, as they form individuals' biological reaction to unanticipated or unique play events. Previous research has established the link between game play and emotional involvement [15]. During game play, individuals find themselves in an immersive environment that drives perceived presence and ultimately elicits an emotional response [16]. Players tend to *escape* to a virtual reality that encourages a suspension of reality and the belief in the virtual world [17]. The experience of gaming events drives players to become emotionally involved [18]. In "Re-Mission", players confront virtual cancer cells that continuously attack them. Such a confrontation occurs while players are in a state of escape, which allows them to perceive virtual cancer cells as threatening. As a result, perceived threat from virtual cancer cells may drive emotional involvement during game play.

1.5 Emotions and Risk Perception

Psychological studies have suggested that emotions are key predictors of risk perceptions [19, 20]. However, emotional involvement is not expected to directly drive change in PCR. Research has sustained that emotional stimulation tends to influence cognitive processes. In the context of "Re-Mission", in-game behaviors allow players to discover the consequences of their actions. Such discovery drives emotions, which in turn may encourage retrospective appraisal through processing. Appraisal may ultimately help young adults understand cancer risks. Prior research on the link between emotions and behavior has shown evidence that emotional appraisal allows individuals to "extract lessons and conclusions about how a different course of action might have yielded better emotional outcomes" [21; p. 173]. As a result, young adults may begin to learn from in-game experience and become provoked to think about the risks of cancer. Such thought provocation may ultimately help them realize cancer severity and susceptibility.

1.6 Fear and Happiness in Risk Perception

According to Ekman [22], six basic emotions (happiness, sadness, anger, fear, surprise and disgust) can be measured as an individual emotionally responds to a stimulus (e.g., events in a video game). Regardless of cultural background, these emotions are universally manifested on the face, and can be recognized and detected [22, 23]. Also, research has shown evidence of coherence between individuals' facial expression of such emotions, and their emotional self-report [24].

Self-reported emotions of fear may play a role in risk perception [25, 26]. It has been proposed that fear is a result of uncertainty and a lack of control. In "Re-Mission", players are expected to face colonies of cancer cells and engage in a battle with them. When many cancer cells attack the player, fear may arise. Such an emotion may ultimately provoke the thoughts of young adult players concerning cancer risk. In addition to the effect of fear on risk perception, happiness may play in important role in the context of "Re-Mission". When players confront cancer cells, fear becomes an outcome of conflict and threat perception. As a result, players may react and begin to fight cancer cells. Such interactivity creates a climax in conflict during which players attempt to kill the cells. Ultimately, successful killing of cancer cells is a form of reward and relief, resulting in the experience of happiness. In turn, happiness may provoke the players' thoughts concerning the risks of cancer.

In the realm of such theoretical frameworks, the present paper hypothesizes relationships linking conflict during game play to PCR. Such hypotheses are presented in figure 1. The paper also posits the following research questions:

RQ1: Which gaming events are most likely to involve the emotions of fear, anger, sadness, and happiness?

RQ2: Which emotions mediate the relationship between perceived threat from virtual cancer cells and thought provocation about cancer risk?

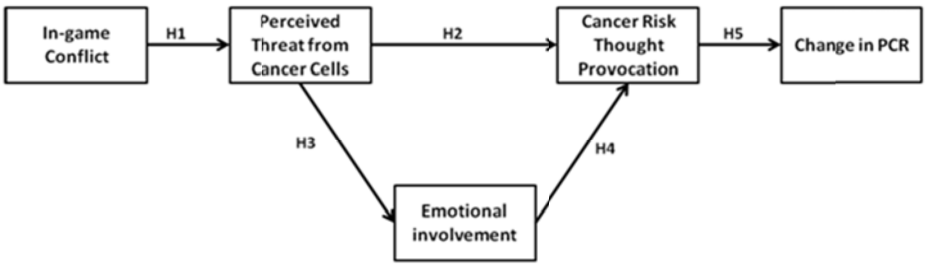


Fig. 1: Hypothetical path model with the mediating role of emotional involvement.

2 Methods

2.1 Participants and Sampling Procedure

Recruited participants were 118 young adult college students at a northeastern U.S. university (47.83% female) between the ages of 18 and 29 years (M = 19.92, SD = 1.73). They participated in the experiment to complete research credit requirements. As for their ethnic distribution, participants were mainly Caucasian (63.72 percent), Asian (20.35 percent), Hispanic (10.62 percent), and African American (4.42 percent).

2.2 Experimental Procedure

First, participants completed a pretest survey one week before the experiment. At the experimental site, all participants completed a tutorial that teaches them how to use the controls in the game when attempting to move their avatars. Similarly to a previous study on "Re-Mission" [11], the duration of the tutorial was approximately 7 minutes.

After the tutorial, participants were randomly assigned to play "Re-Mission" at low or high conflict (Table 1). Participants were seated in front of computers of the same brand and size. They were asked to start the first mission of the game and played for a period of approximately 40 minutes. Every time the players completed the mission and every time they lost in the game, they were asked to play it again. The reliability of this procedure has been previously investigated and validated [11]. Directly after game play, participants completed a post-experience survey.

Table 1: A description of the operated parameters to manipulate conflict

*Game Feature**	*Description*	*Low Conflict*	*High Conflict*
Difficulty level	High difficulty level involves a high number of cancer cells attacking the avatar and the need for a high number of ammunitions to kill each cancer cell.	Low	High
Invulnerability option	Vulnerability involves susceptibility to lose health (as shown in the health bar), as cancer cells attack. Invulnerable players cannot lose in the game. Their health remains at maximum as indicated by their health status.	Turned on	Turned off
Unlimited ammunition	Players who have unlimited ammunition have an unlimited amount of weaponry to kill cancer cells.	Turned on	Turned off

*These game features have been previously considered in the manipulation of conflict (Khalil, 2012).

2.3 Conflict Manipulation

Three attributes of conflict have been manipulated as part of game features to create a high conflict environment: confrontation between the player and cancer cells, difficulty level, vulnerability to enemies, and limited ammunition (Table 1). Participants at the "low conflict" condition played "Re-Mission" at low difficulty level, were not vulnerable to cancer cell attack, and did not lose ammunition when fighting cancer cells. On the other hand, participants at the "high conflict" condition played the game at high difficulty, were vulnerable to attacks, and did lose ammunition when shooting cancer cells.

2.4 Measures

The outcome variable of PCR was assessed at both baseline and post-game play. Perceived threat from cancer cells, provocation of thoughts on cancer risk, and emotional involvement were measured after game play. Change in PCR was calculated by subtracting the measure at baseline from the measure at post-test. A list of the main measures and covariates in this study and their descriptive statistics are presented in table 2, with measure references and reliability.

Table 2: Means, standard deviations, description, and Cronbach's alpha for the measures

Measures	T1[a] M (SD)	T2[a] M (SD)	Description[b]	α
Perceived threat from virtual cancer cells	-	4.28 (2.52)	Four 9-point semantic differential items were used such as "While playing Re-Mission, how threatening did you feel cancer cells to be?" (from "not at all threatening" to "extremely threatening").	.95
Emotional involvement and emotions at gaming events[d,e]	-	3.20 (2.08)	For each gaming event of conflict, participants were asked how much they experienced each of the following emotions: surprise, fear, happiness, sadness, anger, and disgust. Overall emotional involvement was also assessed by asking players how much they felt emotionally involved in the game. Answer choices from 1 = not at all to 10 = extremely.	-
Thought provocation related to cancer risk	-	3.21 (1.26)	Five items such as: "After playing the game, the first thing that came to my mind was related to cancer" and "the pictures pushed me to think further about my opinion concerning the risk of cancer." (from 1 = very strongly disagree to 7 = very strongly agree) (Khalil, Recently submitted).	.92
Perceived susceptibility	2.57 (0.82)	2.44 (0.60)	Two items: "Compared to most people my age, my risk of getting cancer is…" and "the likelihood of my getting cancer is…" (from 1 = extremely low to 5 = extremely high) (Rimal & Real, 2003).	.89
Perceived severity	5.72 (1.15)	5.39 (1.26)	Four items such as: "Cancer is a serious disease that can kill" (from 1 = very strongly disagree to 7 = very strongly agree) (Rimal & Real, 2003).	.77
PCR		13.40 (4.59)	Scores for perceived susceptibility and severity were multiplied to form perceived cancer risk (PCR) (Rimal &	-

Measures	T1[a] M (SD)	T2[a] M (SD)	Description[b]	α
			Real, 2003).	
Perceived control over the game	-	4.38 (1.52)	An adapted scale with nine items such as: "For me to feel in control over all cancer cells was difficult" (from 1 = very strongly disagree to 7 = very strongly agree) (Rapee, Craske, Brown, & Barlow, 1996),(Kraft, Rise, Sutton, & Røysamb, 2005).	.95
Perceived challenge	-	3.49 (1.45)	Five items such as "Playing Re-Mission has challenged me to perform to the best of my abilities" (from 1 = very strongly disagree to 7 = very strongly agree) (Novak & Hoffman, 1997).	.90
Attitude toward Re-Mission	-	4.56 (1.70)	A 9-point semantic differential scale for attitude with eight items (e.g., dislike/like and not worth owning/worth owning) (Forest-Boucher, Brunet, & Fredette, 2008).	.95
General control over stress	4.76 (0.82)	-	Seventeen items such as "I am able to control my level of anxiety while playing a video game" (from 1 = very strongly disagree to 7 = very strongly agree) (Rapee et al., 1996).	.80
Perceived skills in game play	3.82 (1.32)	-	Six items such as "I am very skilled at playing shooting games" (from 1 = very strongly disagree to 7 = very strongly agree) (Novak & Hoffman, 1997).	.87
Cancer connection	0.87 (0.33)	-	Participants who reported that they have been screened or diagnosed for cancer or that someone close to them (i.e., family member or friend) has been screened or diagnosed for cancer were considered to be connected to cancer (0 = No; 1 = Yes).	-

Note. Standard Deviations appear in parentheses below the mean.

[a]T1 and T2 indicate measures at pre-test and post-game play respectively for all participants.

[b]Description includes items followed by the answer choices.

[c]Coefficients for Cronbach's α were calculated from post-test data, with the exception for measures with data collected at T1 only.

[d]Mean and standard deviation presented for this measure are for the overall emotional involvement.

[e]Gaming events of conflict are the following: exposure to cancer cells, cancer cell multiplication, cancer cells attacking, and killing cancer cells

In addition to the presented measures of table 2, event-based emotional involvement was also measured. Considering the identification of gaming events of conflict in "Re-Mission", emotional involvement at each of such events were measured. For the event of confrontation of cancer cells, participants were asked if they saw any cancer cells in the video game. For the event of cell multiplication, participants were asked if they saw cancer cells multiply. For the event of cancer cell attack, participants were asked if many cancer cells attacked their robot. For the event of killing cancer cells, participants were asked if they killed a colony of cancer cells. Answer choices to these questions were "yes" or "no". For each of such events, if the answer was "yes", then participants were asked how much they felt each of the following emotions at the event, from not at all (0) to extremely (10): happy, sad, angry, surprised, and afraid. Such a self-reported measure of emotional experience has been found reliable and coherent with facial expression of emotions [24]. Emotional responses were not obtained for the "no conflict" group, because this group did not confront cancer cells.

3 Results

3.1 Conflict Manipulation Check

Differences between the conflict conditions were investigated by conducting the analyses of variance (ANOVAs, table 3). There were no significant differences between the conditions with regard to skills in digital game play, reaction to threat during game play, control of stress, or number of hours of game play per week. After participants played the game, there was no significant difference between the conditions with regard to attitude toward "Re-Mission." Significant differences were observed with regard to perceived control over "Re-Mission", perceived challenge, and perceived easiness to kill cancer cells (Table 3).

Eight separate one-way ANOVAs were performed to analyze the differences between the conditions in these variables. The sample size of 118 participants involved 64 players in the high conflict condition and 54 players in the low conflict condition.

Table 3: Manipulation checks with expected differences and similarities between the three conditions

Variables	*Low Conflict*	*High Conflict*	*F*	η^2
	M (SD)	M (SD)		
Perceived Skills	3.76 (1.35)	3.85 (1.41)	0.14	0.013
eneral reaction to threat	3.95 (1.03)	3.96 (1.21)	0.00	0.023
Control of stress	4.68 (0.81)	4.82 (0.80)	0.87	0.009
Number of hours of game play per week	2.52 (3.91)	3.91 (6.69)	1.75	0.013
Attitude toward Re-Mission	4.57 (1.70)	4.43 (1.81)	0.19	0.008
Perceived control over Re-Mission	4.65 (1.49)	3.45 (1.29)	19.05***	0.230
Perceived challenge	3.34 (1.52)	4.00 (1.28)	3.78+	0.110
Perceived easiness to kill cancer cells	3.15 (2.08)	5.32 (2.31)	28.20***	0.270

Note. *** = $p < 0.001$. Standard Deviations appear in parentheses next to the means.

3.2 Emotions and the Gaming Events of Conflict

To answer RQ1, a series of ANOVA's was performed (Table 4). Gaming events were compared with respect to each emotion: surprise, fear, anger, happiness, and sadness (Figure 2). Knowing that the gaming events occurred at conflict, the analysis was conducted with the conditions of low and high conflict. For the emotion of surprise, results were statistically significant [$F(3,441) = 8.76$, $p < 0.001$]. Self-reported surprise was significantly higher when cancer cells attacked the player, than during mere exposure to cancer, or during the killing of cells. Surprise was significantly higher when cancer cells multiplied than during mere exposure to cancer cells. Surprise was highest during cell multiplication and when cancer cells attacked. The same results were obtained for the emotion of fear [$F(3,441) = 10.45$, $p < 0.001$]. Self-reported fear was significantly higher when many cancer cells attacked the player, than during mere exposure to cancer cells, or during the killing of cells. Fear was significantly higher when cancer cells multiplied than during the killing of cells. Fear was highest during cell multiplication and cancer cell attack. Participants reported a higher level of happiness when killing a colony of cancer cells, than during cell multiplication, cell attack, or exposure to cells [$F(3,439) = 106.83$, $p < 0.001$]. For the emotion of sadness, results show that when cancer cells attacked the robot and when cells multiplied, players reported a higher score on sadness than when they were killing the cancer cells [$F(3,439) = 6.58$, $p < 0.001$]. Sadness was marginally significantly higher when seeing cancer cells than when killing cancer cells. ANOVA results show that anger was lowest during the killing of cancer cells, and highest when cancer cells attacked the robot and when cancer cells multiplied [$F(3,438) = 19.64$, $p < 0.001$].

Table 4: Statistical difference between conflict events with regard to each emotion

	Mean (SD)					
Emotion	E1: Exposure to cells	E2: Cell multiplication	E3: Cell attack	E4: Killing cells	F	η^2
Happy	1.89 (1.83)	1.43 (1.17)	1.35 (0.92)	5.64 (3.43)	106.83***	0.42
Sad	1.81 (1.60)	2.15 (2.20)	2.16 (2.17)	1.2 (0.66)	6.58***	0.04
Angry	3.24 (3.08)	4.81 (3.55)	4.65 (3.55)	1.99 (2.15)	19.64***	0.12
Surprised	2.41 (2.21)	3.70 (2.92)	3.99 (3.07)	2.74 (2.50)	8.76***	0.05
Afraid	2.43 (2.35)	2.78 (2.75)	3.53 (3.15)	1.67 (1.40)	10.45***	0.06
	Significant Difference Between:					
Happy	E1 and E4***, E2 and E4***, and E3 and E4***					
Sad	E1 and E4+, E2 and E4***, and E3 and E4**					
Angry	E1 and E2**, E1 and E3**, E1 and E4*, E2 and E4***, and E3 and E4***					
Surprised	E1 and E3***, E1 and E2**, E3 and E4**, and E2 and E4*					
Afraid	E1 and E3**, E3 and E4***, and E2 and E4**					

SD, standard deviation

+p<0.1, *p<0.05, **p<0.01, ***p<0.001

E1, E2, E3, and E4 stand for event 1, event 2, event 3, and event 4 respectively.

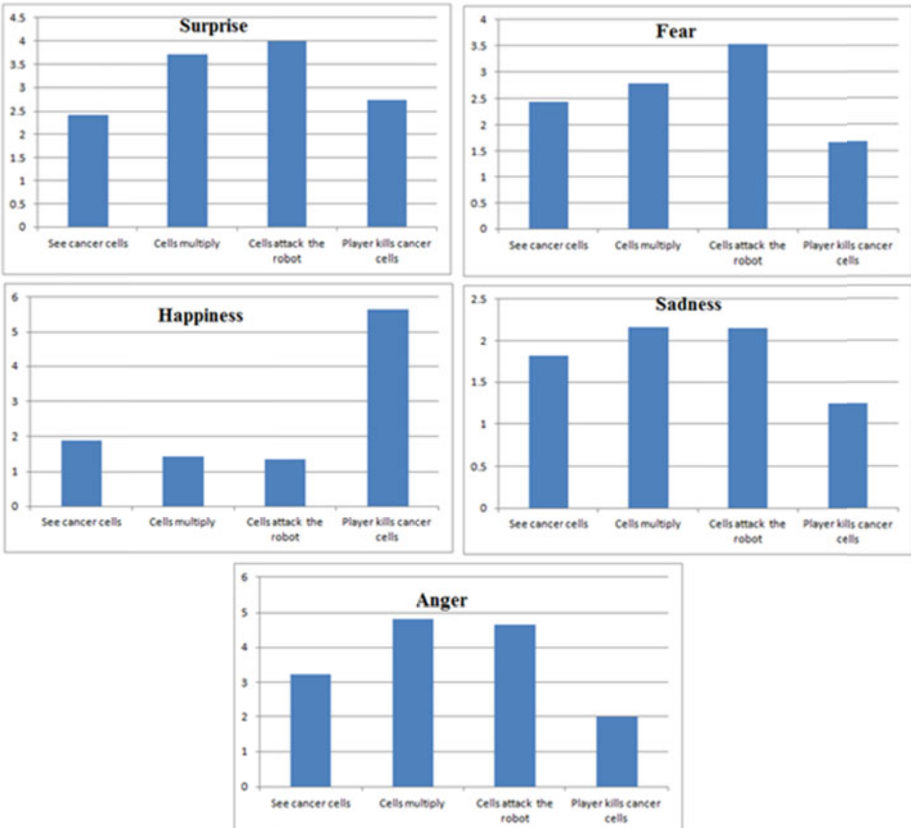


Fig. 2: Mean score for each self-reported emotion at the gaming events of conflict with cancer cells

3.3 Emotional Involvement as a Mediator

To test hypotheses 1 through 5, Pearson's correlation was first conducted (Table 5). Then, path analysis was performed to investigate mediation (Figure 3). The maximum likelihood estimation procedure was used, setting the error term for each endogenous variable at a mean of 0 and a variance of 1. Model fit was assessed using the following criteria: (a) a non-significant χ^2 goodness-of-fit statistic, (b) a comparative fit index (CFI) of 0.90 or greater, and (c) a root mean square error of approximation (RMSEA) less than or equal to 0.08 [27]. Overall emotional involvement was found to partially mediate between perceived threat from cancer cells and thought provocation concerning cancer risk (Figure 3). In the absence of emotional involvement, there is a significant relationship between perceived threat and thought provocation ($\beta = 0.35$, $p < 0.001$). When emotional involvement is included in the model, the relationship weakens in coefficient and significance ($\beta = 0.22$, $p < 0.01$).

Table 5: Pearson's correlation between the main measures

	1	2	3	4	5
1. Change in PCR	-				
2. Thought Provocation about Cancer Risk	0.21*	-			
3. Emotional Involvement	0.09	0.37***	-		
4. Perceived Threat from Cancer Cells	0.089	0.33***	0.48***	-	
5. Condition	-0.06	-0.02	0.01	0.24**	-

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

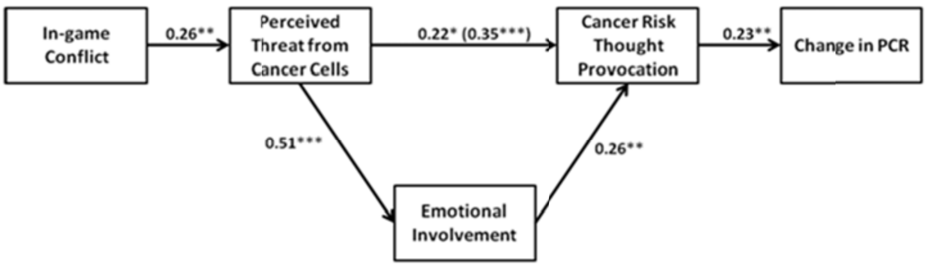


Fig. 3: Path model explicating the mediating role of emotional involvement between conflict and PCR.

Note. Coefficient in parentheses indicates the result in absence of emotional involvement.

All coefficients are standardized.

PCR stands for perceived cancer risk.

All path models conducted in this study involved a sample size of 110 participants.

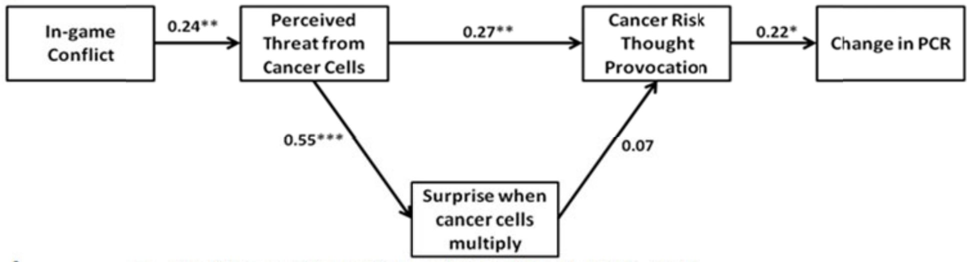
Eight participants had missing values and were not considered in the models.

** $p < 0.01$; *** $p < 0.001$

3.4 Modeling Emotions

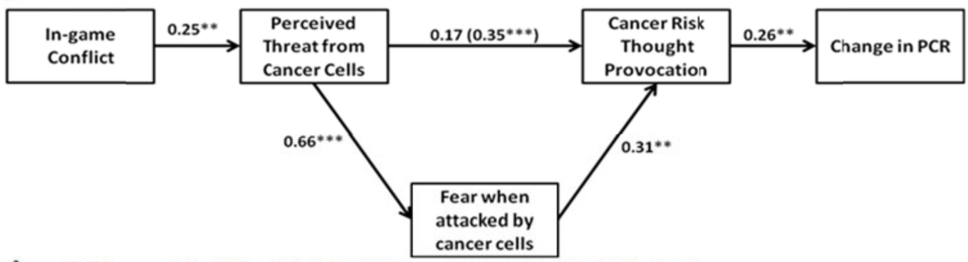
Based on the event-based emotions obtained by answering RQ1, RQ2 may be answered by conducting a series of path analyses. The model in figure 3 may be reproduced, replacing overall emotional involvement with each of the obtained emotions at the different gaming events. The emotions and events considered in such models are those that have shown significantly higher scores (Figure 2, table 4).

a



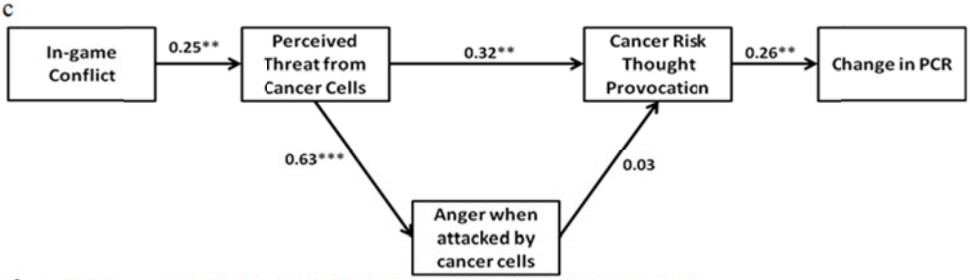
$\chi^2_{(5)} = 5.12, p = .40$, CFI = 1.00, RMSEA = 0.01, 90% CI: 0.00–0.13

b



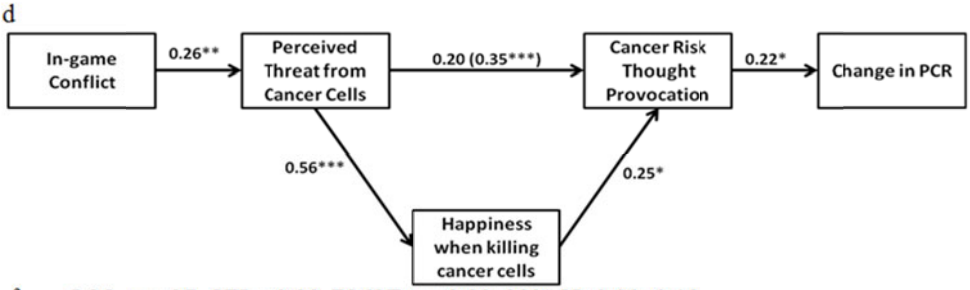
$\chi^2_{(5)} = 5.71, p = .33$, CFI = 0.99, RMSEA = 0.03, 90% CI: 0.00–0.15

c



$\chi^2_{(5)} = 8.68, p = .12$, CFI = 0.95, RMSEA = 0.08, 90% CI: 0.00–0.18

d



$\chi^2_{(5)} = 5.35, p = .37$, CFI = 0.99, RMSEA = 0.02, 90% CI: 0.00–0.13

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Fig. 4: Alternative path models for the emotion mediating the relationship between perceived threat from virtual cancer cells and cancer risk thought provocation. Coefficients in parentheses indicate the relationship between perceived threat

and thought provocation when emotion is removed from the model. PCR stands for perceived cancer risk.

As a result, four models are investigated (Figure 4), looking at the mediating role of surprise when cells multiply, fear when attacked by cancer cells, anger when attacked by cancer cells, and happiness when killing cells. Findings show full mediation for fear when attacked by cancer cells and happiness when killing cancer cells (Figure 4b and 4d). With such results in mind, a final model was conducted such that both fear and happiness are considered (Figure 5). As previously mentioned, fear during the attack of cancer cells may explain happiness when killing the cells, as a sign of relief. Also, research on conflict events has shown that cancer cell attack occurs before the player begins to kill the cells. The results in figure 5 show a significant relationship between fear and happiness. However, happiness in this model is not significantly related to cancer risk thought provocation. While considering happiness, fear during cell attack is still a significant mediator between perceived threat and thought provocation. When the fear construct is removed, happiness regains its mediating role (Figure 4d). The model in figure 5 shows excellent fit ($\chi^2_{(7)} = 6.90$, $p = .43$, CFI = 1.00, RMSEA = 0.00, 90% CI: 0.00–0.12).

4 Discussion

The results of this study offer support for the hypothesized relationships between conflict in a digital game and cancer risk perception. Two main findings are highlighted in this study. The first finding mainly suggest that conflict-induced play may create an environment in which perceived threat from virtual cancer cells can provoke young adults to think about cancer risk and ultimately increase their cancer risk perception. The second finding points at the role of event-specific emotions as mediators between threat perception and thought provocation.

Experiential play of "Re-Mission" allowed young adults to face the consequences of cancer invasion. They were able to experience the continuous multiplication of cancer cells, their invasion of organs, and their offensive behavior toward healthy cells and the avatar [11]. Such an experience encouraged players to confront virtual cancer cells and engage in conflict with them. Results of this study indicated that young adult players of "Re-Mission" at high conflict were more likely to perceive threat from virtual cancer cells than players at low conflict. During conflict, players confront virtual cancer cells that continuously attack them. Such a confrontation occurs while players are in a state of immersion, which allows them to perceive cancer cells as threatening. Threat from virtual cancer cells ultimately translates to appraisal concerning cancer risk. Results in this study show that the more players perceived threat from virtual cancer cells, the more they were provoked to think about cancer risk. In-game behaviors may allow players to discover the consequences of their actions. Such discovery allows them to engage in deductions concerning the risk of cancer, and become provoked to think about cancer risk. As a results of thought provocation, players increase in PCR.

The present study extends such findings by delineating potential mediators between threat perception and thought provocation concerning cancer risk. While the relationship between conflict and cancer risk perception is indirect, pathways involving threat perception and emotional involvement may explicate previous findings on conflict in "Re-Mission". First, results from this study show that overall emotional involvement partially mediates the relationship between threat perception and thought provocation. The findings pinpoint the salience of specific events of conflict by measuring the emotions expressed at such stages. Two main event/emotion pairs were identified. Analyses show that fear when attacked by cancer cells and happiness when shooting cancer cells fully mediate the relationship between threat perception and thought provocation. The more fear was expressed during cell attack, the more happiness was reported when killing cancer cells. However, when considering both emotions in the model, only fear showed mediation. These results suggest that emotional response to the obstacle (i.e., cancer cell attack) is a more salient mediator of the relationship than a rewarding emotion when overcoming the obstacle. On the other hand, anger when attacked by cancer cells and surprise when cancer cells multiplied did not mediate the relationship between threat perception and thought provocation.

The main limitation of this study is its dichotomous manipulation of conflict, neglecting its continuous nature. Even though some aspects of conflict have been manipulated to create conflict conditions, several other characteristics of the conflict experience have not been manipulated. Both conflict conditions included a high number of cancer cells that attacked the avatar at the same frequency. Also, cells multiplied at the same rate in both conditions. As a result, direct manipulation differences were not observed between the two conditions with regard to PCR. In this study, players were randomly assigned to either low or high conflict, regardless of their perceived skills in game play or hours of game play per week. Despite the lack of difference between the two conditions with respect to such factors, players may have experience a disruption in flow by being assigned to specific conditions. Young adults with high skills may have experienced boredom when playing at low conflict. On the other hand, young adults with low skills may have experienced frustration when playing at high conflict. However, no significant differences were obtained with regard to attitude toward "Re-Mission". Also, players at high conflict were more likely to experience a positive challenge of "Re-Mission" than players at low conflict.

In addition, having been designed for a different purpose and a different intended population, "Re-Mission" is not expected to drive actual preventive behavior among healthy young adults. No direct relationship was obtained between conflict manipulation and the health outcomes. However, exploring further the features of "Re-Mission" and their ability to drive cancer risk perceptions may shed light on potential characteristics of game play that can be used to design a future game for young adults. The present study pinpointed two main events in "Re-Mission" (i.e., cancer cell attack and killing cancer cells) that elicit certain emotions and drive thought provocation about cancer risk. As a result, future research may explore such gaming events of conflict by manipulating them in an experimental setting. In absence of cancer cells attacking the avatar, fear is not expected to be elicited, and ultimately thought provocation concerning cancer risk may not be observed. Similarly, in absence of the ability to kill cancer cells, players may not engage in a rewarding experience and happiness may not be stimulated to drive thought provocation. In practice, game designers may take advantage of the role of such gaming events of conflict in shooter games to design a prototype of a new game for health that can take advantage of both challenge and reward for cancer risk perception and ultimately protective behaviors.

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Game Design, Development and Business

Bias Blaster – Aiding Cognitive Bias Modification-Interpretation through a bubble shooter induced game-flow

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Abstract

This paper presents the design and development of Bias Blaster. Bias Blaster is a proof-of-concept integrated bubble-shooter game with an evidence-based therapeutic intervention, i.e., Cognitive Bias Modification Interpretation (CBM-I). The game is tailor-made for patients of the Dutch national mental health organization (GGZ) recovering from a First-Episode Psychosis (FEP). Cognitive Bias Modification-Interpretation treats the self-stigma and its associated interpretation bias as experienced by patients recovering from a FEP. The amount and frequency of CBM-I items and training is regulated by the patient, through an integrated game-mechanic of the modified bubble shooter. The game implements a motivational and reinforcement paradigm, which paves the way for the use of the rigorous and demanding CBM-I therapy. Moreover, Bias Blaster exploits the natural game flow of the bubble shooter to increase resilience and adherence throughout the treatment of FEP patients. This paper presents the design and development process of the game. The lessons learned are summarized in implications for the design of serious games: design for "acceptance" and as a "serious therapeutic".

Keywords

First Episode Psychosis, Cognitive Bias Modification-Interpretation, Casual Video Game, Social Anxiety, Interpretation Bias, Flow, Design for acceptance, Serious therapeutic.

1 Introduction

In this paper we present the design and implementation of the game Bias Blaster, a dedicated game that assist treatment of patients recovering from a First-Episode Psychosis (FEP). The design of the game as therapeutic instrument involves a careful balance among the interests of different stakeholders such as the player/patient, the psychotherapist, and game designer.

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Despite many years of research and development into psychosis and schizophrenia it still remains one of the most costly and uprooting illnesses worldwide [1]. A First-episode psychosis typically emerges during the sensitive developmental period of adolescence and emerging adulthood. FEP is most prevalent between the ages of sixteen to thirty-five [2]. Psychosis is a condition characterized by loss of contact with reality and can involve severe disturbances in perception, cognition, behaviour, and feeling [3]. A psychosis manifests symptoms in a range of domains that include positive symptoms, negative symptoms, mood symptoms and cognitive symptoms, each of them underlying specific pathophysiological processes and treatments [4].

The onset of a psychosis can have a variety of causes, including: substance abuse, exposure to severe stress, inherited and/or acquired medical conditions and mood disorders. After a FEP, preventing a 'relapse' by a patient in remission is the primary concern of treatment [5]. Relapse refers to the recurrence of positive symptoms such as delusions and hallucinations. These positive symptoms are typically treated and stabilized with a combination of antipsychotics and therapy. The majority of patients experiencing a first psychotic episode relapse during the 2–5 year period after initial diagnosis [6,7]

Patients recovering from a FEP often experience a syndrome-influenced self-stigma, which affects the patient's perception of themselves as well as the world around them. Patients with a First-episode psychosis (FEP) tend to interpret ambiguous social situations and stimuli in a negative way and attribute these negative experiences to themselves. This cognitive interpretation bias can have serious effects for the patient's self-image and results in a why-try-effect [8]. To prevent relapse, amongst other treatment, psychoeducation is given to the patient as well as the family in addition to other therapeutic interventions. Psycho-education is defined as 'systematic, structured, didactic information on the illness and its treatment, including integrating emotional aspects in order to enable patients – as well as family members – to cope with the illness or psychiatric disorder' [9]. Self-stigma is one of the subjects encompassed by psychoeducation.

Two problems arise in the deployment of psychoeducation for adolescents with a first-episode psychosis; firstly, psychoeducation shows mixed results [10,11] and secondly, the current form in which it is presented does not seem to fit the target audience [12]. Therefor the mental healthcare is reaching out for new approaches within the realm of serious media.

Serious games and simulations for this specific target audience have mostly been used for exposure therapy and assessment of positive symptoms [13,14]. Some recent advances in serious games for FEP do exist [15,16], but Bias Blaster has unique properties.

Healthcare nowadays is driven by evidence-based practices. The initial scope of the Bias Blaster project was to create a game based on the existing psychoeduaction curriculum [17]. Taking into account the better part of psychoeducation becomes infeasible, since it yields a too abstract therapy and lacks scientific rigor. Therefor a specific subject of psychoeducation has been selected for treatment with a different form of therapy. Cognitive Bias Modification Interpretation was chosen as a suitable treatment for self-stigma and the attached social anxiety. Firstly because, well-documented evidence exists for its effectiveness [18] and secondly, the method is suitable to be seamlessly integrated in a game.

This paper is organised as follows. In Chapter 2 we present the basic elements of Bias Blaster and their integration into the game. Bias Blaster seamlessly integrates CBM-I with a bubble shooter in a way that leaves the player/patient in control. Chapter 3 summarises the lessons learned in the form a design approach, design for acceptance, and a conceptual model of serious therapeutics. Chapter 4 concludes and elaborates on future work.

2 The evolution of Bias Blaster

2.1 Cognitive Bias Modification-Interpretation

The term cognitive bias was first coined by, Tversky & Kahnemann [19], and is defined as "a pattern of deviation in judgment, whereby inferences of other people and situations may be drawn in an illogical fashion" [20]. A cognitive bias is an automatic response of the mind, a mental shortcut in decision-making. Cognitive biases are unconsciously prevalent within the standard population, cognitive biases can be assessed by performing an Implicit Association Test (IAT). Cognitive Bias Modification (CBM) is a technique to modify specific Implicit Associations, i.e., an interpretation or attention bias. CBM trains individuals to interpreted ambiguous stimuli in a positive way, rather then following their automatic response of interpreting them in a negative manner.

Cognitive bias modification training provides appropriate content to address self-stigma and interpretation bias in social situations as experienced by the FEP-patients [21]. Psychotherapists make a distinction between attention bias and interpretation bias. An attention bias manifests in the prevalence of noticing negative cues and stimuli over neutral or positive ones, whereas an interpretation bias is the tendency to interpret ambiguous information in a threatening manner [22]. CBM has proven to be suitable modify interpretation bias [23], CBM-I is regarded a promising tool for treating psychosis and schizophrenia [21]. Unfortunately, sessions typically contain more than a hundred items of uninterrupted text-based exercises, which are exhausting, demanding and boring for patients.

2.2 Bubble shooter

Casual Video Games (CVG) are run of the mill, are simple to understand, have easy access and use, and require no special video game skills. Moreover they allow for short and irregular play time [24]. Interestingly, positive effects on stress reduction as well as on depression were found by playing CVGs [25].

There are countless types of CVGs. Bubble shooters are a well-known class of casual video games, with a wide range of implementations. The game mechanics of a bubble shooter is a juxtaposition of Tetris, Connect-four, and space invaders. The objective of the game is to limit the amount of bubbles that surface in the playing field, by shooting them with similar kind of bubbles. Similar bubbles connect, which subsequently depletes clusters of bubbles.

A Bubble shooter game encompasses the mechanics to create immersion and flow to facilitate fun and engagement. Immersion [26] and flow [27] are phenomena that affect the experience while playing games [28, 29]. The degree to which the player feels integrated with the game is a measure of the players' sense of immersion [30], while flow is experienced when the player has such an intense concentration that time and fatigue disappear [27]. Flow might be determined more by task-factors then by the realism of the game [31]. The influence of realism is less pronounced than that of the relation of possibilities and necessities to act [32].

2.3 Bias Blaster

Bias Blaster is a bubble-shooter based CBM-I game, implemented in untity3D as a web-browser game. Bias blaster combines the rigorous psychometric qualities of CBM-I and the de-stressing and flow-inducing qualities of a bubble shooter. The game play supports the cognitive bias modification interpretation according the motivational and reinforcement paradigm [30]. Bias Blaster implements a modified version of the traditional bubble shooter game mechanics; a bomb (Figure 1) connects the game play and the therapy, acting as a gateway to self-regulated therapy. The bomb serves as a game mechanic to deplete a multitude of bubble clusters independent of their shape and colour. In the game the continuous threat of stacking bubble-masses increases the cognitive task load. Combining a cognitive task load with flow and immersion presumably keeps the player from explicitly processing implicit CBM-I scenarios. When in trouble, the player is left the option to load the bomb to regain further progress in the game. It is consequential to realise that the player controls the frequency and length of the CBM-I sessions.

Fig. 1: Shows the bubble shooting part of bias blaster including a bomb that is the gateway to CBM-I items (you can only load it by working through CBM-I items), as well as the in-game reward (you can deplete a large area of bubbles by using it).

Traditionally CBM-I is presented in a text-only form to trigger the mental imagery of the individuals' own experience in social situations. Because of the clashing styles of the classic plain-text based CBM-I items and the frivolous bubble shooter some compromises in the design were required. Bias Blaster maintains the traditional CBM-I style as well as the order of elements, however decorated with additional comic-drawn stick figures (Figure 2 & 3). The decorations are interpretation free, thus without social cues and without distracting stimuli.

Fig. 2: From left to right, (a) the implicit onset of the situation, (b) the social implications of the situation, which cues the interpretation bias and (c) the initial unfolding situation is presented and ends with the question how you would interpret this particular situation. The three slides trigger a mental image of the scenario by the patient.

The stick figures are stimuli-free and ambiguous so as to maintain the psycho-diagnostic qualities of the CBM-I, in particular the process of mental imagery. If the comics had been richer in context and content, the stimuli and social cues in the comics would have presumably uprooted the modification training.

Fig. 3: From left to right (a) the completion of the word by inserting a letter that completes the word that creates a plausible interpretation possibility in the training; a positive outcome of the scenario, (b) the control question to check whether the patient understood the scenario and to reinforce the positive outcome (c) the possibility to return to the game or answer another CBM-I item, thereby adding extra power to the bomb.

In the dashboard of the game (Figure 4) the player can choose different environments to play in. The environments, or themes, fit the overall theme of the specific CBM-I items and the in-game environment of the bubble shooter. On top of that the theme determines the portrayal of the bubbles.

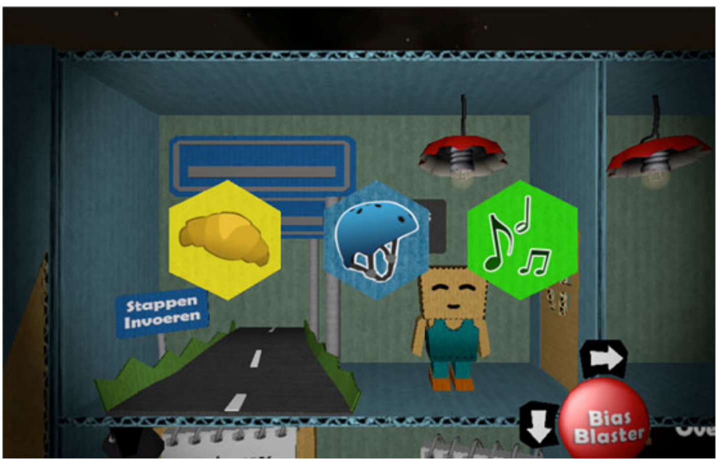

Fig. 4.: The dashboard of the game where the avatar can buy swagger and select themes, each representing different social environments (bakery, skateboard and a music concert). The themes drive the environment of the game and set the context in which CBM-I scenarios take place.

3 Implications for Game design

3.1 Design for Acceptance

Innovation in general entails introducing methods and tools in a novel domain, which implies new activities and new customers for the domain where the technique originates from and new technology for the receiving domain. But first and foremost, innovation is about use and actual deployment. For innovation put to work it is instrumental that stakeholders perceive the probability on success as good combined with a plausible good yield. Stakeholders must demonstrate a certain level of belief in order to engage.

In serious gaming projects, again in general, there is a minimum of three stakeholders: the designer, the deployer, and the player or client. Each of them takes a different perspective on the game and the gaming. The designer is typically concerned with the engagement of the player, whereas the deployer is concerned with the behaviour and learning goals of the client. The client and player being one and the same thus enrol in the serious gaming paradox. The player presumably engages voluntarily in the game, after all play is free, without purpose, and consequences in reality [33] whereas the deployer has a clear objective to change the player's attitude or behaviour.

Bias blaster has three principal stakeholders: the game designer, the psychotherapist and the first episode psychosis patients. Design for acceptance is a strategy to balance stakeholder's Perceived Usefulness, Perceived Ease of Use, and the consequent Behavioural Intention to Use [34, 35]. Stakeholders will attribute the properties of the game from their own perspective, taking into account their specific expertise, context, and organisational culture.

The psychotherapist comes from the mental health sector, in which evidence-based interventions and programs are the only accepted means of treatment [36]. Prior to accepting novel technologies, such as interactive games, it is crucial for them to have a clear understanding of the underpinning principles and a priori validation of the treatment.

Game designers come from the creative industry, in which entertaining the customer is the principal motivation. Creativity implies a way of work that involves explorative development and experimenting with serendipitous formats. As a for instance, game designers combine proven game mechanics in new forms, hence the wide variety of games in different genres.

The FEP adolescent is challenged to combine two worlds, the world of game play and the world of psychotherapy. As a player, he or she is familiar with different game genres such as FPS (first person shooters), MMPORG (massive multiplayer online role playing games), social games, and a wide range of casual games. Each of these commercial titles have in common that they are entertaining, can be played smoothly and intuitively, have well structured levels, are rewarding, can be played any time, and for as long as the player desires. As a client the FEP patient is used to follow a tedious psychoeducation program to remedy his health disorders. But only because he has been told that the programme is good for his mental health.

3.1.1 How to design for acceptance

Design for acceptance is in its essence a practical approach to multicriteria optimisation problem of the perceived Usefulness and perceived Ease of Use of the principal stakeholders. This emerging approach to design for acceptance includes multiple iterations with tangible experiments and the assessment of acceptance from different points of view.

The first step in design for acceptance is the exploration of the design space. Each stakeholder creates a view on the product. In case of Bias Blaster that resulted in a wide range of topics taken from psychoeducation that should be solved simultaneously. Topics were supported by a set of evidence-based interventions and their respective assessment tests. The game designers outlined a range of potentially suitable game mechanics and game designs. These too were supported by user test procedures. The player/client finally sketched a Utopia of a triple A game with an integrated non-patronising intervention.

The perceived Ease of Use includes feasibility. Given the limited amount of resources and time the first iteration of the design process should be a small yet effective step. Hence the choice for a casual game with a proven engagement, hence the choice for an isolated objective, i.e., mitigating self-stigma, and the choice for an accepted intervention, i.e., CBM-I. From the perspective of the player/client this may seem a small step, however it is a step on the route towards a serious therapeutic [12].

The perceived Usefulness includes belief and recognition. The first prototype of Bias Blaster involved a squirrel climbing up a tree. This game meets the abstract game model including immersive and flow-inducing principles and creating barriers, which can be overcome through a "voluntarily" engagement in the therapy. However, the disbelief of the psychotherapist experts with this concept urged for a more familiar game type. The behavioural Intention of Use by the player/client depends on the perceived flow and immersion and their perceived disturbance when the intervention kicks in. In case of Bias Blaster, it is the player who chooses to engage in the therapy for the sake of the game play.

During the course of the project many assessments for acceptance have taken place, but rather informally. A method based on questionnaires and quick scans to attribute the properties of the design from the various perspectives is yet to be developed. These attributes obviously will help to solve the underpinning multicriteria optimisation problem.

3.2 Towards a Serious Therapeutic

Though the design of Bias Blaster is far from ground breaking, the modes of use for the different modalities manifest interesting parameters for the development of games for health. Wartena et al [12] defined a serious therapeutic as “an application that operates on a trade-off between control of parameters by the therapist whilst acting as an assistive aid for the patient”. However that definition is far from complete and to narrow to encompass all the functionalities and modes of use games for health have to offer, and needs revision. Bias blaster has several interesting modalities that impact the potential of the game as well as the modes of use.

In Bias Blaster the healthcare professional has control over the CBM-I items in the database, while the patient has the control on when and how to access the game, a form of self-regulated learning. In case of Bias Blaster any surplus playtime outside of the therapy sessions (therapist-free-therapy) is a direct gain. Through logging, any action in the game can be monitored and analysed to assess the progress of patients throughout the therapy program. This embedded assessment is crucial in the monitoring and validation process of Bias blaster.

Serious games usually lack validation [37]. Even when an attempt is made to engage in a validation study, it is extremely hard to validate games that create completely new interventions, for healthcare. Because of that lack of validation, introducing serious games into an actual healthcare-related treatment-plan usually proves to be a lengthy endeavour. By not or minimally chancing the psychometric qualities of the CBM-I in Bias Blaster, the validation process can rely on the same questionnaires and scales used in the non-game version.

Bias Blaster is an adaptive, assistive self-regulatory mobile health game, which integrates monitoring as well as embedded assessment of the patients progress, which facilitates the validation process of the therapy as well as the added value of the game. All of the properties make Bias Blaster a potential cognitive vaccine [38, 39] for mental healthcare, i.e. a serious therapeutic.

4 Conclusion

Bias Blaster integrates an evidence-based therapeutic intervention and a casual game for the mitigation of self-stigma. Self-stigma is a principal obstacle in the treatment of first-episode psychosis adolescents. The intervention method is an adapted form of cognitive bias modification interpretation (CBM-I), whereas the choice of game play is a bubble shooter. The integration is by means of an add-on game mechanic: the bomb. Contrary to a classical bubble shooter, Bias Blaster creates a barrier that can only be resolved through the use of a bomb. Enabling the bomb is instrumented by an executing series of CBM-I scenarios. Thus the game flow potentially persuades the player to engage in the therapy by free will.

The design of the game balances the interests of the principal stakeholders, being the psychotherapist, the game designer, and the player/patient. In retrospect a design method emerged which we dubbed design for acceptance. Since using a game in psychotherapy is true innovation, the behavioural Intention of Use is crucial for any innovation to succeed.

The iterative approach for design for acceptance involves: exploration, feasibility, belief, recognition, and seamless integration. Exploring the design space puts marks on the horizon for each of the stakeholders. Addressing feasibility yields small steps in two dimensions of innovation, introducing a game technology in psychotherapy and introducing therapeutic activity into game design. Although the initial steps are small, the marks on the horizon can still be attained. In future iterations, steps may possibly be increased without jeopardizing the degree of perceived acceptance. Belief and recognition showed up when the actual game was designed from an abstract game model; all stakeholders must acknowledge the game play, not only the players. Creating a truly integrated game and therapy is essential for exploiting the virtue of game technology. In this case, the player voluntarily engages in the therapy persuaded so through the game play.

Taking design for acceptance one step further yields serious therapeutics. Bias Blaster's properties include the essentials of serious therapeutics such as: facilities to monitor and assess patients in game, instrument self-regulation, stimulate use out of the therapeutics context, and (integrated) support for validation.

5 Future work

Bias Blaster demonstrates several interesting concepts, which call for further research.

In Bias Blaster CBM-I has been used to mitigate self-stigma, however people suffering from more general social anxiety deficits may well benefit from CBM-I [40]. We intend to explore options in these directions. Questions that must be answered are obviously can we extend the range of CBM-I scenarios, in what form will they be implemented, do we have to discriminate between users etc.

The current implementation of CBM-I uses stick figures to link the game with the therapy and to introduce the context of the scenarios. It is an open question whether different implementation forms can be used. For instance more playful forms can easily be constructed.

Although the choice for CBM-I to mitigate interpretation biases is supported by literature, the actual validation, whether or not CBM-I is effective in this form has to be executed. A Randomised Control Trial (RCT) has been set up for this purpose. The RCT addresses issues such as the form of the CBM-I sessions, number of items, their length and frequency induced by the game play, their effect on the perceived engagement, and general effect on self-stigma and interpretation bias.

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Attributing Design Decisions in the Evaluation of Game-Based Health Interventions

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Abstract

The use of games as interventions in the domain of health care is often paired with evaluating the effects in randomized clinical trials. The iterative design and development process of games usually also involves an evaluation phase, aimed at identifying improvements for subsequent iterations. Since game design theory and theories from associated fields provide no unified framework for designing successful interventions, interpreting evaluation results and formulating improvements is complicated. This case study explores an approach of monitoring design decisions and corresponding theories throughout the design and development cycle, allowing evaluation results to be attributed to design decisions. Such an approach may allow the game design and development process to iterate the game more efficiently towards use in practice.

Keywords

game design, game development, design cycle, evaluation, validation.

1 Introduction

In the past years, a steep increase in the use of games or game-based tools as health interventions or part of such interventions can be observed – as noted in for example [1] and signified by the launch of a dedicated journal [2]. Results from case studies looking at the effective outcomes of the use of games in health are generally positive and indicate promising results for this field of study; particularly in the domain of exergames. For a case study example see for example [3]; for an extensive literature overview see [4].

Most of the game research in the domain of health care can be characterized as 'evidence based practice'. In such research empirical observations and research designs are employed to establish if an intervention has reached outcome targets. If the empirical outcomes substantiate such a claim, the intervention is characterized as 'successful'. In terms of research design, usually clinical

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randomized controlled trials (RCT) are required to validate proposed interventions before general use in practice [5]. In this context, the increased use of games as health interventions calls for case-by-case statements about the effects of a proposed products, as well as generalized frameworks for setting up and conducting such trials. We find however that most evaluation studies lack the required intrinsic connection to (serious) game design principles and related theories. Our findings were affirmed by various recent sources [6][7].

2 Design and Development Process

The game-based interventions that are the subject of evaluation studies are the result of a design and development process which we will first outline. The process of implementing a game-based health intervention is usually iterative in nature. In order to characterize the distinct types of steps in the implementation process, we can take a closer look at the difference stages in a design cycle as observed in practice – roughly following the human-centered design method for serious games [8]. This method consists of repeatedly conducting four phases: analysis, design, development and evaluation.

The main goal of the first phase (analysis) is to formulate the objectives of the game-based health intervention and identify preconditions for the implementation – such as constraints pertaining to time, budget and the domain and the context of application. In this phase the main activities are (desk) research and formulating the boundaries of the implementation together with stakeholders. Possibly, the first ideas of a promising game concept maybe formulated.

The main goal of the second phase (design) is to specify the design criteria, product specifications and formulate a game concept that meets these requirements. This design may be formalized in a game design document and/or evaluated through (paper) prototyping with a focus group. As such, quick improvements may be made to the design before developing any assets for the final product.

The goal of the third phase (development) is to develop a working version of the game; a non-digital or digital prototype at first or a polished final product in later stages. This phase is the most defined and well-known phase as it heavily draws upon common development methodologies in general IT – such as for example Scrum [9] and/or the spiral model of software development [10].

The goal of the fourth, and final, phase (evaluation) is to evaluate the current game version through various means. Usually, a focus group representing the target audience plays through the game in a context that approaches the real-life context of use in later stages. Furthermore, in earlier stages, expert reviews are used to identify the correct translation of domain knowledge into the game. To complete the cycle, the results from such an evaluation phase are used to feed into the investigation-stage of the next iteration of the cycle. The design is adjusted, selected improvements are implemented in the development phase and the resulting game version is presented for evaluation. This way, iteratively, the prototype is ideally developed towards an intervention functioning in practice [11].

It is important to note that the design cycle approach outlined above does not operate in a vacuum: the context provided by the domain of application and the body of theory provided by previous research provides opportunities to leverage scientific or operationalized previous findings. According to Hevner [12], this context is characterized by a 'relevance cycle' that takes opportunities from practice and probes proposed solutions in the same domain of application; the 'rigor cycle' imports well known theories and methodologies from the knowledge domain and exports possible new approaches and artifacts for future use. In the field of game-based health interventions, the domain of application is the area of health care in which the intervention is intended while the domain of knowledge is the area of game design and related fields.

3 Problems in Game-Based Health Intervention Evaluation

While the field of serious games design alone has seen an increase in applicable principles and theory, no unified game design theory or framework exists [13]. Furthermore, the models and theory used from related fields such as psychology, persuasive technology and behavior change provide only rough guidelines for game design and are only partially integrated with each other. Especially in the investigation and design phases in the design cycle approach outlined previously, such theories are required to underpin a successful design of a game-based health intervention. Ideally, design decisions about aspects of the game mechanics, game dynamics and game aesthetics should be based on literature or best practices. When moving from a carefully constructed game design to realizing the game in the development phase, we have identified two problems from our experience with such projects. First, as available budgets and development time are limited, corners are often cut when implementing the design leading to a necessarily hampered game as opposed to theory used to design it. Second, carefully considered design decisions in preparing the game concept are lost in the implementation phase as they are not monitored as design decisions into the development phase. The potential of iteratively improving games as health interventions during design and development is limited as opportunities for focused improvement in the next iterative design phase are being missed.

As a result, evaluating the resulting game in an empirical study may provide insights in effectiveness but fails to attribute any conclusions to the corresponding decisions in the design phase [14]. The field of game design and game development for health care thus lacks a general framework that links theory-based design decisions to results from evaluating such interventions [4].

The problem, now, is threefold. First, the translation of decisions made during the design phase may be poorly transmitted into the development phase. This is particularly important ad decisions made under time pressure and budget constraints during development effectively alter the design, which may weaken the conceptual design. Second, the evaluation of the resulting game can only provide findings with regard to that version of the game. However, in an iterative process we are more interested in establishing improvements as design decisions before the next development phase commences. Without a clear link between design decisions and development results such conclusions cannot be coherently drawn. Third, and last, the currently available theory does not present a unified approach to either design or development and as such fails to underpin findings in evaluation of the product with theory used before or during the design phase – which is the overarching cause for the first two problems.

In this paper we aim to outline a design cycle approach to design, development and evaluation of game-based health interventions that connects theory-based design decisions with the findings during evaluation by tracing design decisions through the development phase. Subsequently, we will demonstrate our approach by discussing a small-scale case study in the field of game-based health interventions.

4 Approach Outline

In the previous sections we have identified a number of problems in evaluating game-based health interventions with the goal of validating intended effects and identifying areas of improvement for subsequent iterations of the design cycle. In this section we outline our ideas for a design and development methodology that allows evaluation results to be attributed to the corresponding design decisions and underlying theory. Such an approach may allow findings of the evaluation phase to be attributed to the corresponding design decisions and could, after further development and elaboration, provide a stable framework for improving the design in the most desirable direction during each subsequent iteration of the design cycle.

Before outlining the proposed approach, it is emphasized that it is not our aim to suggest specific game design theories, game design or development practices or specific evaluation methods. The aim is to establish a method for improving evaluation of both the intervention and underlying theory without promoting or demoting specific theories or applied in constructing the intervention itself. In the case study we have, naturally, adopted a selection of theories and practices which are described in the corresponding sections. However, this selection is not the focus of this approach.

The process of identifying and monitoring requirements has become a standard practice in the field of Software Engineering – for example, see [15]. In the traditional waterfall model [16] requirement engineering is the first phase of development, while agile methods such as Scrum are aimed at continuously identifying and adjusting requirements throughout the project. While such an approach is beneficial to the development of game-based health interventions – and often adopted as such – it does not provide sufficient methods to answer to the problems identified in the field of game design. An emphasis on non-functional requirements and the importance of affective components of gameplay are some of the factors that differentiate game design from software engineering. Also, software engineering is usually based on the premise of optimally supporting a user in performing a certain task, whereas game design aims to establish a meaningful experience for a player. The objectives in game-based health interventions are the indirect result of this experience, rather than the direct result of using the game.

In the initial phase of analysis, the objectives and preconditions of the intervention are to be formulated. In the field of health interventions, many objectives emerge from the application domain and are external to the intervention itself – for example, a training objective may be formalized in terms of an increased capacity of the players to perform a certain task. Such external objectives establish the primary outline for subsequent evaluation. During the analysis phase, however, applicable theories from the field of game design that may be leveraged to change knowledge, skills and behavior of the players must also be identified – for example, the theory of flow [17] may be selected in order to keep players motivated to continue playing long enough to benefit from the intervention. Such game design choices establish a secondary outline for subsequent evaluation. Finally, in the analysis phase other conditions and limitations for development – for example budget and available time – are identified. The result of the analysis phase thus is an informed selection of application domain and knowledge domain objectives and methods that, in combination, may provide the outlines for an effective intervention.

In the second phase of design, the goal is to specify a concept for the game-based health intervention that uses the selected theories to guide the players towards the selected objectives within the available limitations. As our aim is to focus on the approach, we will not elaborate on the complex and creative process of designing a successful game in this context, without a unified framework for (serious) game design. The key in our approach is, however, to document any design decisions in combination with the objectives and theories they relate to. For example, if the game concept describes an increased difficulty level over time, we document that the theory of flow is the theoretic basis for selecting such an aspect. If the game concept involves gesture-based control by the player, we document that the objective of exercising a certain gesture is the practical basis for selecting such a control scheme. The result of the design phase thus is a formalized game concept that meets the criteria from the analysis phase, annotated with the underlying considerations for designing the game in the chosen way.

In the third phase of development, the goal is to develop a useable version of the game. The process of development is, in practice, largely based on software engineering methodology. Maintaining the design cycle approach, no conceptual or creative adjustments should be made during this phase. In practice, however, progressive insight, effects of under- or overestimating the required effort or costs, etc., may lead to on-the-fly adjustments. For example, a certain feature may be excluded due to lack of sufficient development time. In our design cycle approach, such adjustments must again be noted in conjunction with the underlying considerations. The result thus is a playable version of the game-based intervention with possibly a number of implemented changes to the original concept.

In the fourth phase of evaluation, the goal is to establish to what extent the constructed intervention meets the objectives and requirements from the initial phase. Established practices of co-creation, focus groups, usability testing, talk-a-loud etc., may be used to gather insights into the player experience established by the intervention. We loosely use the term player experience to cover the results identified in both the objectives from the application domain (of health care) and the methods from the knowledge domain (of game design). The key to benefit from evaluation for improvement as well as validation is to interpret the results correctly. In our approach, we have emphasized the need to document objectives and theories from the analysis phase throughout the design and development phases. This approach allows results from the evaluation phase to be interpreted by attributing specific results to specific design decisions. As such, the current version of the intervention can be evaluated with increased focus. Moreover, the design choices and underlying theory are being evaluated in their own respect. While drafting conclusions on the intervention itself, we can attribute such conclusions to the underlying design choices by tracing the results back through development and design into the analysis phase. The result of the evaluation phase thus is a series of conclusions on the effectiveness of the game – in terms of application domain objectives and knowledge domain methods – attributed to corresponding design choices and theories.

In outlining the method in the previous paragraphs, the focus is on the initial iteration of the design cycle, which is usually aimed at identifying areas of improvement to be addressed in a subsequent iteration. The approach of attributing design decisions is then used to reconsider design decisions and, as a consequence, the game concept. In later iterations, evaluation may be increasingly aimed at validating the effectiveness of the intervention. The approach of attributing design decisions may then be used to identify the choices that are responsible for the observed effects.

5 Pilot-Study in Physiotherapy

We have adopted the previously outlined approach of tracking design decisions in conjunction with the underlying theory supporting those decisions in a pilot study, to assess the benefits and complications of linking evaluation results to theory per design decision. The context of this study was the desire to develop an iPad-based game for use with a so-called balance board – a board suspended on a hemisphere used to exercise balance as the board will only remain horizontally oriented through active balancing by the person standing on it. Leveraging the fun-factor of games to motivate clients to carry out their home exercises as part of therapy, we aimed to increase the therapy efficacy while away from the physiotherapy practice. We designed and developed an iPad-game using tilt-control to be used within the balance board while the game scene is presented on a connected Apple TV screen. The game is a 3D maze-navigation game with various sub goals such as opening gates and collecting treasures. The player controls the game by tilting the balance board – and thus the iPad – in the direction of movement and subsequently returning the system to the horizontal position. This moves the main character one step/square in the maze at the time, thus requiring repetition of the exercise to navigate the maze successfully. The level designs for the mazes are constructed such that the appropriate exercises are most likely to occur – for example a balanced mix of left, right, forward and backward movements or particular emphasis on one of the directions. Impressions of the balance board and the game are shown in Fig. 1. The project of designing, developing and evaluating the game is extensively documented in the corresponding graduation report [18].

Fig. 1: Impression of the game setup; from left to right: (a) the balance board with an iPad embedded; (b) an early 2D-prototype of the maze navigation game and (c) a screenshot of a further elaborated 3D version of the game.

As the first step in the analysis phase, a selection of applicable theories and models was made to base the design of the game upon – given the aforementioned objective of increasing therapy efficacy. Such a selection was made from both (serious) game design theories as well as domain-specific theory from physiotherapy. For example, common game design frameworks such as the MDA-framework [19], principles such as flow [17] and general game design principles from Schell [13], Rogers [20] and Bartle [21] were used in combination with for example persuasive technology principles from Fogg [22] and Cialdini [23]. In the design phase such models from theory were translated into specific and categorized design criteria for the implementation of the game. In particular, the design criteria were labeled and formulated towards implementation in the development phase.

In this pilot, the proposed game can roughly be divided into three components: a small pre-game component (including introduction, main menu and instructions), a core game component (the gameplay and in-game feedback itself) and a small post-game component (providing generalized feedback towards the number of movements exercised and an indicative judgment of the performance). Drawing from various theories, the design specifications were categorized by this subdivision and labeled with the underlying theories to support the corresponding design decision. A summarized example of this approach is shown in Table 1.

The total of design criteria and product specifications were used as input for the design phase, during which a game design for the maze game was constructed based on the selected theories. To organize the specifications we used both the component-subdivision of pre-game, game and post-game aspects as well as a subdivision into the categories interface, functionality and graphics. In this manner, as the game design was elaborated and formalized in a game design document, the underlying design decisions and corresponding theory were tracked. During the development phase the game was implemented according to the game design, while monitoring design decisions and ticking off implemented specifications.

Table 1: An example of selected theory and design guidelines in the design phase of the game, ordered by the component-subdivision of the game. Since the mentioned theory is shown only as an illustration of the approach, no citations are included with this table.

Component	Theory Label	Summary (paraphrased)
Game	Rogers, S.; accelerometer controls.	"Emphasize accelerometer-control by enlarging small real-world movements to large in-game effects."
Game	Schell, J.; camera perspective.	"Leverage the power of the camera to focus the player on the gameplay."
Game	Schell, J.; puzzle design.	"Provide the answer to the puzzle."
Game	Schell, J.; game design.	"Provide the player with genuine choices."
Pre-game Post-game	Rogers, S.; interface design	"Create an interface that conveys the style and setting of the game."
	Isbister, K. et al.; game usability.	"Create an interface that depicts the game state in a clear fashion."

The specific goal in the evaluation phase of this project was to assess the effective quality of the prototype. The conclusions drawn from the evaluation phase can be used to further improve the game-based intervention towards use in practice in subsequent iterations of the design cycle. In this study, we have conducted an expert review with three physiotherapists to validate the incorporated domain knowledge. Furthermore, we have play tested with a focus group consisting of four physiotherapy clients in the age group of 15-80 in the setting of a physiotherapy practice. For a first iteration, a small focus group may provide rough insights into the areas for improvement. In later iterations of this project we may evaluate for validation of the interventions using a (much) larger test group. The play test was conducted by providing players with a basic introduction to the game followed by an unguided session of playing through the game. The observations during the play test were verified in post-playing interviews with the players.

As expected, during trials with actual clients a number of possible improvements in the prototype turned up. For example, clients reported that the required tilt angle for control was too large for the game to register the actual tilting. Also, players reported problems with interpreting the in-game prompts and the location of the main character. Further comments focused on the lack of challenge in solving the puzzle of the maze and a disconnected feeling towards the game's interface. Using the previously described design criteria sourced in theory, combined with the component subdivision of the game, the test results can be attributed to their corresponding design decision. As an example, this link is shown for a selection of test results in the first three columns of Table 2.

Table 2: Relating test results to design decisions and corresponding underlying theory using the component-subdivision of the game. Since the mentioned theory is shown only as an illustration of the approach, no citations are included with this table.

Component	Test Result	Theory Label	Analysis	Improvement
Game	The minimum tilt angle is too large to effectively move the character.	Rogers, S.; accelerometer controls.	The character cannot be moved by tilting the board because the required tilt setting for detecting a successful tilt is ill-adjusted.	Adjust the angle in accordance with a realistic tilt angle determined from testing.
Game	The location of the main character in the maze is unclear.	Schell, J.; camera perspective.	The shape and color of the main character is too indistinctive w.r.t. other elements of the scene. Also, the camera does not focus on the character, requiring the player to search.	Adjust the shape and color of the main character to stand out more. Adjust camera movement to always focus on the main character.
Game	The puzzle of solving the maze is not challenging enough to be motivating.	Schell, J.; puzzle design.	The entire maze is in view, allowing the player to solve the maze mental-ly before ex-ploring. While theory mandates a full view of the puzzle, the solution is too apparent too soon.	Adjust the camera perspective such that only a portion of the maze is visible at any time.

Component	Test Result	Theory Label	Analysis	Improvement
Game	It is impossible for the player to lose the game.	Schell, J.; game design.	There is no choice for the player not to succeed – let alone stopping playing the game. Game design theory desires [complications]	Introduce damaging elements in the maze and allow the player to 'game over'.
Pre-game Post-game	The interface of the game feels disconnected from the game world.	Rogers, S.; interface design Isbister, K. et al.; game usability.	The interface feels disconnected from the style and setting of the game world, breaking part of the experience. Theory promotes game interfaces in the theme and style of the game.	Develop a game-specific interface in a matching style to emphasize the in-game experience throughout the application.

The conducted expert review validated the translation of the intended exercise objectives in the context of physiotherapy. Since the actual exercise movement is external to the game through the use of the balance board, this is only as expected. Additionally, experts supported the clients' claims regarding the disconnected feel of the user interface. Finally, while experts expected forward/backward movements on the balance board to be as demanding as left/right movements, it turned out that forward/backward movements are more challenging to perform. The results of the expert review did not bring up radically different or additional insights into the design of the game itself.

As Table 2 shows in the last two columns, it is straightforward to reconsider the application of theory and propose improvements for the game. In other words, evaluation results are attributable to design decisions within the frame of reference of corresponding theories. For example, the claims that the puzzle is not challenging enough because its solution is obvious from the start, made us reconsider the decision of showing the entire puzzle. As the theory-link shows, this decision was arrived upon by following the puzzle design guidelines outlined by Schell [13], which suggest providing the solution to the puzzle from the start. However, after finding the members of the focus group unchallenged by this presentation, we reconsidered the guidelines from the theory underlying this design decision. The difficulty in game design that stems from the inherent divide between designer and user is indicating a different result in this particular case.

In this case study we have adopted an approach of tracking design decisions in conjunction with the underlying theories in order to be able to improve interpretation of the evaluation results. We have found that interpreting evaluation results is more focused and straightforward because the theoretic context is made available after design and development phases. The process of systematically tracking theoretic backgrounds with the design decisions throughout all phases of the design cycle allows the results of the evaluation phase – be it a focus group play test or an expert review – to be attributed to these decisions. By reconsidering the design of the game from a focused theoretic perspective – rather than reconsidering the implementation alone – the design and development process iterates more efficiently towards a successful game-based health intervention ready for use in practice. One drawback of this approach is that a larger part of available resources is invested in monitoring design decisions in all phases of the design cycle.

6 Conclusions

The approach outlined in the previous description of the balancing exercise project describes the first steps to how decisions made during the design phase of the construction of game-based health intervention can be identified and made traceable during the development phase. Such an approach has the benefit of shifting attention away from make-do decisions during development and focusing on the underlying design decisions instead. This reduces development time and as such benefits both developers and practitioners. Furthermore, this approach allows the evaluation phase of the game to not only draw conclusions towards the workings and effectiveness of the individual game mechanics. This benefits both the process of evaluation and the adjustments in the design in the subsequent iteration of the design cycle. Monitoring design specifications in this manner may very well benefit the focus and management of production throughout the development cycle; this perspective is not further explored in this study. We believe that such an approach generally allows for more optimized iteration towards a successful intervention.

Additionally, the tracking of specific design decisions throughout the development cycle sheds light on the way development decisions influence the effectiveness of the design. As we are limited to evaluating products rather than designs, insight in the translation of a theory-based game concept into an operational prototype or finished game is a necessary condition for developing a unified framework for design, development and evaluation of health games. The outlined approach explores ways of linking together design, development and evaluation into such a unified framework.

The approach outlined in this paper is only a first attempt at establishing a design cycle-based method of improving the effectiveness of evaluation. Future research in this area is required to refine the methodology of such an approach – both in terms of research methodology in design research using the design cycle, as well as in its application to game design and game development and evaluation. The elaboration of this approach may well benefit from software engineering and game production methods existing in practice. Furthermore, an elaborated version of the approach needs an extended evaluation both in sample size and variation in application (sub)domain. The main objective of future research is to establish best practices for the design and development process of health games and bridging the gap between design and evaluation through attributable evaluation results.

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Servitization versus Commoditization: the Business Model Dilemma Confronting Serious Games for Health

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Abstract

There is growing interest in the use of Serious Games (SGs) to tackle major health issues. Challenges to their adoption and use includes the cost of development and the need to provide evidence of effectiveness. However, an equally pressing dilemma facing the establishment of a market for SGs is the general commoditization of digital media and erosion (diminution) of economic value. Given the substantial upheaval in the entertainment games, software, music, book publishing, and newspaper industries, it seems unlikely that SGs for health will be immune from such market pressures if they persist in being conceptualized and designed as products. The solution is to switch business strategy by re-conceptualizing and designing SGs for health as networked services. The benefits will include personalization, integration with health administration systems, and importantly, the ability control access and therefore the adoption of pay-per-use revenue models, and ultimately the preservation of value.

Keywords

serious games, health, business model, servitization, commoditization, service, product, design

1 Introduction

There have been many attempts to define Health, but the aspirational nature of the World Health Organization's definition "Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" [1]

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is a good starting point for serious games (SGs) for health as it does not constrain the potential range of applications. While statistics relating to “ill” health continue to dominate the media, health, and fitness are both very personal topics that touch every citizen and are ultimately about individual lives and how those individuals make sense of themselves and their own health and well-being [2]. The interactive nature of SGs means that they are likely to have significant potential in this application field. The Games for Health project was initiated in 2004 by the Robert Wood Johnson Foundation in USA as part of their SGs Initiative and has been a pioneer in the field. Their working definition is “use cutting-edge games and game technologies to improve health and health care” [3]. Estimates for the size of the Health SGs market are difficult to come by, but in 2008 it was estimated at the time to be worth US$ 7 billion [4]. However, consumer exercise (fitness) SGs were by far the largest segment and the immature nature of the market is such that viable business models are yet to emerge.

2 Serious Games for Health

There are many potential applications for Health SGs, and a few areas of interest will now be highlighted. An early study into use of video games in healthcare found that by providing a source of distraction during chemotherapy, the incidence of nausea was reduced [5]. With increasing miniaturization and automation, diagnostic tools that would have previously been the sole domain of a central hospital are now moving out into the community, resulting in a training need for general practitioners (e.g. Lung spirometry) [6]. Furthermore, diagnostic measurement and monitoring are often challenging, particularly in children. Using lung spirometry to monitor childhood asthma is one such example that requires the child to be sufficiently motivated to perform the diagnostic maneuver. An interactive motivational game for lung spirometry has shown significant promise in this regard [7]. New medical students have a high degree of technological literacy and a clear preference for active, first person, experiential learning. A survey of students reported that they had potential for role playing games to teach doctor-patient communication, learn about ethical and professional values and to help in career (specialty) choice [8]. Effective team working in disaster management is an important skill, yet hard to train. Even in very severe situations, taking appropriate action early on may help to mitigate both the short and long-term impact of disaster scenarios. SGs have significant potential to improve and enhance training in this area [9]. Regular physical activity is beneficial to health for all, including groups with special needs. Certain exergames may have the potential to meet the needs of groups who are currently lack an adequate provision [10]. Social inclusion of rural communities and the provision of opportunities is a key strategic agendum of the European Commission. Providing sporting opportunities [11] that use networking to facilitate remote interactions is a growing area of interest [12]. Research into physical education practice has indicated that the overemphasis on skill development at the expense of tactical awareness means that children are often frustrated because they don't understand how best to play the sport [13]. Sports video games are becoming highly realistic and offer the potential to teach tactical awareness in a controlled environment. Much of the enthusiasm and interest in SGs is owed to the rich experiences that they can offer [14], and that the high levels of interactivity that they require are likely to result in greater user engagement compared to traditional media [15]. More generally, digital games often take place in rich game worlds and a include a strong narrative (story) element [16] and can also include opportunities to promote health objectives through social support features [17]. While the precise make-up of health games and the ways in which certain game mechanics and features can influence users is an active line of investigation [18], it is clear that the have many differential experiential facets.

3 Challenges Facing Serious Games for Health

Many health professionals are skeptical about the potential for Health SGs. This is likely because of the popular perception that entertainment video games are to blame for many of society's current ills but also the increasingly high demands, and rightly so, of evidence-based practice. To address the issue of limited and often inadequate evaluation studies, Lewis [19] has argued for the inclusion in a SG development team of expertise in evaluation in order to ensure the production of a strong evidence base regarding effectiveness of SGs in health. In addition to the need for proof of value, Chen [20] has also highlighted other barriers that SGs face including the time they take to develop and the general lack of upfront investment. However, according to Gershenfield [21] is that a major problem with SGs is a general lack of product designed from the ground up to successfully meet a market demand and that many current funders of SGs are in fact, game publishers - and yet most do not realize it where a key role is to determine the financial viability and manage the development process through to market. While the former challenges described above are for the most part acknowledged and the latter gaining wider acceptance, the purpose of this paper is to highlight an even greater dilemma that has arisen because of the array of technological advances that have heralded the advent of the "networked society." In order to explain the origins of this dilemma and what can be done to overcome it, we must first consider some of the trends that have occurred since the Games for Health project was first initiated almost 10 years ago.

4 Recent Trends

Over the last 10 years, the concept of a "networked society" has become reality. Furthermore, more and more online activity is being conducted through mobile and tablet devices and less through traditional personal computers. The advent of such an all-embracing network at high speed and low cost has both lowered the cost of digital distribution and offers significant economies of scale. At the same time the move to "cloud-based" applications and services are making possible new forms of data sharing and collaboration. The mainstream games industry has responded to this with the development of "casual" games and games specifically developed for mobile devices. The music industry has also experienced significant disruption with the move to digital downloads and the associated unbundling of albums to individual tracks. Television and film are also facing increasing competition for viewers attention from an array of different online media offerings. The software industry is also undergoing substantial changes with a move towards hosted data and applications that are run over the network rather that being installed on the client's computer(s). This has resulted in a change in the design and development software practice away from an all-encompassing product to "Software as a Service" model and an associated component-based development process.

Health and well-being are important aspects of every citizens' daily life, yet are often taken for granted until there is a problem. In the developed world, the major infectious causes of diseases have mostly eliminated. However, there has not been a corresponding reduction in spending on healthcare and it remains a significant proportion of developed countries' GDP. Physical inactivity and over-consumption of food along with other lifestyle factors have replaced infectious agents as the major determinants of ill-health. While there are efforts to reduce inefficiencies in the systems of healthcare, there is a growing recognition of the need to focus more on prevention by investing in long-term health and wellbeing of the population. Despite this, budgets for prevention are still disappointingly modest and in the market driven health system is USA there is a notable absence of financial incentives [22]. With a people living longer and falling birth rates in the developed world, there is a major demographic shift taking place. Coupled with the high cost and limited capacity for training health professionals and projected increases in demand means that there are major concerns about a projected shortage of medical professionals and carers to meet future needs.

The cost of healthcare treatments including drugs tends to increase by around 15% per year (so called "Medical Inflation") and hence is a major financial pressure coupled with the global economic recession has resulted in a greater than ever focus on cost-effectiveness of treatments. There is now a greater realization that the while a given treatment may have on average a positive net benefit to patients, in reality some individual patients respond very well to treatment and others not at all. Major advances in DNA testing technologies have allowed researchers to investigate this issue and it has now become apparent that at least some of these differences in treatment repsonse are attributable to genetic differences. This has given rise to the concept of "Personalized Medicine" [23], where treatments are tailored to an individual patient as a result of enhanced diagnostic testing. There is also a growing educational awareness of the need to better personalize education to take account of individual students' abilities and needs and to facilitate continuing professional development and life-long learning.

The advent of the networked society provides many affordances for healthcare. It can be delivered remotely reducing the need for patient travel and increasing access to specialists. The ready access to health data can help improve management of treatment and empower patients to take a more active role. Microsoft's Health Vault is one such service and provides a platform for a wide range of monitoring devices (over 70) and applications (around 300). The widespread availability on health information via the internet means that people can potentially become much better informed about how best to improve their health and wellbeing. There is a call to create learning environments specifically for this purpose [2]. The ability to access such information on a mobile phone means that it can be available at the time of need and get much closer in time to influencing key decision points compared to traditional health promotion campaigns. In addition, social network type functions that would permit the formation of networks of like-minded peers to provide mutual support have significant potential. It almost goes without saying that digital media are inherently scalable with significant economies of scale possible. Finally, the development of a variety of low cost sensors (some medical, others consumer) has both lowered the burden of collection of self-reported diary-type data and enabled new forms of data and significantly greater amounts to be collected. Furthermore, new forms of motion/movement sensors have given rise to new forms of activity in that physical movement/exertion can be used to control video games i.e. so called "Exergames."

The effect of the network has been to significantly lower the cost of distribution and thereby offering the possibility of increased sales. However, this may be tempered by greater more difficulty in gaining traction because of an increasingly crowded market place. Furthermore, the ever increasing commoditization of digital media is causing major economic disruption. Simply put, the potential price premium that the producer of a digital good can charge is under constant downward pressure and over time will be significantly eroded (diminished). Consumer expectations have had a part in this, with a general expectation that anything online should be free [24]. Both music and entertainment games industries face significant challenges in this regard. In book publishing, prices for ebooks have fallen to, but the appears to have been at least partially compensated for with increasing sales. In contrast, faced with falling readerships and advertizing revenues, newspapers are struggling to monetize their online offerings. In contrast to the above, increased network bandwidth coupled with cheap server processing and online storage has facilitated the move to offer software as a service. Not only is it often an attractive proposition to client companies in that it offers a way to cap or reduce IT expenditure, but it is also can benefit the company providing the service. By virtue of being able to control access to the software, the provider is able to adopt some form of pay-per-use (e.g. subscription) revenue model which will lead to a steadier income stream compared with one-off purchases and payment for upgrades. Given the nature and scale of the scenarios described above and their opposing outcomes, prospective developers and producers of Health SGs would be well-advised to consider them carefully rather than ignore them at their peril.

5 Business Model Dilemma facing Serious Games for Health

Simply put, there does not seem to be any reason why SGs for Health as currently conceived will be immune from commoditization. In fact, such is the speed with which the digital media landscape is changing, that the potential value may be eroded even before it is established. Before we proceed further, it is worth considering several exceptions to this nightmare scenario. Consumer fitness exergames have managed to establish themselves but not without the experience, deep pockets and marketing muscle of the major video games publishers [25]. A second obvious SGs market segment which is likely to be relatively immune to commoditization is that concerned with high fidelity training simulations, which while expensive to produce, provide significant value to clients. A third segment where commoditization may be avoided is where SGs are commissioned for specific promotional campaigns and as such are likely to be produced as work-for-hire. In this specific context, the SG can perhaps be best thought of as a media artefact chosen for its greater ability to reach the target audience compared with other media forms. Finally, a fourth market segment where commoditization seems less threatening is in “Gamification” where game elements are added to an existing service process to act as a differentiating factor and/or increase efficiency.

In an earlier section, we described how SGs have several different experiential aspects. However, SGs are still largely both conceptualized and designed as products. Perhaps this is understandable as marketeers have long recognized the importance of the tangible aspects of an offering on the overall perception of the value [26]. It is therefore our contention that as long as the status quo remains, the market for SGs (apart from a few specific segments) will be powerless to resist the pressure of commoditization. So the key question is whether or not there is an alternative business model for Health SGs? And if so, what form might it take?

Our proposed solution is to look to the software industry which has established alternative revenue models by moving from a product to a service offering and by virtue of being able to control access, are able to charge a pay-per-use fee of one form or another (e.g. monthly subscription, per transaction, per volume). Such a general move by corporations from products to service-based offerings was first described in the late 1980’s and referred to as “servitization” [27]. In fact, having a subscription-based business model is what Massive Multiplayer Online Role Playing Games (MMORPGs) have been doing successfully for many years now. Such a shift in the conceptualization and design of Health SGs from a product to a service offering will not be easy. However, the dilemma as we see it facing SGs is to persist with a product-based business model and be exposed to the pernicious value eroding forces or switch to service-based business model and the associated pay-per-use revenue streams. In short, the choice is between servitization or commoditization.

6 Servitization of Serious Games for Health as an Alternative Business Strategy

The switch to the conceptualization and design of SGs for Health as services is likely to result in the generation of increased value and therefore the possibility of charging higher prices. However, the are also likely to be some increases in costs, at least until there is a well-developed infrastructure. There is a clear need to be able to interface with record keeping systems. Most obviously this will constitute patient record systems, but in a learning context this will be institutional learning management systems (LMS). The capture and reporting of appropriate metrics through the SG will offer the possibility of integrated evaluation of effectiveness, thereby reducing at least some of the cost associated with separate evidence gathering. A service-based approach could also be designed to provide an interface for health professionals to tailor particular game parameters to the specific needs of an individual or group and to monitor and obtain reports on progress/outcomes. Adopting a component architecture to develop a SG as a service will be a significant resource intensive undertaking in the first instance, but many of the components will be able to be re-used in subsequent projects. The advent of HTML5 and a re-invigoration of browser-based games on mobile devices is a significant development in this regard. Finally, the ability to control access will permit various forms of pay-per-use pricing models.

Looking to the future, as an example of what a servitized Health SG might look like, VirtualRehab [28] is a next-generation physical exercise rehabilitation system that uses the Microsoft Kinect Body Movement controller and PC connected to the internet and runs on the Azure cloud platform. A range of different rehabilitation games can be customized by professional therapists who can monitor use and track the progress of patients. Finally, service performance can be monitored by health institutions via a management interface.

7 Conclusion

SGs for Health would appear to have significant potential to make a positive to the health and wellbeing of significant numbers of individuals in society. There are several issues that have been recognized as needing to be overcome in order to grow a sustainable SGs for Health market, not least the need for clear evidence for effectiveness. However, it is our contention that in recent years the technology landscape has changed so dramatically, such that the downward pressure of commoditization of digital products has now emerged as a major new obstacle that will more than likely erode economic value before such a market for Health SGs is even establish. In this paper, we have taken the first steps to outline a potential solution to this problem that lies in a strategic change of business model that re-conceptualizes SGs for Health as services and designs and develops them as such.

8 Acknowledgements

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IGER: A Game Engine Specifically Tailored to Rehabilitation

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Abstract

Exergames for rehabilitation, both in the physical and cognitive fields, have been the target of much research in the last years. Such exergames, however, are often created for a specific impairment and cannot be generalized to other domains. More generally speaking, the lack of shared design and development guidelines for rehabilitation games can be highlighted. The Intelligent Game Engine for Rehabilitation (IGER) described here has been developed with the intent to provide a framework for building rehabilitation exergames that are functional, accessible and entertaining. Several features, mandatory for rehabilitation, have been incorporated: configuration, adaptation, monitoring, data logging and feedback through a virtual therapist. Besides describing how these features have been implemented in IGER, we describe here also a few games we created with it and their rationale.

1 Exergames for Rehabilitation

In the last years, National Health Service Providers have become overly saturated and are forced to shorten the duration of the rehabilitation service, increasing the period in which patients have to rehabilitate outside the hospital [1]. Enabling patients to exercise at home seems a good answer and serious games are believed to be the most adequate tool to provide this opportunity due to their motivational benefits. Therefore, much research from both academics and the industry has been directed towards creating games for rehabilitation, with the underlying purpose of providing a correct rehabilitation session while entertaining the patient [2-3]. The exergames combine the benefits of exercising with the engagement, motivation and fun typical of gaming applications.

Many games for rehabilitation are nowadays available for a wide range of dysfunctions and there is a broad agreement that they are beneficial [4] although few systematic clinical studies have been carried out and almost none for their use

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in a home environment without supervision of a therapist. One of the first works to be completed has been published this year [5] and it is based on the use of the Wii Fit games for postural rehabilitation. In the same study, however, several adverse events were registered, namely related to pain at the hip and knee joints developed during the training; the major risk highlighted in the study is that patients do not execute the exercises correctly and develop maladaptation that, in turn, may easily lead to training-related injuries.

This calls for methods to monitor the patient during her training: this is a fundamental feature that distinguishes any exergame developed for fitness from the ones developed for rehabilitation. Moreover, a clear feedback on wrong doing should also be given to the patient while gaming so that he can correct wrong postures and attitudes. Besides this, clinicians should also have the possibility to analyse the outcome and trend of the rehabilitation to advice and tune the therapy and to adapt the exercise's difficulty to the patient both to make the exercise more effective and to make it interesting: a difficult exergame wold never be completed and an easy one would be boring.

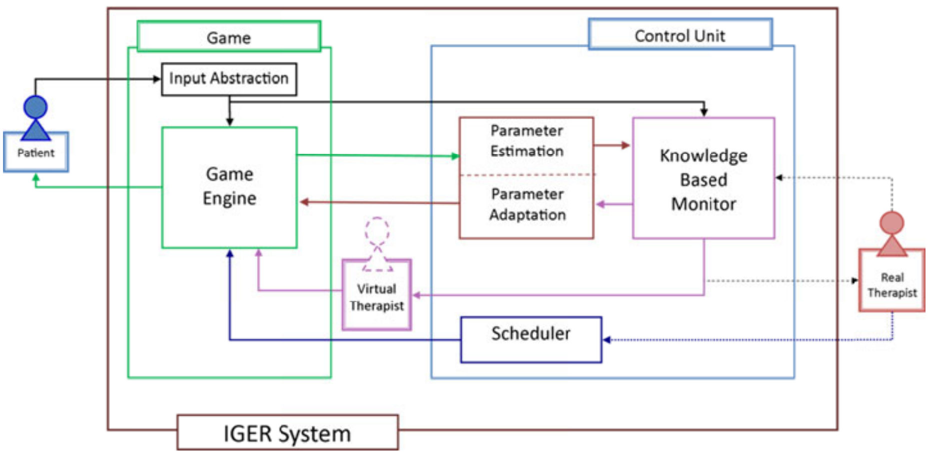

Fig. 1: The IGER system and its inner workings: the patient interacts with the games, while the control unit makes sure that the rehabilitation is correctly performed.

This situation calls for a further advancement, as the exergames that can be currently found on the market or in research laboratories are often thought for a single patient condition and thus aim to treat a single dysfunction, using a fixed platform and input device. In addition, the complete set of features that are required for a correct rehabilitation cannot be found in all exergames, making the use of multiple, different games for rehabilitation harder for the therapist.

We propose here a game engine, IGER (Intelligent Game Engine for Rehabilitation - see Fig. 1), specifically tailored to rehabilitation that addresses these issues. A few games developed to address posture rehabilitation will be described along with their shared capabilities. IGER leverages computational intelligence to provide all the assistance needed during exergaming. In section 2, we detail the features of the game engine. In section 3, we introduce some of the games we have developed using IGER and our results. In section 4, we draw our conclusions.

2 IGER: A Game Engine for Rehabilitation

A game engine allows developers to focus on a higher level on the design of games, their gameplay and graphics style, while the engine takes care of the game's inner workings (rendering, input handling, physics, collision detection and so forth), thus making the creation of games much easier. In the case of games for rehabilitation, the game engine can be even more useful as it can also provide all the features required for a correct rehabilitation to all the games created with it: the engine can provide shared components that limit maladaptation, adapt the game difficulty to the patient and allow the therapists to configure and review each rehabilitation session.

The features of a game engine for rehabilitation can be grouped in three macro-areas: efficacy, accessibility and motivation. For each area, we detail what the engine should provide and our implementation inside IGER.

2.1 Efficacy

Effectiveness must be the main focus of any exergame used to guide rehabilitation, as a correct therapy is more important than the entertainment side, although the former should not overshadow the latter (see section 2.3). To make sure that each exergame fulfils this important requirement, the game engine should provide components that aid the developers and the therapists in this task.

Configurable and Adaptable Exergames. To design a rehabilitation session, a set of exercises is defined by the therapist and tailored to the patient and her residual functional ability. A session is constituted of a mix of exercises often involving both coordination and strength [3]. The exercises usually consist of repeated movements and actions that aim at stimulating the recovery of the impaired function.

Exergames are defined to guide the patient through these exercises: a variety of games is therefore required to implement a whole rehabilitation session through exergames. Moreover, different patients have varying degrees of impairment and this requires that each exergame is tailored specifically to their residual abilities: for this reason, range of motion and intensity of the exergame should be defined by the therapist. This calls for exergames that need to be fully parameterized so that they can be set-up by the therapists for each specific patient, also defining a proper difficulty level by setting the value of a few adequate parameters, such as the movement range or speed of targets [6]. This operation can be carried out by the therapist in the hospital and it can be facilitated by a graphical display on how the game would be played with a set of parameters. Such parameters can also be modified automatically during play to achieve an autonomous day-to-day adaptation of the patient's status as described in section 2.3.

Monitoring of Patient's Movement. While exercising, the patient must be monitored constantly. This is another important requisite for a correct rehabilitation, because the execution of erroneous movements may trigger maladaptation. In a classic rehabilitation scenario, the therapist usually accompanies the patient during the whole training session and corrects her movements where needed. When the therapist is not present, the exergames should provide a suitable replacement for the monitoring of the patient's movements.

IGER features a fully configurable set of monitors that can be attached to any game. They are implemented as a set of fuzzy rules that check in real-time the data gathered from input devices and compare them to the constraints defined by the therapists. These constraints can be related, for example, to the straightness of the back, the bending of the legs, or the distribution of the weight between the right and left side of the body.

Whenever a monitor detects wrong actions, it issues an alarm level that increases in severity the farther the action is from the constraints. An immediate qualitative feed-back is given to the patient by a change in colour of the avatar's body part that is violating the constraint. For instance, if the patient is tilting his back during an exergame, the avatar's back would change the colour from green to yellow, orange and then to red in the most severe cases. When the maximum limit of the constraint is violated, the game is paused and the patient is given advice about the correct execution of the exercise through her virtual therapist (section 2.3). We refer to [7] for further details on the fuzzy engine.

Assessment of the Exercise Goal. The game engine must be able to record the movement data of the patient and the data that describes the interaction with the games (for example, the time of interaction with game objects) while the patient plays her exergames. The therapist can then use these data to review the session and assess the progression. From these data a few parameters can be extracted to portray the rehabilitation outcome to the therapist who can evaluate the rehabilitation effectiveness, advice the patient and possibly tune the therapy. Most commercial games discard any input data after using it for controlling the game, therefore they lack this feature.

A clear distinction between assessment and monitoring is required: while assessment is related to the exercise goal, monitoring is related to the correctness of the exercise. For instance, during weight shift exercises, required in posture rehabilitation, while the goal of the exercise is to learn to shift the center of pressure of the body (COP) laterally with little sagittal oscillations, correctness requires that the body is kept straight during the motion.

Assessment data constitute the documentation of the rehabilitation activity and are required by clinicians for evaluation. Moreover, they may be used to replay the whole exercise or extract specific information; extracted parameters can be, for instance, the trajectory or the variance of the COP, the covariance between trunk and legs and so forth. The same parameters can be shown to the patient at the end of each session, along with the values obtained in the previous sessions, as a feed-back on his effort.

2.2 Accessibility

The majority of commercial games are unsuitable for rehabilitation also because of their cognitive complexity and of the speed and physical skills required to play them [8]. There have been attempts to make developers aware of accessibility[1], but the application of guidelines is still rare. While entertainment games are designed for non-impaired people, as they must appeal to a wide market, for which accessibility may not be a high-priority issue, rehabilitation games must instead be tailored to a specific niche of patients for which accessibility is a very important matter.

Natural User Interfaces. Natural User Interfaces (NUIs) represent a good asset to provide accessibility to most users, who can be of any age and come from any background and thus not necessarily attuned to technology and videogames. NUIs allow the user to interact with a software application using natural means, such as body gestures or speech, making the actual human-computer interface transparent and in turn making the interaction more comfortable for the user.

Using suitable input devices such as cameras or microphones, innovative control schemes such as gesture control or speech control have already been introduced [9]. In IGER they have been implemented for navigating the rehabilitation sessions and playing the games. We use the Microsoft Kinect sensor in IGER for gesture or speech navigation through the menus but any other suitable device can be used to control an on-screen cursor for the same purpose.

Input Abstraction. To obtain the most effective exercising capabilities, a wide range of input devices should be supported by the game engine. Patients possess very diverse impairments and no input device exists that can be effectively used to track all important movements for each condition. A pressure board may be indispensable for balance and posture rehabilitation, but it would not be of any use to a patient who is regaining her cognitive functions or when the patient is required to make steps. On the other hand, that same patient may benefit from the

1 Game Accessibility Guidelines - http://gameaccessibilityguidelines.com

use of haptic devices that could give additional feedback through force and vibration.

To address this need, we have created a middle layer between IGER and the input devices, so that any device suitable for a specific pathology can be used. Such layer, called IDRA (Input Devices for Rehab Abstraction layer), matches the animation data required by the game with the movements required by the exercise and the features supported by the physical device. Moreover, it avoids conflicts between multiple devices and allows users to play all games regardless of the chosen device. IDRA also makes the introduction of NUIs easier, since the most natural device for the specific patient condition can be used.

At present, IGER has been used with several input devices: the Microsoft Kinect sensor, the Nintendo Wii Balance Board (Fig. 2), the Tyromotion Tymo plate, the Moticon OpenGo Insoles, the Sony PS3 Camera, the PM10 robotic arm and the Novint Falcon haptic device.

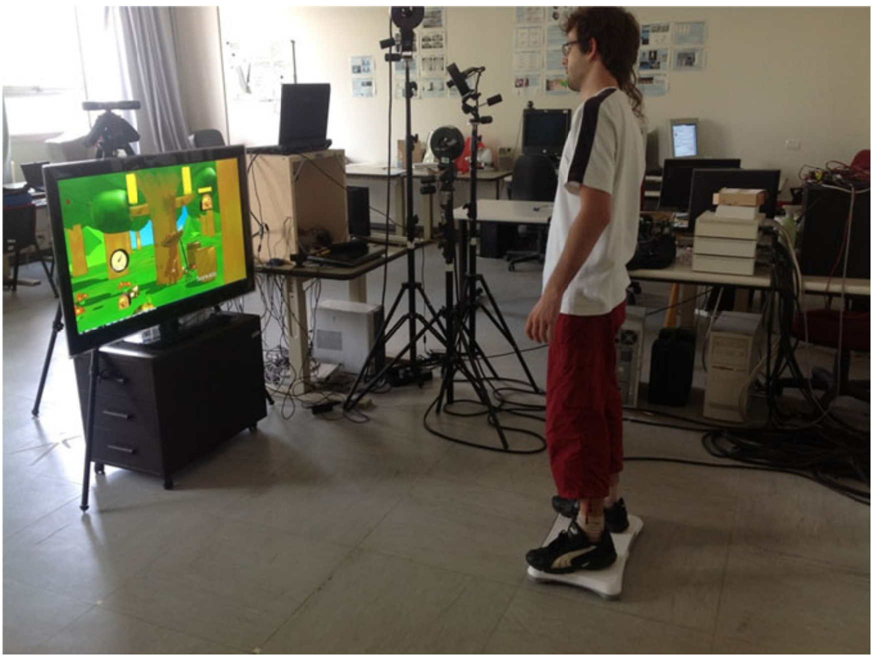

Fig. 2: Playing the Fruit Catcher game (see section 3) using a Nintendo Wii Balance Board

Instructions and Tutorials. There are many things that the patient needs to keep in mind while playing rehabilitation exergames: the therapeutic goal of the each exercise, the gameplay objective, the setup of the play space and of the input devices, and the monitoring constraints. Especially in the case of at-home personal rehabilitation, such instructions should be clearly provided to the patient.

We provide the patient with different means to get this information and the preferred mean can be configured by the therapist. Each game is provided with written, spoken and video instructions, localized in different languages (we tested English, Italian and German versions). We also allow the patient to play a *tutorial* version of each game, during which she can experiment with the game mechanics prior to playing it and is thus taught how to play. This will be used by the clinician inside the hospital to train the patient but it could also be used autonomously by the patient at home.

2.3 Motivation

Games have a great motivational impact on the rehabilitation experience. At their base, games require that a lot of care is put into crafting meaningful play into even the most basic mechanics [10-11]. In addition, suitable feedback and plenty of immediate rewards can contribute to a fun experience and to allow the patient to enter a state of flow, in which the focus on the game distracts from the actual impairment [12].

Rehabilitation exercises often require multiple, repetitive, mechanical movements to be performed for a correct therapy, hence why the motivational aspects brought forward by a game can be so beneficial. Rehabilitation games must thus be designed with great care as the game mechanics are constrained by the underlying rehabilitation exercise. It can be very hard to come up with good game ideas and implementation for some exercises as the prolonged period of time in which rehabilitation extends may make a single game, although entertaining per-se, boring on the long run.

Other motivational mechanisms have been added inside IGER through very different means that can cooperate to achieve a shared effect, some of which are introduced in the next sections.

Adaptation Mechanisms. Commercial games create challenges for the player to complete, and this is an integral part of the fun experience of playing. The challenge needs to be neither too easy (resulting in a tedious experience) nor too hard (resulting in anxiety): game developers should aim for the sweet spot between these two extremes as thoroughly explained using flow theory [13]. The balance between the player's skill and the game difficulty is created, in games for entertainment, during the development phase by the game designer through heavy play-testing, with the specific user target in mind of an average-skilled person. This cannot be achieved in exergames for rehabilitation. Patients may have a wide variety of residual skills; moreover, they are expected to improve these skills during the rehabilitation sessions and thus greatly modify their abilities.

Rehabilitation games need therefore adaptation mechanisms that automatically balance the game to the patient's skill while she is playing. Balance can be achieved by tuning a few game parameters that directly determine the difficulty of the exergame. By choosing suitable parameters for adaptation, the exercise can require the same actions but the difficulty may be largely increased, for example by requiring faster movements. Inside IGER, we implemented a Bayesian approach in which the parameters are modified in real-time by analysing the actual success rate and the a-priori parameters deemed appropriate by the therapist. Such adaptation acts on a set of parameters that are defined by the therapist in the hospital at configuration time and therefore allows adapting the game to the specific status of the each patient. More details are reported in [14].

The adaptation mechanism is tightly connected with monitoring: a repeated intervention of the monitor has an impact also on the level of difficulty of the game. When errors are detected, the increase in difficulty is disabled and when repeated errors are detected over time (up to 30% of the time), difficulty is progressively made easier to let the patient return to a correct execution of the exercises.

Long term Motivation. While short-term motivation deals with the immediate feedback given to the patient that makes her enjoying the single gaming instance, long-term motivation deals with capturing the attention and the focus of the patient in the long run, since the time extension of rehabilitation can be several months or even years. There are many methods for achieving long-term motivation that should be integrated into the game engine to help link the different games and even the different sessions of the same game together.

A basic mechanism to provide long-term motivation, widely explored by the entertainment industry, is a balanced scoring system. This mechanism can be used by the patient to evaluate her performance during a single session compared to previous sessions, thus motivating her to play again to improve in an attempt to reach a higher score and therefore exercise more intensively. A balanced score should depend both on the gameplay successes and on the correctness of the execution of the movements required by the exercise. In our implementation, the correctness acts as a multiplier of the score earned during each game-related action.

More advanced mechanisms are related to the social competition when games are played by multiple players, to the introduction of a larger theme common to all games (e.g. the farm theme in our case) and to the randomization of the game assets to increase variability. Such mechanisms are currently subject to further investigation.

We have already introduced a balanced scoring system in IGER and therefore in all implemented games and we are currently adding the other motivational mechanisms.

The Virtual Therapist. In the case of at-home rehabilitation, the central figure for rehabilitation, that of the therapist, is missing. In IGER, the therapist is partially replaced by a Virtual Therapist (VT) that provides feed-back similar to the one given in routine sessions by a real therapist.

The VT is an avatar that accompanies the patient during her rehabilitation sessions throughout the life of the application and advices her. This character can be useful for multiple purposes: it can explain how to navigate the interfaces and how to play the exergames, it can introduce options, congratulate on achievements and motivate during challenges. It also explains to the patient how to correctly perform the exercises when wrong movements are detected by the monitors. Even if the character is virtual, having a face to refer to can be beneficial for the patient. Many entertainment games use similar figures as guides for the player, such as the Wii Fit games and their cartoon-like animated balance board.

3 Results

We show here how we have designed and implemented a set of exergames using IGER, we also show some preliminary results following their use. The exergames we designed regard the rehabilitation of posture and balance and the rehabilitation of neglect. The games can be played with any of our input devices and we detail a few differences when a specific device is chosen. All these games share the same theme: life in the farm.

The Balloon Popper game (fig. 3A) represents a refinement of DuckNeglect [15], a game developed for neglect rehabilitation. The game requires the user to reach a set of balloons and pop them. In the native version, the game has been designed to be played with a 2D camera: the silhouette of the patient is extracted from the images and pasted inside the virtual scenario. Very good results are obtained when the background can be controlled and is stationary. When using a Kinect sensor, thanks to the superimposed skeleton, the position of the hand can be located and the interaction with the target and distractors determined also when the hand passes in front of the body and with any constraint on the background. This game is meant to allow patients to explore the neglected field following balloons that move from right to left. However, the same game could be played also with a haptic device: we have adopted the Novint Falcon as an input device, allowing the patient to reach the balloons on the screen with its cursor. In this case, there is no silhouette of the patient, but a visual cursor moving on the screen. We could also play the same game with the Nintendo Wii Balance Board: the lateral movement is in this case mapped on lateral weight shift and the up/down movements on the front-posterior weight shift. We also remark that the game has been tested for use with the PM10 robotic arm for upper-arm rehabilitation.

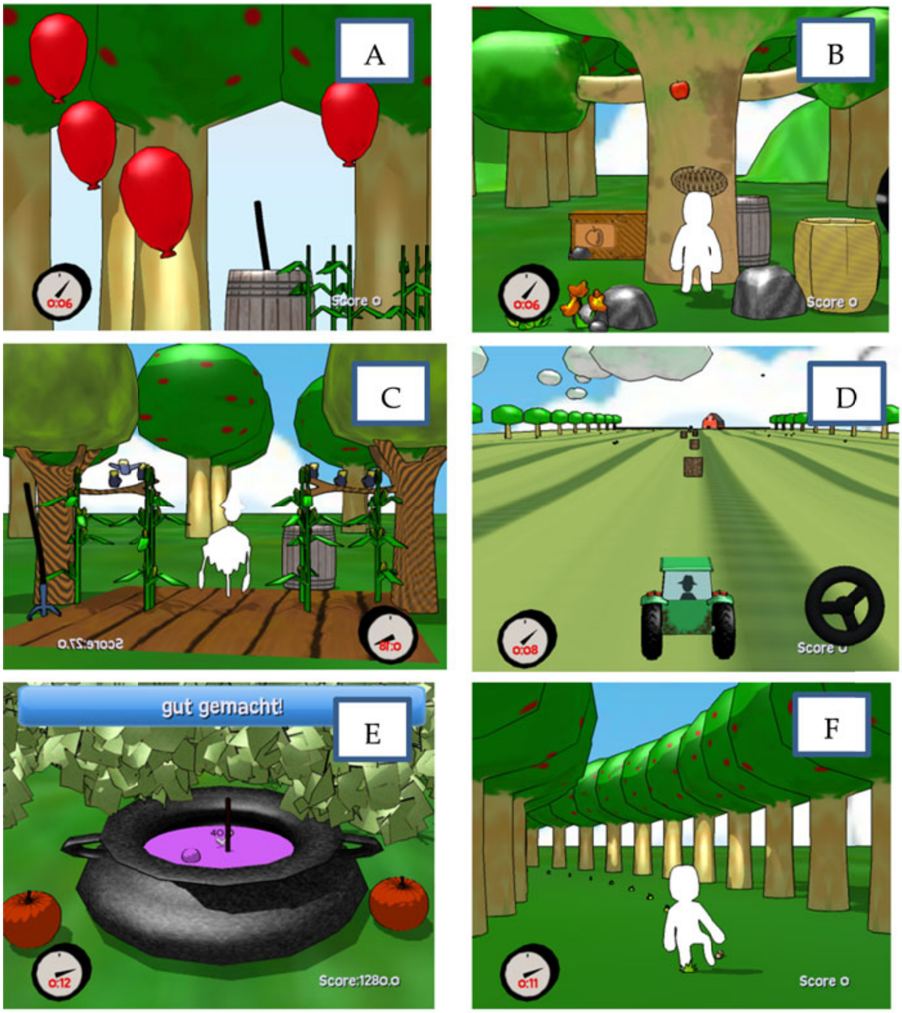

Fig. 3: Some of the games built with the IGER system. From the top left: Balloon Popper (A), Fruit Catcher (B), Scare Crow (C), Hay Collect (D), Mix Soup (E), Animal Hurdler (F).

A second game, Fruit Catcher (fig. 3B), has been developed to train lateral weight shift. The game asks the patient to catch fruits as they fall from a tree, using a basket placed over the head of the player's avatar. The game is played in third person, with the user viewing the scene from behind the avatar's back. The player is required to catch the fruits as they fall laterally in a range specified by the therapist. The Fruit Catcher game can be run with two different exercises. For the first exercise (i) the patient is required to shift his body to the left and to the right, while keeping the feet still on the ground. For the second exercise (ii) the patient must instead step laterally inside the play area. The game can be played using either a Wii Balance Board, a Tymo Board or the Kinect sensor for the first exercise (i), while for the second exercise (ii) only Kinect can be used as a tracking device since foot tracking is required for lateral movement.

The Scare Crow game (fig. 3C) is designed to train static equilibrium and asks the patient to stand still while birds fly over the shoulders of her avatar. The Hay Collect game (fig. 3D) is used to train reflexes and perception; it asks the patient to drive a tractor across a field while collecting hay bales. The Mix Soup game (fig. 3E) can be used for balance rehabilitation, upper-arm rehabilitation (for example using a robotic arm) and even for cognitive rehabilitation; it requires the user to touch a set of bubbles that appear on the surface of the liquid in a cauldron. A cognitive load can be added by generating bubbles of different colours and requiring that only bubbles of a given colour have to be touched. The Animal Hurdler game (fig. 3F) is designed for in-place stepping exercises and asks the patient to rise one foot when small creatures try to pass below it.

The IGER system and the games were tested on seven elder people (75 ± 7 years old) to analyse usability and accessibility. All subjects reported a very good reaction to the games. They did not get tired while playing them and did not report any fatigue or interaction difficulty. The monitoring through colour coding was rated particularly useful as it allowed them to focus immediately on the wrong features of the implemented movements and to correct them. The same was true for adaptation as each subject could see the game slow down when the pace was too high or to increase progressively the speed and therefore become progressively more and more interesting to the user. The interaction was rated extremely natural and easy to perform. No particular preference between speech and gesture was found. Further validation is currently being performed at the Neurological clinic of Zurich hospital, at the Virgin de Rocío hospital in Seville and a pilot study is scheduled to start in January 2014.

4 Discussion and Conclusion

IGER starts from the observation that commercial games are indeed too hard for most rehabilitation patients. At its core, IGER is built upon the open-source Panda3D game engine, but it has been expanded with a set of modules tailored to rehabilitation: configuration, adaptation, monitoring, logging of the data and feed-back through a virtual therapist. Without these additional components the effectiveness and reliability of any game-based exergame for rehabilitation at home can be severely questioned. Moreover, these additional components cannot be developed as stand-alone but should work in synergy: adaptation has a prominent role in motivation, and monitoring has an influence on the scoring system and modulates adaptation.

As far as adaptation is concerned, the Bayesian approach followed here does not make any hypothesis on the particular data domain as for instance in [16] in which a specific heuristic for arm motion has been proposed, but it is general and it can be applied to any parameter or combination of them. It also does not require any particular model that would require calibration by testing the games on a significant number of homogeneous patients as required by the RGS system [17].

Another characteristic of IGER is the abstraction layer that couples the input devices with the game. Such layer allows different devices be used with the same game thus making the engine extremely flexible. To highlight this, our current selection of games spans a range of rehabilitation domains: from full-body postural and balance physical rehabilitation to cognitive rehabilitation for neglect patients to arm rehabilitation. The same game can be used for different rehabilitation domains, changing the tracking device or modality. This can be a great asset for rehabilitation.

Components that take care of monitoring, of configuration, of adaptation to the patient's skills, of accessibility and usability by patients with diverse skill ranges require a considerable development time and the advantage of reuse is thus great. Using a specifically developed game engine, the designers can use the methods made available to build their own games without having to write them from scratch.

Moreover, the rehabilitation game engine can also be used to enforce a shared design intent and thus provide design guidelines for both games and exercises, thus making the process of creating efficacious exergames easier and, in the meantime, helping in guaranteeing their validity. The game engine can also, as in our case, suggest a shared theme in both visuals and narrative to promote cohesion between different exergames, provide a framework to insert motivational elements and ultimately increase the user's immersion in the game world.

IGER is not meant as a stand-alone system. It has been embedded into a Patient Station (PS) developed for the REWIRE project[2], financed by the European Union, to be deployed at patient's home to support their rehabilitation therapy. The PS integrates the IGER with bidirectional communication through Internet with the reference hospital. Such communication has a dual role: transfer the configuration of each rehabilitation session from the hospital to the patient's home and open a video-communication with the reference clinicians in case of need.

We explicitly remark that the PS has been designed to be used autonomously by the patient at her own home, without needing the presence of a therapist. For this reason, all exercises have been carefully designed in collaboration with the therapists to be performed without their presence. We also remark that the IGER engine is used to support the therapists in their absence, but their role is still of

2 http://www.rewire-project.eu

utmost importance in defining and configuring the exercises, following remotely the rehabilitation progression, advising and directing patients and reviewing and validating the results. Morever, we believe that rehabilitation sessions carried out in specialized centers with the help of the therapist intermingled with rehabilitation at home would make the approach most effective.

Given all these characteristics, the IGER system can be a good candidate to be successfully used as a game engine upon which rehabilitation games can be built to make rehabilitation at home possible and valid from the clinical point of view. This would represent a large step forward in rehabilitation, that could be taken out, at least partially, from the clinics and enable patients, discharged from the hospital, to continue their treatment intensively at home, where they feel most comfortable.

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Designing Games for Children with Cerebral Palsy

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Abstract

Within recent years the implementation of games as an acknowledged and important part of health care has become increasingly apparent. With positive results of game studies targeting conditions such as cancer, diabetes, and asthma it seems that further research is of great importance to ensure development within the field.

In this paper we will describe the creation of a game that contributes to the realm of health games. Our research, design, and product were directed towards children with *Cerebral Palsy* (CP) and the game was designed in accordance with the success criteria of socialization, entertainment, and rehabilitation.

By consulting with experts within the area of cerebral palsy, we attempted to create a game that would fulfil the needs of our specific target group and improve their abilities both cognitively and physically.

Keywords

Cerebral Palsy, Games for Health, Rehabilitative Games, Mirror-Neurons, Action Words, Learning, Socialization, Inclusion

1 Introduction

> *"For years, computer games have been associated with negative effects on health, blamed for spawning a generation of lazy, overweight children, who lack social skills because they spend their time indoors, sprawled in armchairs, staring at screens." (Taylor, 2011, Introduction section, para. 2)*

Ever since the making of games such as *Oregon Trail* in 1974, *Serious Games* have been expanding within the games industry. Rather than designing for entertainment and profit the maker of a serious game has an instrumental purpose. Among others, serious games have tackled issues such as education, health, social problems, and politics.

A sub-category of serious games, known as *Health Games*, has become a promising tool within the realm of health care. The fact that a digital game has the ability to reach a large number of people, without the costs of distribution unduly affecting

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DOI 10.1007/978-3-658-02897-8_8,

its affordability, makes access to digital games a straightforward resource for the improvement of health.

Because of their potentially vulnerable users, health games demand a greater involvement of expertise from areas not usually connected to the process of game production.

In general, games for health aim at providing a specialized piece of software for their specific target groups. The use of software makes it possible to match the abilities of the users more efficiently than when using a static piece of equipment.

This project aimed to add to the growing branch of health games. By positioning our product within this field, we hoped to increase the quality of life for a group of children that live with a chronic medical condition. This led to us formulating the following research questions: *How do you design a game for children with physical and cognitive limitations? How do you help them increase their motor skills, train their cognitive skills, and increase their chance of social contact?*

2 Cerebral Palsy

Cerebral palsy, commonly referred to as CP, is used as an umbrella term for several different types of disabilities. Some CP individuals move and develop almost normally, while others need assistance with most daily tasks. All symptoms of the condition appear in the first few years of life, and have a slow and abnormal development of motor-control in common.

Peter Rosenbaum, the preeminent source for research into CP, introduced a new definition in 2006. This definition has since become the standard and is used by health care professionals the world over. It is included here in full:

> *"Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour; by epilepsy, and by secondary musculoskeletal problems." (p. 9)*

Cerebral palsy is a non-progressive condition, which simply put means that the damage to the brain does not become worse. However, the functional impairments that the child has can change over time. Which means that the limitations that the child has to live with evolve and this makes for new challenges to overcome. This can affect the child's well-being in an adverse way and explains the need for a constantly evolving treatment plan.

Children with Cerebral Palsy ...

- ... are often behind other children of the same age in cognitive aspects. Thus our originally proposed target age group of 3-5 years was raised to 5-10 years.
- ... are often severely spastic and have little control over their fine motor skills, for example, finger movements. Thus, our focus changed from those fine motor skills to gross motor skills in the upper body; namely the movements of wrists, elbows, and shoulders.
- ... are often socially isolated and feel keenly that they are different from normal children. Thus, we will make sure to include a wireless multiplayer mode in our game, where they can play with other children, both CP and normal.
- ... often have one 'affected' hand. That is, one hand that is curled in on itself through continuous muscle spasms or shortened ligaments.

Fig. 1: An Affected Hand

They will not use this hand if they can bypass it in any way. The control scheme of the game, of avatar control through accelerometer movement, is meant to force them to hold the iPad with both hands. And thereby train the affected hand along with the dominant one.

3 Methodology

The base of our project was a series of expert interviews conducted at the Helene Elsass Center, Denmark. We were introduced to a theoretical direction that focused on the benefits of socialization. The experts emphasized, that a product targeting the issues children with CP experience with socialization, would provide us with a better opportunity of increasing their life quality. This also served to steer us towards making a product unlike those that are already present on the market. Although several rehabilitation games for CP children have been made, the socialization aspect is often left out in favour of focusing on physical rehabilitation. Our project aims to lessen the gap between the two aspects.

3.1 Design and Implementation

The basic design concept for the project, and the focus on developing for the iPad, was made very early in the preparation process. The original idea was centred on a series of touch-controlled mini-games, designed in accordance with the children's disabilities. The aforementioned interviews validated the general concept, but moved the control focus towards an accelerometer-based scheme.

Once a prototype had been made, an expert gave her opinion as to whether the controls would be fitting for our target group. Her comments did much to validate our design of the controls and helped us refine the overall design of the prototype.

In preparation for our end-user playtests we refined our prototype to represent the information from the experts. The personnel at the Helene Elsass Center were incredibly helpful in setting up the playtests and getting us in contact with our target group. The outcome of our tests was then analysed and the prototype refined once more in accordance with the results.

4 Games for Health

Games for Health are specifically directed at improving physical and mental health issues, as well as increasing awareness about health in general. The Dutch games company *RANJ*, which specializes in serious games, has developed health game titles such as GRIP, Divo´s Buzz, and The Great flu.1

The main purpose of *GRIP* is to make children, who are diagnosed with Diabetes, more aware of their own condition:

> *"GRIP is a serious health game which lets children experience how activities and food are influencing their blood sugar level. In a playful way, they learn to deal with the consequences of diabetes."*2

In Health Games specifically directed at children with cerebral palsy an interesting initiative has been made, to make controlling devices more accessible. David Hobbs, PhD candidate at Flinders University in Australia, heads a project for creating new controllers and several games for children with CP.

1 http://www.ranj.com/educatie/health%20games
2 http://www.ranj.com/content/werk/grip

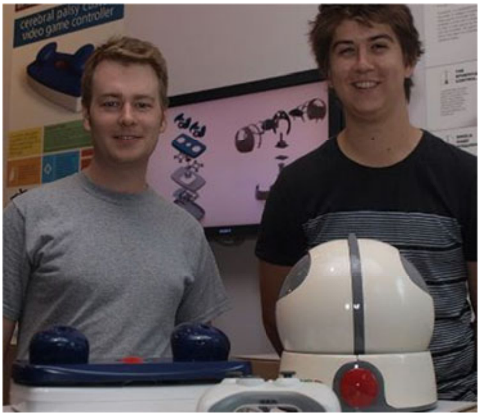

Fig. 2: Hobbs' Students with the Controllers

According to Hobbs the group has received a lot of positive feedback from the children who have tested the games. In an interview made for ABC radio, he emphasizes that the children liked the fact that the controllers did not look like medical devices, and that it opened up the possibility of playing with other children:

> *"She said it was the best two weeks she's ever had in her whole life, because she can now play games that her cousins can play as well."*[3]

Another project is the Mitii, the first game created by the Helene Elsass Center, specifically directed towards home-based physical training for children with cerebral palsy. The Mitii is an interactive and individualized training program and, in tradition with health game development, it is made in collaboration with the experts at the Helene Elsass Center.

5 The Expert's opinion

Subject matter experts make it possible to create the right product for a specific target group, but according to Pedersen, Khaled, and Yannakakis (2011), partners in the Games for Health initiative, it also complicates the design process:

> *"To solve this task, we started by forming a hierarchy of design concerns, in the following priority: functional design, treatment design, technology design, and game design. This design hierarchy was used to resolve any design conflicts - e.g. treatment design concerns would always take precedence over game design concerns." (p. 14)*

3 http://www.abc.net.au/local/stories/2013/01/08/3665717.htm

Making a Health Game thus becomes an analytical question of how to make the necessary adjustments to create the best possible product for the player.

According to Michael Bas, CEO at *RANJ* games, the usefulness of subject matter experts goes beyond the role of external consultants:

> *"Actually, they are in the lead, they are the ones who decide which direction it should go. Of course you have to keep in mind, as a game designer, you have to be very cautious about the fact that things have to be funny. But, you shouldn't be too arrogant as a game designer and say, "We know what to do", because you don't know anything." (Bas, 2013).*

The experts' opinions are thus an indispensable resource in the making of any health game.

The close collaboration with subject matter experts challenges the role of game designers and developers. The making of a game that only contains therapeutic value may very well undermine the ability that games possess to make tedious tasks fun and entertaining (Kato, 2010).

6 Why Make Health Games?

Health games are intrinsically linked to the realm of health care and medicine, and perhaps just as much to the area of psychology. The Dutch psychologist Pamela M. Kato(2010) states that patients often refrain from taking full advantage of the possibilities that the health care system has to offer, due to mental barriers:

> *"Engaging a patient's motivation is frequently necessary in health care because patients are often required to undergo procedures or engage in behaviors that are painful and aversive on the one hand (e.g., undergoing chemotherapy) or boring and mundane on the other (e.g., taking pills, exercising on a regular basis)." (p. 113)*

Games have proven to have therapeutic effects on a number of conditions such as asthma, cancer, anxiety management, and diabetes. Kato names the motivational nature of gameplay as a reason for the excellent results. Both Kato and Michael Bas (2013) emphasize that games may be a great resource to break down the psychological and behavioral barriers connected to health care and to optimize treatment.

A study made with young cancer patients showed a decrease in side effects to chemotherapy, simply by making the patients play a digital game for 10 minutes during treatment:

> *"The therapeutic effects of games are attributed to the distraction that games provide that focus attention away from these aversive side effects." (Kato, 2010, p. 114)*

In addition, the study compared two groups of children. One had received standard relaxation training from a therapist while the other group merely played the aforementioned video game. The results showed that the methods were equally effective in decreasing nausea and high blood pressure.

7 Theoretical Framework

7.1 Inclusion

Children who suffer from cerebral palsy often become secluded from the group activities that their peers participate in. This seclusion is naturally connected with the physical disabilities that become apparent in the early years of the child's life. The exposure to children their own age may therefore be challenging and overwhelming, especially if the activity requires a high level of concentration.

In accordance with our aforementioned success criteria, we aim at making a game that targets issues connected with CP, physical as well as cognitive. By including a multiplayer section in the game, we are hoping to inspire a different kind of group activity, one that is made in accordance with the children's abilities. We aimed to create a space in which the children feel in control of the environment, and therefore may have the surplus energy for interaction.

According to professors of social psychology Graham M. Vaughan & Michael A. Hogg, there are a number of benefits to encourage group activities. Social Facilitation, examines the changes that occur when we perform tasks in the presence of other people:

> *"(...) an improvement in the performance of well learned/easy tasks and a deterioration in the performance of poorly learned/difficult tasks in the mere presence of members of the same species." (Vaughan and Hogg, 2005, p. 156)*

An example of this could be playing a computer game in front of your friends. If the level you are playing is providing the right amount of challenge, you will likely perform even better with your friends watching; if the level is too difficult your performance may be worse than if you were playing alone.

According to Vaughan and Hogg (2005), simply making a group of children play a game together, may not necessarily result in an improvement in their task-solving performance. This indicated that we needed to take into consideration where each child was positioned on the game's learning curve, when analyzing their performance.

7.2 Learning

The prospect of making a game that improves the life quality of children with cerebral palsy is our primary goal with this project. In order to achieve this goal we made a game that was meant to serve as an entertaining addition to the children's lives. As a secondary, but also important, aspect of the project we attempted to make a product that also affords the prospect of learning, both cognitively and physically.

According to Stella Vosniadou (2003), there are certain guidelines as to how children will profit the most from a learning situation, and she emphasizes that:

> *"Learning is primarily a social activity and participation of the Social life of the school is central for learning to occur." (p. 18)*

The game was designed in accordance with the abilities of our target group, but we also see a great opportunity in the possibility that normal children could be interested in the game as well. Not only would this expand our possibilities for a wider audience, but it also provides us with a better chance of creating the social platform that we aim to provide.

The idea of an open space where different children can interact and compete may also bring with it a side-benefit when it comes to learning.

The concept of *Vicarious Learning* emphasizes the relevance of learning as a social activity, and was of importance in our analysis of how to create optimal circumstances for learning. The many social and communicative benefits that normal children gain from a traditional classroom situation are not necessarily a part of a CP child's life. We therefore find it important to attempt to implement a learning structure that builds upon social learning, but also to create a dynamic situation where the players have the opportunity to learn by watching:

> *"We now want to emphasize a process of social learning, in which the learner's approach to learning something, is shaped by the observation of others attempting to learn it." (Mayes, Dineen, McKendree, and Lee, 2001, p. 2)*

The role of spectatorship could be a highly beneficial way of clarifying the questions relevant to the game controls. Mayes et al. emphasize that one of the advantages about the classroom structure are the answers to other student's questions, that the class as a whole becomes familiar with. The questions and answers become part of a structure that affords a group mentality, in the shared effort to understand the subject matter:

> *"One of the keys to successful learning, of course, is being able to ask appropriate questions. It may be that this involves confidence as much as skill or knowledge, and observing other learners engaged in such dialogues has its effect by providing a model for good learning behavior." (Mayes et al, 2001, p. 2)*

Watching others play may therefore not only provide answers to many of the same questions, but could also familiarize the child with the norms of how to communicate in a learning situation.

Our hope is that creating situations, where the children are physically present in a playful setting, will afford a socially based playing style through the multiplayer option at home. Mayes et al. (2001) propose that learning devices may be created to automatically ask and answer questions, to mimic the social learning situation, but are critical as to whether this is an adequate substitution for real dialogues.

A good learning situation relies on good communication. This is relevant not only when it comes to dialogues between the players, but also when deciding how to make the feedback in the game as intelligible as possible. In the making of this game we will limit the amount of words as much as possible. However, the specific words that are used may prove to be important in connection with the training of the children's motor- and communicative skills. Olaf Hauk, Ingrid Johnsrude and Friedemann Pulvermüller (2004) have conducted an interesting study involving the concept of *Action Words*:

> *"In the case of words referring to actions performed with the face, arm or leg, neurons processing the word form and those processing the referent action should frequently fire together and thus become more strongly linked (...) (p.1).*

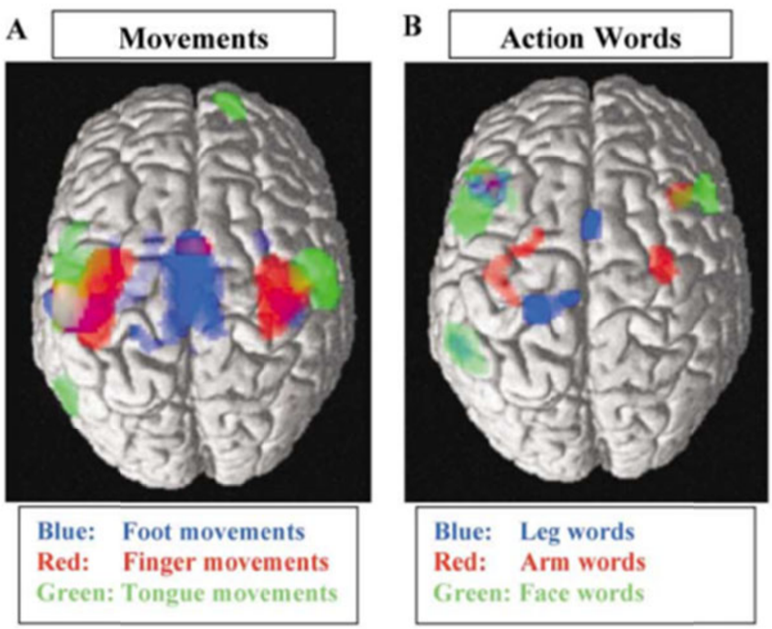

Fig. 3: An Example of Action Words

Making the feedback from the game as simple as possible is of great importance. The children may easily lose interest if the non-gameplay part of the game demands too much attention. In addition, the action words have a proven effect on the areas of the brain that are usually only activated through physical tasks, see Image 1-3.

The vicarious learning theory can be extended when contextualized with the research of a specific mechanism in the brain, namely the *Mirror-Neuron* system.

The mechanism in charge of our ability to imitate - and understand - the actions that others perform, is called the mirror-neuron mechanism. According to Giacomo Rizzolatti and Laila Craighero (2004), action understanding is the very foundation for social organization.

The mirror-neuron mechanism supports the aforementioned notion of action words, since it causes neurons to fire even when we merely observe actions performed by others:

> *"We stress, in particular, those properties specific to the human mirror-neuron system that might explain the human capacity to learn by imitation." (Rizzolatti and Craighero, 2004, p. 169.)*

8 Design

Our product, *Astro Eventyr*, is a vertical slice of the game part of our master thesis project. Its design was based on the design constraints discussed in section 1.5 Cerebral Palsy.

The controls were designed in such a way that the entire iPad has to be moved, using the accelerometer. The movements incorporated into our control scheme are shown in Image 1-4.

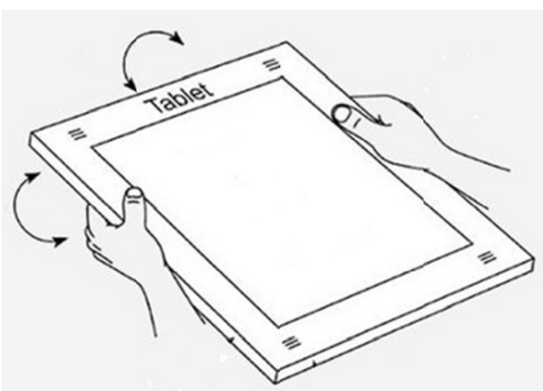

Fig. 4: Movement axis in control scheme

The controls are meant to help train the gross motor skills of the players. They tilt the iPad forwards, backwards, to the right, and to the left. The children are likely to benefit from increased exercise in the hands, wrists, arms, and even shoulders.

8.1 Empathy in Design

> *"If we agree that all design is in the end about having a conversation with the intended user it would be ridiculous if the design of games – systems that rely on player's active participation – would not have a player focus."* (Sotamaa, 2007, p. 456)

How does a designer design for a target audience that she is not a part of herself? Her preconceived ideas are certainly not enough to make sure that the end-user's needs are met. According to Koskinen and Battarbee (2003), professional designers, in any discipline, are deeply knowledgeable about the building blocks of their products; the techniques involved in developing them, in aesthetics, and ergonomics. Thus, if a designer depends only on her own imagination of what the end-user needs, she will be judging her ideas and work not as a typical user, for he does not have her wealth of knowledge, but as a professional designer. Therefore, she may be overly dismissive of the design, when it could potentially have fulfilled the user's every need.

Another side of this designer-centric approach is that people often assume that others will like what they like themselves and understand the world as they do. This can lead to poor design decisions, for there is no guarantee that the user will instinctively know what the designer knows (Fulton Suri, 2003). Will he know intuitively that a particular button should be turned? Or that a certain shade of blue is meant to remind them of a spring sky? What seems like common sense to the designer will likely mean something quite different to a person with a different set of experiences and knowledge.

In user centered design methodology great emphasis is put on the *"problem of understanding the user and his or her experience"* (Kouprie and Visser, 2009, p. 437). By basing the design process on the user, rather than the designer, we focus on how users may use the product, how they may see themselves as users of that product, and what is likely to either please or displease them.

This leads us to the concept of empathic design, a user-centered method, where the designers attempt to understand the experiences and lives of their intended audience. This increases the chances of correctly meeting their user's needs (Kouprie and Visser, 2009).

The tenets of empathic design, in particular the importance put on the needs of the user, fit well with the development of a health game.

Empathy means the projection of the self into another's situation. An understanding of how the user sees, experiences, and feels about something is key to empathic design. Designers need to make sure that their creations are the translation of emotions into a product – that they *"...give tangible form to elusive experiences"* (Koskinen and Battarbee, 2003, p.39).

8.2 Unlocking Emotions

Traditionally, research into usability has been focused on minimizing user errors and functionality. Design has to utilize a user's experiences and emotions, *"to provide joy for people, not just smooth functioning."* (Koskinen, 2003, p. 7)

To be able to unlock the player's feelings is a worthy goal for a game designer, providing an emotional connection that serves to deepen the player's experiences.

According to Nicole Lazzaro there are four keys to unlocking emotions in games, and thus to increasing the entertainment value of said games,

- "Easy Fun (Novelty): Curiosity from exploration, role play, and creativity
- Hard Fun (Challenge): Fiero, the epic win, from achieving a difficult goal
- People Fun (Friendship): Amusement from competition and cooperation
- Serious Fun (Meaning): Excitement from changing the player and their world"[4]

Considering our constraints and target group, we chose to focus on three of the four keys; *Easy Fun*, with the connotations of exploration being intrinsically linked with our chosen theme setting of space exploration; *People Fun*, since we want the gameplay to represent and foster a social connection between the player and other children; and *Serious Fun*, because we hope to change the player's life for the better by changing their body and giving them a training tool that is entertaining.

8.3 The Game

Astro eventyr contains a racing game which has five levels, two single player and three multiplayer. In the multiplayer each player has an iPad, and both view the same seen (see Fig. 5.). The only difference being that your avatar and points are high-lighted to distinguish them from the other player's.

4 http://www.xeodesign.com/whyweplaygames.html

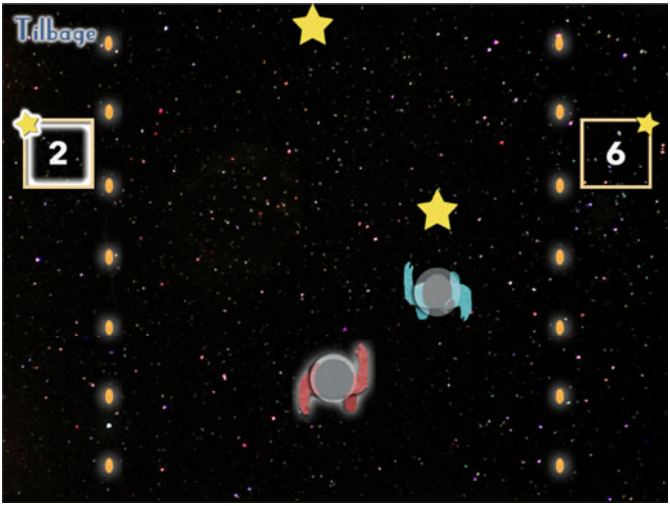

Fig. 5: Screenshot of Multiplayer Gameplay

Single-player:

- The player collects stars that appear at the top and bottom of the screen. Only one star appears at a time so the player can concentrate on learning the controls without too many distractions. When the player has collected ten stars the game ends. This level contains no lose-condition.
- The player avoids asteroids, building upon the control-scheme knowledge gained in the first level. The background moves to simulate movement forwards and the asteroids appear at the top of the screen and move downwards. The player has five lives and colliding with an asteroid means losing one life. The game ends when the player has either survived for 30 seconds (win-condition) or lost all five lives (lose-condition).

Multi-player:

- The players collect stars, competing to be the first to collect ten. The background moves to simulate movement forwards and the stars appear at the top and move down the screen.
- The players avoid asteroids, they play for 3 minutes or until one player has lost all their lives. The player with the most lives at the end of the game wins.
- The players avoid asteroids while competing to collect 10 stars. The game ends when a player either collects 10 stars or is hit five times by asteroids.

9 Tests and Results

The playtesting methods chosen for this project were observation, semi-structured interviews, and the think-aloud method with constructive interaction. Our playtesters consisted of a group of six children with cerebral palsy.

For the end-user playtest we first tested four of the children in single-player, where an informal variant of think-aloud was explained. The children were encouraged to verbalize their opinions, and the conductor tried to keep prompting to a minimum. Because of the issues children with cerebral palsy may have with concentration, we did not want to force them to multitask in case it made them uncomfortable.

All the children were then paired for constructive interaction and asked to play the multiplayer levels. Als et al. (2005) discuss O'Malley's suggestion, that when pairing subjects for constructive interaction, the level of expertise on the subject's part is an important factor. When pairing the children we attempted to pair them by both age and expertise. The children were encouraged to talk to each other while playing. In all but one instance they played in a so-called acquainted pair, since children may be more likely to give information to their friends which they are hesitant to give to the conductor (Als et al., 2005).

9.1 Results

How limited is the fine motor control of our players?

We observed our players in their use of the on-screen menus and the Game Center invitation process, the only parts of the game requiring precise fine-motor control. Our players did not seem to have much trouble while using the menus. Some seemed to need to concentrate more than others in order to choose the correct game-mode and levels, but managed without help from us. This sort of interface can possibly be used to activate their fine motor skills on a limited scale, simply by them using it when starting the game themselves.

Does the presence of other people seem to affect an improvement or deterioration in the performance of the players?

This question deals with social facilitation in general and the presence of spectators in particular. The results of the test indicate that the theory of social facilitation is valid in connection with spectatorship. In all instances, except one, the children seemed to be paired appropriately, according to their place on the learning curve. In the case of the single exception, the tester performed admirably in the lowest difficulty single-player, but became very frustrated when playing the multiplayer level of a higher difficulty. His frustration was mainly caused by external factors, such as his friend's taunting comments during gameplay. This indicates that since his skills were less progressed than his friend's, his performance deteriorated in the presence of others.

Can we design the controls is such a way that we force the player to use both hands to play the game?

All of our players are hemiplegic, that is, they have fine-motor problems in one side of the body, but only some had a visibly affected hand. All of them used both hands to play the game without encouragement. They were simply shown how to play the game and none showed an inclination to not use both hands to control it.

Can we design the controls in such a way as to make the player increase function in their hands, wrists, arms, and shoulders?

This question is very difficult to answer from such limited testing. Several children using the game over an extended period, under the supervision of a physiotherapist, would be needed in order to answer this question conclusively. However, all our players made large movements with their whole upper bodies while playing the game, especially with their wrists and shoulders.

Fig. 6: Playtesters' movements while playing

This is a good indication of the game being helpful in training these muscles if it is played regularly over an extended period of time.

Will the player be able to learn how to start and play the game by watching? Will the player be able to learn how to connect a multiplayer game through watching us do it?

All of the players observed us intently when preparing the games, which menu items we chose and such, and were able to mimic that with minor help when starting a new game.

Setting up a multiplayer game is more complicated than a single player, with several steps that must be completed in the Apple Game Center. However, after watching us set up a game several times the testers, all except one, seemed to have caught on and could perform the necessary actions with little prompting. The one exception did not observe the connection process and thus did not learn how to perform it on his own.

All but one of the children appeared keen on learning how to set-up a game on themselves, which is a very encouraging sign. Indeed, one of the factors behind the game creation was the need for a tool that the children could use independently of their caregivers.

Does the player seem to enjoy the game? Would they like to play it again?

According to the video recordings of the playtests and the players' answers to our post-interviews, we answer this with an emphatic yes. We had to physically remove the iPads from some of the children in order to get them to stop playing the multiplayer game.

10 Conclusion

In this paper we address the question of whether digital games can serve as a rehabilitative tool for children with physical and cognitive limitations. In order to find the answer we created a vertical slice of a game, *Astro eventyr*, designed specifically for children with cerebral palsy. The design of our vertical slice was based on our three-faceted success criteria; entertainment, socialization, and rehabilitation.

The results of our end-user playtests indicated that the children found the game entertaining. The most significant indication of this being that the children refused to stop playing and ignored any requests on that subject. We had to physically remove the iPads from the children in order to proceed with the playtest session.

We have emphasized the importance of group activities in the children's lives, through social and vicarious learning as well as social facilitation. Our tests seem to indicate that the children found enjoyment in both playing the game themselves and watching others play.

It is difficult to answer the question of whether the prototype can act as a rehabilitative tool. Any definitive answer would require a child to play the game for an extended period of time while being assessed by an expert in cerebral palsy. However, the movements of the players during testing seem to indicate that it might help them train their gross motor skills.

Although several games for children with cerebral palsy have been made, none have approached it from the direction we chose. Our focus on not just rehabilitation, but also on the importance of entertaining the player, in combination with our accelerometer-based control scheme, serves to add something new to the field of health games.

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The Core Mechanic in *Battlefood*: A Design Journey

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Abstract

This research aims to improve the practice of designing educational video games ("learning games"). Specifically, this paper aims to demonstrate need to improve Shelton's theory of activity-goal alignment, which focuses on the relationship between a player's activity and the designer's intended learning goal in any learning game. Using the research method of autoethnography, the data is an account of the evolution of the core mechanic in *Battlefood*, a learning game research project. While Shelton's prior findings, that activity-goal alignment theory meets an important need in learning game design practice, are largely confirmed, this research draws two main conclusions: the literature's typical modality (primarily lengthy text-based discussions) is not a good fit for practising designers, and Shelton's theory could be more useful if it were made more accessible to practicing designers.

Keywords

learning game, design, game-based learning, autoethnography

1 Introduction

This paper argues the need for improved ways to apply theory in the design of learning games. After thirty years, there is much theory to support learning game designers, yet I argue it is not used often enough in practice. Here, I aim to highlight and improve upon one simple, useful theory: Shelton's activity-goal alignment [1]. Previous theorists have proposed similar ideas [2], [3] but I chose Shelton's theory because I felt it best related foundational theory while being grounded in practice, and most clearly stated the importance of this particular relationship over other design issues (e.g. single versus multiple players). Shelton's theory focuses on the relationship between a player's activity and the designer's intended learning goal.

In this paper I argue the value of Shelton's theory by presenting an autoethnographic account of the design of the core mechanic of *Battlefood*, a video game that

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aimed to teach players about nutrition[1]. By showing my team's design process, highlighting key points of failure, I argue the need for improved tools that present activity-goal alignment theory in a form that is simpler and clearer for practicing designers than the existing literature does. I also argue more generally that the modality of today's theory needs improvement, if it is to impact practicing learning game designers.

1.1 Significance

Broadly speaking, the field of learning game[2] research has enjoyed renewed interest recently, including millions of dollars in funding worldwide [4]. Respected institutions such as MIT [5] and noted scholars [6] have argued that learning games have great potential that has not yet been met. The project underscores the prevailing advice among many respected designers and researcher of learning games: today's learning game designers must go beyond the „low hanging fruit" to design and tackle deep challenges to build fundamentally excellent learning games [5], [7], [8].

Assuming that we must improve design of learning games, why is Shelton's activity-goal alignment theory significant enough to merit attention? In answer, I argue two points:

- The relationship between activity and goal is an important problem for all learning games
- Activity-goal alignment theory has improved the prior understandings of the activity-goal relationship

Regarding the first point, the reader should understand the general idea of "activity-goal relationship," which is the relation between a player's activity within a game and the overall learning goal of the game. For example, a learning game might provide a player activity[3] of exploring an abandoned cave, and a goal of teaching long division. How does a spelunking activity relate to the mathematical

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1 The game *Battlefood* itself has been submitted as a creative work separately for the Games for Health Europe conference by Mathieu Allaert, a colleague of mine.

2 While this research applies reasonably well to a variety of serious games, including game-based learning and some gamification projects, I use Klopfer et al's term "learning game" throughout this research. Their definition follows: "Learning Games are differentiated from Games for Training in that they target the acquisition of knowledge as its own end and foster habits of mind and understanding that are generally useful or useful within an academic context." They cited several examples easily located the literature including Lure of the Labyrinth, Immune Attack, Civilization, Rollercoaster Tycoon, and SimCity." [2, p. 21]

3 The term "activity" relates closely to, but is not identical to, the concept of "game mechanic" from the game design literature [9]. A good definition of "'activity" is available in [1].

learning goal? Shelton argued that such a question focuses designers' attention on an important issue that could be otherwise lost in the cut and thrust of the many other design questions they face [1].

The foundational theory behind activity-goal alignment theory is not tidy. From a variety of perspectives and through various research fields, the idea has reappeared over many years. For example, the noted psychologist Piaget stated that an over-emphasis on free activity can lead to aimless play, while an over-emphasis on the learning goal can lead to a curriculum that most students fail to understand [10]. Thomas Malone, a pioneering learning game researcher, noted "it is not clear how to structure educational environments in which free choice leads to productive learning" and suggested we consider the problem using the notion of player choice [3, p. 339]. As research continued, the field of simulation appeared and developed ideas such as fidelity [11] to explain the relationship. Cognitive scientists, game theorists, educational theorists such as instructional designers, and researchers have all discussed similar ideas. Today in game design literature, the idea has resurfaced in relation to the gamification debate [12], typically relating intrinsic and extrinsic motivation [13] to game mechanics.

While the general concept of activity-goal alignment is common, the literature is unclear as to its meaning, applicability, and impact on practice. The advice given is a complex blend of many varying voices, terms, and positions. As part of this research project, I reviewed the literature and concluded that learning games designers would benefit from focusing on the relation between a player's activity and the learning goal as they work. I also found that Shelton's theory summarizes this prevailing view reasonably well for today's practicing learning game designer.

1.2 Method

To illustrate how Shelton's theory of activity-goal alignment could benefit the practicing designer, and the need to make such theories simpler to apply in practice, I next present and defend my choice of method: analytic autoethnography.

Ethnography is commonly employed by design researchers [14] [15]. Autoethnography [16] is a form of ethnography that avoids the notorious "participant observation" problem [17]. Like any method, autoethnography has drawbacks. Of Chang's six criticisms of autoethnography [18], one issue is particularly galling to many scientists: it is obviously a highly subjective method. Anderson developed a more analytic approach [16] that I employed in this research.

I chose autoethnography despite its drawbacks because it has been found exceptionally suited to formative, exploratory questions in interactive software design [19], which describes this research. By not requiring my tacit understanding of a phenomenon or experience to be communicated to others, autoethnography gives access to "insider meanings" [16]: the truth that is known only to those who participated. Such truth is valuable to understanding the subtle forces at work in the practice of game design.

Analytic autoethnographers must demonstrate that the researcher has the authority to be a valid source of data [16]. To that end, I note that I have been fortunate to have the opportunity to work in design capacities in a variety of video game development projects over 22 years, writing backstory, designing levels, exploring game mechanics, programming tools, and creating content (models, textures, and animations) for around 40 games. I helped design and build early 3D games for the PC, including *F22* (Sega Enterprises 1991), *Ultima Underworld: The Stygian Abyss* (Origin Systems 1992), *Car and Driver* (Electronic Arts 1992), and *Descent* (Parallax Software 1994). While a great deal of my career has been spent building commercial video games for entertainment purposes, I have also worked on numerous projects that we might today describe as “serious games”: projects whose aim was not primarily entertainment. These projects included several typing programs, structural simulations, data visualization, and virtual training applications such as truck driving and material handling.

2 The Story of *Battlefood*’s Development

The following autoethnographic narrative describes the development of *Battlefood*, a learning game intended to improve players’ knowledge of basic nutrition. For years I had imagined that a game mechanic that used unhealthy foods as dangerous weapons in a fast-action “food fight” game. I imagined that such a game could teach nutrition. I got my chance to explore this design idea when I was lead researcher for a pilot project in a cooperative research venture partially funded by the Australian Federal government. The other developers were a programmer “Sam”, an artist “Andy”, and a nutrition expert, “James.” Andy, Sam, and I met weekly, while James’ availability was limited to approximately one meeting a month.

The learning goal was to explore nutrition’s role in a mathematical model of human metabolism. The game was designed around incentivizing players to seek this learning themselves, without the guidance of a human teacher, and aimed to be self-assessing: players could not win without understanding the game’s model of nutrition.

2.1 The Core Mechanic

In an unpublished grant application I described my vision for the core mechanic of *Battlefood*:

Using a multiplayer shooting game mechanic, our game is based on a "food weapon system:" a mathematical model of human energy consumption and expenditure, with simple nutrition model. Using minor variations on proven mechanics, the game offers a progression from fast action to tactical and, later, strategic, excellence via mastery of weapons system.

I hoped that the masterful player would have something like twenty hours of intense interaction with the Food Weapon System, and imagined this interaction as an experiential, self-motivated type of learning that fit the positivist theory perfectly. I imagined that winners of *Battlefood* would walk away with a conceptual understanding of human metabolism of a depth and subtly that no other form of study could match.

2.2 Significance of the Food Weapons System

At the start of the project, I regarded the "food weapons system" as the most important part of Battlefield's design. I wanted the game's weapon system to embody the learning goal: understand how nutrition relates to our health. I aimed to bring the typical deep understanding of fantasy weapons to a real-world question. In Shelton's terms, I was aiming for extremely high alignment between learning goal and activity, although I had not encountered his theory at the time.

This design sprang from an observation common among game designers: Players typically exploit models in games [20]. The more specific case of weapons system mastery is an established, if tacit, heuristic in gamer culture: to win a first-person shooting game, study the weapons (Bowler 2008). Accordingly, I assumed players would study *Battlefood's* weapon system in great detail, if the game rewarded such mastery to progress.

It is well recognized that weapon systems are extremely important in video games that revolve around shooting as their core mechanic. For example, consider the intensely competitive multi-player team-based video game *Team Fortress 2* [21]. Each weapon is very different and understanding these differences is crucial to winning, so players carefully study attributes such as range, damage and accuracy and related them to in-game effects. Bowler [22], a *Team Fortress 2* player and early-career professional game designer, illustrated a typical player's mental model of *Team Fortress 2*'s weapon system balance (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

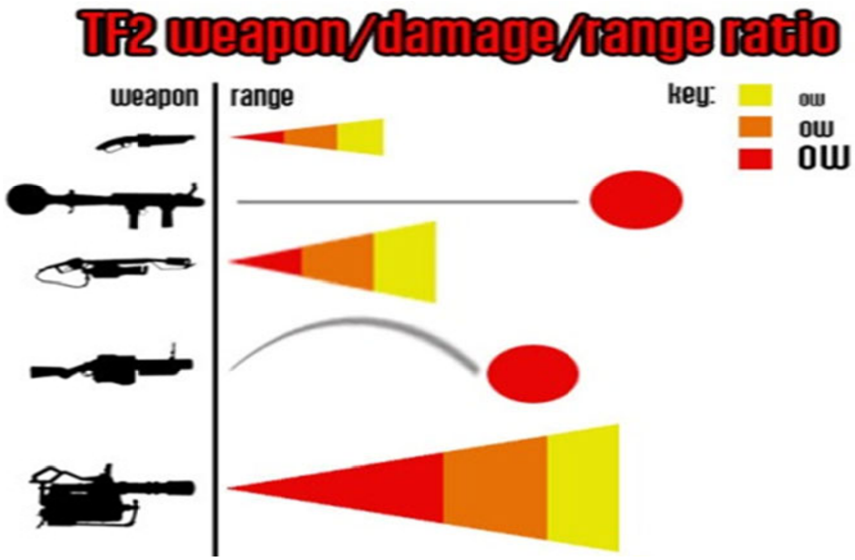

Fig. 1: Player's conception of the difference between weapons in the video game *Team Fortress 2.*

Bowler's chart only shows attributes that directly affect gameplay (range and damage), even though the weapons have other obvious differences such as sound, appearance, and visual effects. For example, the flamethrower is compared directly to the rifle. To a nonplayer, these two weapons appear to be so dissimilar as to be unrelated, but in the player's mind, they are reduced to two variables: range and damage. This suggests that in the player's mental model of the game, the weapon's "winning affordance" is a key factor in player weapon choice. Unsurprisingly, the wealth of player knowledge about a game's weapons system is substantial, as can be seen in online player discussions. The training modules in *Team Fortress 2* focus beginning players' attention on strategic, not aesthetic, weapon differences.

In almost any game, designers can assume players want to win [23]. To win in a multiplayer combat game, players must somehow distinguish themselves from other players. Players assume that any decent multiplayer game provides some skill-based method of distinction. Normally, this distinction is a player's skill, especially accuracy of aiming. I steered players away from focusing on accuracy skills by adding "auto-aim," a feature that helped the player hit opponents even if their aim was off. This reduced the challenge of the "shooter" mechanic, and required them to seek distinction using other elements of the game. My design then focused player attention on choosing the correct weapon. For beginning players, whoever could distinguish between healthy and damaging food would score highest. *Battlefood*'s design de-emphasized other player skills to keep players focused on the learning goal. For example, popular first-person shooters typically require fine motor skill and quick reflexes to win [22]. In addition to auto-targeting, the speed of the projectile was designed to make reflexes less important, when compared to other similar shooting games. To win, players would have to find another skill to differentiate them.

I also designed for advanced players, who exploit the food weapons system to their advantage. I intentionally did not design a particular path for advanced players; instead, I wanted clever players to engineer new ways to combine or sequences foods to achieve specific purposes. I also hoped for an "arms race" between defensive and offensive strategies: players could eat certain healthy foods to protect against certain lethal combinations of unhealthy foods.

I imagined the mathematical model would use more than two or three type of information from each food weapon, and generated many subtle variations to explore, yet every option would express real world knowledge, reducing the "transfer problem" that plague many learning games [24]. For example, I imagined the final game would tutor and assist the player in progressing, by rewarding the players with hints and gifts "You won a chicken/chips combo-pak! Their saturated fat is 80g per serving–super-lethal!"

2.3 The Fatal, Hidden Assumption: There Is No Equation

In this imagined Food Weapons System design, I failed to investigate a crucial assumption. I had assumed there existed a widely accepted mathematical model of human metabolism, detailed enough to predict weight gain/loss from any reasonable combination of calories, protein, fats, and carbohydrates. I assumed the nutrition information on the back of a box of cornflakes could all be plugged into an equation, along with body metrics, and I could know if I would gain or lose weight, healthiness, and other clear, definite answers.

As the project progressed, I contacted several experts in nutrition, and eventually recruited James, who had both research and clinical intervention expertise on obesity, exercise, and nutrition. He agreed to participate and in our first meeting, I explained the vision and presented him with a spreadsheet that listed seven key attributes of any food (calories, protein, carbohydrates, fat) and any person (age, height, activities). I asked him to create a formula that would predict the weight gain/loss of the person. He was unable to do so easily, to my surprise. James and I worked together for several months, researching and developing the food weapons system, but we could not come up with a formula.

There were two important problems that prevented us from reaching agreement right away: My ignorance of nutrition, and my inability to express the concept of "activity-goal alignment". James struggled to reach an understanding of the need for a nuanced, mathematical "food weapon system" model, and often suggested simplified models, or models that incorporated training or other unrelated elements. Although I tried several times, both in written form and in meetings, to convey the "activity-goal alignment" idea, and although James seemed to understand and express the idea back to me in meetings, it was apparent from his suggestions that he didn't really understand the implications. For example, in an early meeting with Tim, I explained again that we needed a mathematical formula that predicts weight gain/loss from any combination of a few properties of any food. After the meeting, James wrote that he was casting the net wider, trying to extend the food weapons system to include injury and nutrients. He was also proposing that the simulation be simpler cause/effect, not a comprehensive equation that would predict weight gain/loss.

As James patiently disabused me of my "common sense" notions of metabolism and nutrition, I was dismayed to discover how little uncontroversial knowledge exists about human metabolism. James explained that while there were published models, experimental evidence was not strong, and one person's claims might conflict with other equally reputable claims. Further, many models dealt with broad population segments such as age ranges, not individuals.

2.4 Major Redesign 1: Add a "Training Mode"

About one-third of the way through development, I became convinced that my initial assumption was wrong: There is no widely accepted mathematical model of human energy consumption in the literature. I believed no one really knows what will happen to a male 18-year-old if he eats 80 grams of saturated fat, versus 60, per week. There are many variables (James said genetics play a huge role, for example) and many of these variables' roles and function are hotly debated. I perceived this was a big problem for the game design. As designer, I had to make a choice: Choose a mathematical model that was unproven, or change the design so as not to require a mathematical model. I did not wish the game to be criticized for teaching wrong information, so I changed the design.

James was particularly keen on incorporating exercise and training, partly because the modelling is less controversial. His influence was apparent in the first major revision of the design. After the conversation where I accepted James' position, I wrote an email to the team: "The big idea is: fight mode is more about fun, and training mode delivers more of the learning. So, we can add fun stuff to fight mode that isn't strictly about learning." By adding training, I was seeking an alternative mechanic to that could have high activity-goal alignment, without throwing out the whole game and starting again.

As a result of other demands on my time as a university lecturer, there was need for more rapid decision making than I could provide. I empowered Sam, who was funded up to full-time, to make most design decisions himself, rather than delay the project. His design influence reflected his personal passion for "hard-core" shooter games such as Counterstrike. We built a video demo that showed a playable prototype with a very simple caloric in/out model, no food weapons system, and functional core multiplayer shooter mechanic. There was little progress on the training component. Sam, the programmer, and I explored why he was resisting this element in meetings.

As I talked to Sam, I realized that this "fight/train" split had two important weaknesses. First, it weakened the clarity and power of the original vision, as the core mechanic was now split. Second, it divided the learning from the play: The "fun" part was mostly in the multiplayer fighting, while the "learning part" was mostly in the training. As I mentioned in the introduction, this felt like a move toward "chocolate-covered broccoli", a term describing a schism between learning and play known to be problematic in past learning games [5]. While the fight/train system was not nearly as split as games like *Math Blaster*, it still felt like the wrong design direction.

When we were half-way through development and playtesting weekly, we decided to return to the original vision but replace the Food Weapons System with a "food pyramid" mechanic. In this version, if player collected the quantities of foods in the categories recommended by an Australian government-approved set of healthy eating guidelines (fats, sweets, grains, dairy, etc.), that player would "power up" and become invulnerable to attack for a limited period of time.

Without a food weapons system, the possibility space for the player to explore was greatly reduced. The "killer weapons" were easy to identify after an hour or less of gameplay by experienced gamers.

3 Modes of Communication around Activity-Goal Alignment

In the narrative above, I have aimed to explain the context that created the general need for activity-goal alignment theory in my design practice. Next, I explain how the theory illuminated my pre-existing notions. During the development of *Battlefood*, I took notes and captured our attempts to communicate about activity-goal alignment prior to my discovery of Shelton's activity-goal alignment. In my attempts to explain, I experimented with alternate modes including verbal conversation, whiteboard sketches, and emails. Below I present and discuss selected attempts.

3.1 Model Complexity as Poor Substitute for Activity-Goal Alignment

In this section I describe how I developed original ideas that were not as effective as activity-goal alignment in explaining activity-goal alignment. During the *Battlefood* project, James and I discussed how the simulation model relates to the learning goals. The discussion began when James suggested that the game could “add on” to an oversimplified model of metabolism: if the learning scope were expanded to include exercise, diabetes, or injury recovery, then useful learning goals might be met, even without the good simulation. I resisted this suggestion because these extensions could not be integrated into a single simulation; instead, multiple small simulations would be needed. This is technically possible, but the interactions between these small simulations would be difficult to build, and could reduce activity-goal alignment. Perhaps if James had access to activity-goal alignment theory he could see that “training mode” lowered the game’s activity-goal alignment and we could have addressed this weakness earlier.

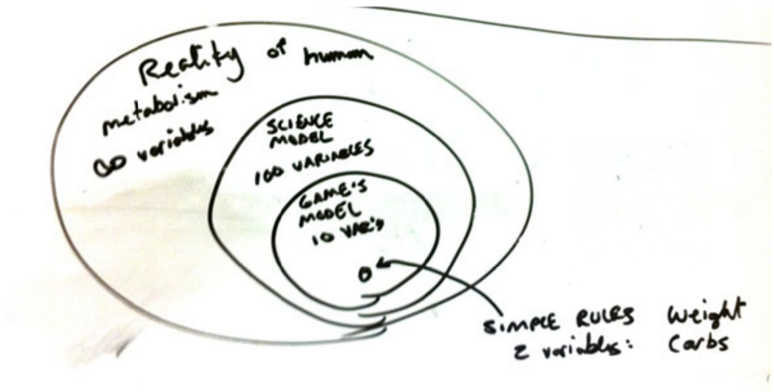

Fig. 2: My whiteboard sketch of the relative complexity of four nutritional models: the original proposed in-game model, science model, all within “reality:” true human metabolism. Note that I used number of variables as an approximate measure of complexity.

In that context, I created the sketch in Fig. 2, aiming to compare the various types of models we might consider. The simplest model, the innermost tiny circle, used only 2 variables - weight and calories (incorrectly labeled "carbs" in the drawing). The next circle, labeled "Game's model," showed my imagined ideal level of complexity for a game, in which ten variables are supposed. The "Science model" circle with 100 variables was supposed to be too subtle and complex for the game's purposes. Finally, reality, in all its infinite complexity was shown in the largest circle to show that the scientific model, while complex, is still not perfect.

The drawing implicitly suggested that the game should have one comprehensive simulation of human metabolism, rather than a series of connected components such as stomach capacity limiting system, energy level, health level. This approach had an important weakness: it suggested that simulation accuracy, rather than effectiveness of the learning game, was important. Simple models are just as useful as complex models [25], and while I and my team knew that theoretically, but this drawing confused that knowledge. Accuracy had no place in the discussion, but there was a need to create a linear relationship between learning game effectiveness and simulation. “Accuracy” was the closest idea I could think of on the fly.

In review, I observe that the lack of terminology may have misdirected James toward accuracy when I wanted to talk about activity-goal alignment. A term like endogenous[26], was too theoretical and broad; it would have been too easy to simply say “yes the game is endogenous because the core mechanic is the learning goal.” However, I can imagine that if James and I had discussed and agreed upon the meaning of a designer’s term like activity-goal alignment, especially if we could have scored it using the tool I later developed and discussed our differences, it could have made the discussion more fruitful and substantially reduced confusion between the team members.

3.2 Design Document

Design documents are one of the oldest and most common tools for communicating about game design ideas [27]. There are many forms of design documents, from a single 2-page concept document to 1000 page “bibles” or groups of documents. *Battlefood* used a large initial concept document, which was replaced by multiple small documents and task lists, in an informal agile development process.

In the initial concept document, the alignment between activity and goal was an important idea to convey. However, it was difficult to express. In an early draft of the grant application for the project, I wrote:

Using a multiplayer shooting game mechanic, our game is based on a “food weapon system:” a mathematical model of human energy consumption and expenditure, with simple nutrition model. Using minor variations on proven mechanics, the game offers a progression from fast action to tactical and, later, strategic, excellence via mastery of weapons system.

In retrospect, I see that my phrase “excellence via mastery” essentially meant “high activity-goal alignment” but my terminology was unclear to the others on the team. Before the project was approved, in notes I wrote while developing the grant application, I discussed objectivity in the game design:

Will an objective simulation (of the human body diet) have important benefits to a game that teaches healthy eating? We hypothesize yes, because “healthy eating” is subjective, and as such [sic]. Human body simulation is objective.

In this incomplete sentence, I relate simulation to learning outcomes, by considering subjectivity. Subjectivity is an essential challenge of teaching nutrition. What is “healthy eating”? Food culture experts state that subjectivity and cultural context is an important component of any answer [28]. While that was true, it was not the point I was trying to address. My attempts to express a specific concern accidentally raised much larger questions.

3.3 The Potential of Activity-Goal Alignment Theory to inform Battlefood Design

To complete my argument that Activity-Goal Alignment theory could have been of benefit in the design process presented above, I review two clear examples from the narrative above.

Recall that James and I revised the game design to include a “training mode,” which would have lowered the game’s activity-goal alignment. It took some time for me to identify why training mode was a bad idea, as it sounded like a reasonable fit during the first few design discussions. I believe activity-goal alignment theory could have saved time in coming to that realization. Specifically, if James had understood Shelton’s activity-goal alignment theory, I speculate that he and I could have realized that a “training mode” would lower the game’s activity-goal alignment as we discussed it, and saved the team time. I feel a visual diagram of activity-goal alignment would have improved James and my ability to communicate about the theory and better address the core problems in this game.

4 Conclusion

This research relates my discovery of the need for activity-goal alignment theory in my practice as a learning game designer. I presented a frank account of our development of the core mechanic in *Battlefood*, and discussed how it was both informed by some existing theory, and could have benefitted from more. Specifically, I have illustrated the need for a tool that helps non-designers and designers comprehend the theory of Shelton’s activity-goal alignment, and apply that theory as they collaboratively design a learning game. I aimed to show that activity-goal alignment might be useful to the learning game designer because it makes an important theoretical position from the learning game design literature clear, but it needs to be simpler to apply in practice. The findings this research suggest a visual tool that makes activity-goal alignment relevant in a production context might be useful. I have developed such a tool, the AGA Scoring Tool, as part of my doctoral work, unpublished.

Finally, I offer a broad critique of the modality of most learning game literature: text is too easily ignored or lost by practicing designer/researchers. This argument obviously applies to many types of learning game literature, not just the specific theories mentioned here.

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Using Vitruvius as a Framework for Applied Game Design

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Abstract

The number of games designed for various applications in healthcare is growing rapidly. However, balancing the needs of an applied game can be a difficult task, especially without a guiding vision or design framework. Here, we propose a philosophical framework inspired by the ancient Roman architect Vitruvius, which can be used as an approach to designing and developing applied games for healthcare and other contexts. Vitruvius believed any well designed artefact should exhibit the three principles of *firmitas* (soundness or sustainability), *utilitas* (utility or purpose) and *venustas* (attractiveness). We describe the Vitruvian approach to applied game design using the design process of Moodbot - a game for mental healthcare - as an example. In this paper, we reflect on the Moodbot project and the application of the Vitruvian triad herein.

Keywords

Applied Games, Serious Games, Games for Health, Philosophical framework, Vitruvius, Mental Healthcare.

1 Introduction

Applying games to healthcare has gained much attention in the last decade, with digital games ranging from *exergames* to training games for medical professionals and self-management games for mental healthcare patients (e.g. Wii Sports, ABCDE Sim, Air Medic Sky One, Heartville, Superbetter). Also, the body of research into how to design, develop, and test these games is growing rapidly. In this emerging field, research and design approaches are increasingly multidisciplinary, as combining the expertise of game designers, medical professionals, researchers as well as gaining input from the target audience has proven to be beneficial (e.g. Keetels, 2012; Kato, 2013). However, applied games are generally judged as single instances of technology, lacking connection to a greater context or discourse about applied game design and development. Also, when

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designing an applied game, it can be hard to maintain a balance between the content of an applied game and its gameplay, which can cause one of the two being underemphasized (Van Roessel & Van Mastrigt-Ide, 2011).

We aim to illustrate our approach to applied game design and how it helps achieve our vision and define the framework required for a good applied game. Our approach is inpired by the ancient Roman architect Vitruvius, who identified three main perspectives when designing his buildings: attractiveness, sustainability and utility/purpose. To illustrate the approach, we use the design and development of the game Moodbot as a case study. Moodbot is a game developed in the context of psychological healthcare, and represents an effort to advance our knowledge about applied game design and development within this context. The game is designed and developed to be used in a clinical mental healthcare setting in order to help psychiatric patients communicate more effectively with their healthcare workers.

The main aims of this paper are to explore the added value of using the Vitruvian framework to design an applied game, and to illustrate how it has been used to communicate the vision of what an applied game could and should be. At the core of this framework we have borrowed standpoints from the long tradition of architecture and explored how an ancient Roman architect's precepts towards architecture have formed our perspectives towards applied game design and development. Our exploration into this realm has led us to ask the same questions that challenge modern architecture (DQI, 2006): How do you manage design quality if you cannot measure it?

We use the term *applied game* to indicate games designed with a purpose other than entertainment. While *serious game* is defined similarly, this term is often confused with games designed for educational and training purposes. With the use of the term applied game, we refer to the multitude of games with applied purposes, e.g. training, education, exercise, persuasion, health, human computing, etc. *Application* refers to the tactical use and usefulness of (the knowledge and skills acquired during) the game activity outside the domain of the game itself (Van Roessel & Van Mastrigt-Ide, 2011).

As mentioned above, currently the discourse and knowledge concerning the analysis, communication, design and development of applied games is growing. The general knowledge of applied game design comes from several perspectives and disciplines. There are practical guides that explore technology, game genre and domains of serious games (Bergeron, 2006; Michael, 2006; Harteveld, 2011). There are several sources that advocate the value of applied games (Gee, 2003; Bogost, 2007; McGonigal, 2011). Other publications concern themselves with methods, frameworks, techniques and the processes of applied game development (Laurel, 2003), many of which are based on the musings of a single experience with game design and development (Van der Spek, 2011; Marfisi-Schottman, George, & Tarpin-Bernard, 2010). Other sources are concerned with the effects and validation of applied games (Ritterfeld, Cody, & Vorderer, 2009; Egenfeldt-Nielsen, 2007). Our general perception of applied games is based on the original ideas and thoughts of the pioneers of serious games (Abt, 1970; Duke, 1974). More recent attempts to create frameworks towards a broader and more general approach to understanding applied games are also available (Egenfeldt-Nielsen, 2007; Harteveld, 2011). Harteveld (2011) in particular calls his Triadic Game Design approach a philosophical framework.

A central theme of the current paper is looking at the value of having the Vitruvius philosophical framework when designing an applied (health) game. Having a 'philosophy' fuses bits-and-pieces of thought and knowledge into a unified form of knowledge and offers the observer a way of greater generalisation (Fullerton, 1915). With the help of examples from our current project Moodbot, combined with our extensive experience as applied game designers, we will explore to what extent a philosophical framework towards applied games can contribute to the creation of sustainable applied games. Our philosophy inspired by Vitruvius aims to frame the minds of those involved before developing the game, and during the design process it can be used to evaluate design decisions. Our intention is to provide an accessible framework for anyone who would like to develop a better understanding of applied games, as well as applied game design and development, through the use of this philosophy. More specifically, this paper will: 1) illustrate ways to design and develop applied games, and 2) show how one can use the Vitruvius framework to do this. Even though the Vitruvian framework could also be used to analyse (existing) applied games, the emphasis in this paper is how to use the framework for designing applied games.

To do so, we will first examine the Moodbot case study. Then, we will provide an analysis of the design process of Moodbot based on the Vitruvius framework. Lastly, we will provide general suggestions for how to use the framework in the design and development process of applied games, while examining the different perspectives within the game project consortium.

2 Moodbot

> *"The opposite of play is not work, but depression." - Stuart Brown (Brown & Vaughan, 2009)*

Moodbot is an online multi-player game currently being developed for psychiatric healthcare. The partners developing Moodbot are HKU (University of the Arts

Utrecht), the mental healthcare organisation Altrecht, and back-end developer Ippo.[1]

The Moodbot project was launched following a period of over a year, during which Altrecht and HKU got acquainted and explored each other's strengths and capabilities. Common ground was found during several meetings. Learning to speak each other's language played a major role in this process.

2.1 Aim

The aim of Moodbot is to prevent patients recovering from mental illness, e.g. psychosis, from relapsing. Communication between a patient and his/her healthcare worker about the patient’s mental state is important for the patient’s path towards recovery. Patients do not deteriorate from one moment to the next; this happens gradually. There are various signs that appear beforehand and indicate whether someone is likely to relapse, however, these signs differ per person. The signs can range from someone being easily irritated, or drinking a lot of coffee, to vacuum cleaning. Therefore, all patient’s signs are described in so-called alert schemes, that, when carefully kept track of, can prevent incidents. In current healthcare organisations, the scheme is stored in an electronic medical record and then discussed once a week with the therapist.

The main aim of Moodbot is to change the alert schemes from passive documents tucked away in electronic medical records to a more user friendly interactive tool that enables clients to have a greater say in their treatment and to allow them to monitor their own mood. While the patients share their current mood and status in a cooperative game with their peers (i.e. the other patients in their department), the healthcare professionals can monitor them at a glance through the use of a back-end overview. As a result, patients gain greater control of their lives and recovery process, and they can help each other by giving advice and support. Consequently, the quality of care improves and the healthcare workers' workload is reduced while their job satisfaction is increased.

2.2 Target Group

Altrecht GGZ is a large mental healthcare institute in the province of Utrecht in the Netherlands. Moodbot is developed for patients of two different departments of Altrecht: Roosenburg and ABC. Roosenburg is a closed ward, and specialises in psychiatric and addiction-related behaviour. Roosenburg’s patients have had encounters with the legal system due to their complex problems and aggressive behaviour, which can lead to incidents of violence. ABC is a clinic for young

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1 In the section about Vitruvius and Moodbot, we will go further into the exact roles of these partners.

people who have been diagnosed as having a non-affective psychosis, usually schizophrenia. It offers both an open facility and ambulatory care. Besides the individual medical and psychosocial treatment, patients can participate in various treatment groups such as psycho-education, coping with addiction or multifamily groups.

These two very diverse target groups were chosen with the scalability of the game in mind. If it is possible to cater the game to two different patients groups, this could be beneficial for further scaling to other target groups in a later stage.[2] In the early stages it helps to have specific groups of people who can provide input for the game and play early prototypes, i.e. participate in playtests. Because the game covers the general needs of the healthcare environment later on, Moodbot could potentially be used in other mental healthcare clinics. By having ascertained that the treatments in ABC and Roosenburg are similar enough, and leaving enough freedom in the game for the healthcare workers to adjust it to specific patients, the game manages to cover the general need of the patients and healthcare workers.

2.3 Design Process

Moodbot is developed using an iterative design process. This means we design and develop in cycles and we repeatedly ask healthcare professionals and patients for their input. After having developed and tested various early paper prototypes, we entered the phase of digital prototypes. After each playtest with our target audience, we evaluate the results and consider what should be changed. This is done by exploratory observation of the patients while playing and interviewing them and their caregivers afterwards.[3] Healthcare professionals and patients, both from Roosenburg and ABC, have come up with valuable feedback and suggestions thus far. Prototypes are also tested frequently with the internal design team at HKU. These tests roughly take place once every two weeks, and are less formal than the tests with the target group. The team then specifically tests the kind of behaviour that certain game mechanics bring about, i.e. do the mechanics encourage the right gameplay in terms of communication between players, does it stimulate them to report their moods etcetera.

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2 This is an experiment, and only time will tell whether this assumption holds. For now, designing, developing and testing Moodbot for Roosenburg and ABC is the primary aim.

3 In early playtests, these interviews are very open-ended. Later interviews were semi-structured, as the testers had a clearer view of the kind of input and answers they were looking for.

2.4 Gameplay

Inspired by these tests, the current design of Moodbot is as follows: Every player owns one room (see image 1) in a large spaceship. Players progress in the game by collaboratively making the spaceship move. Players collect action points by performing actions in their own rooms and in other players' rooms. Within his/her own room, a player expresses how (s)he feels that day. A player has three ways to do this, by: 1) adjusting their moodbot (a small robot depicting its mood by facial expression and posture, see image 2), 2) setting a wallpaper or *moodtube,* and 3) setting their dashboard. For the latter, they set up to five sliders that have meanings connected to their personal goals and the above mentioned alert scheme. For instance, the dashboard can indicate their current level of tiredness, fear or aggression (see image 3). These parameters have been defined together with the healthcare professional(s). For the moodtube, the player can choose one or several pictures that reflect their mental status. Players can visit each other's rooms and leave advice or tips if the moodbots suggest a negative feeling. These actions will gain action points, which the player can spend to make the ship go forward.

Fig. 1: Moodbot's room

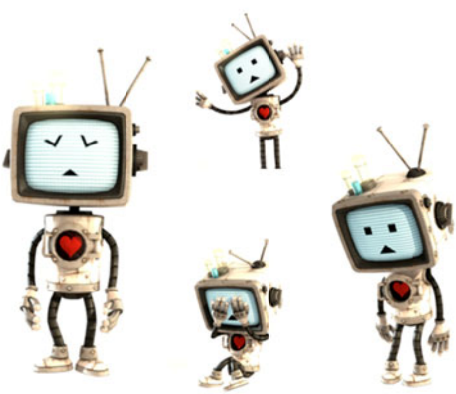

Fig. 2: Moodbot's Avatar

Fig. 3: The Dashboard

2.5 Graphics

The aim of Moodbot's graphical style is to make players feel at ease, and to enable them to communicate their mood by means of their avatar (i.e. moodbot) and rooms. The rooms are open and organic, which should bring about a safe environment in which sharing feelings and thoughts is intuitive.

The airship in which the game is set, is overgrown by a tree, whose branches and leaves reach all the rooms (see image 4). When looking out of the large windows, the players see a light blue sky, which creates a spacious feeling. The main avatar, the Moodbot, represents the player's mood. The moodbot is a robot, but a robot with emotions and other humanlike features. Several facial expressions and postures can be chosen. See also images 1 and 2 for an impression of Moodbot's graphical style.

Fig. 4: The Overall Airship

2.6 Playing Moodbot and its Current State

Considering all of the above: what will using Moodbot be like in practice? The game has been designed for patients to play the game daily, for approximately five to ten minutes a day. They can quickly update their room (moodbot, dashboard, moodtube) and look into their peers' rooms. The game as well as the back-end overview will be developed for both pcs and tablets. This way, the therapist can also take the status overview with him/her while working in the clinic, and the patients that have outpatient care can play the game whilst traveling or at home.

Note that Moodbot is still in development. Currently, a working prototype is finished and ready to be tested at Altrecht. These tests go further than a simple playtest and will investigate how Moodbot works in the mental healthcare setting for a longer period of time. The tests should indicate whether it is useful to further develop the game as it is, or whether design adjustments are necessary. Testing Moodbot will also entail training the trainers: healthcare workers at Altrecht need to become familiar with the game and know how to use it effectively, so that they can explain how to play the game to their patients.

3 Vitruvius

> *"As for philosophy, it makes an architect high-minded and not self-assuming, but rather renders him courteous, just, and honest without avariciousness. This is very important, for no work can be rightly done without honesty and incorruptibility. Let him not be grasping nor have his mind preoccupied with the idea of receiving perquisites, but let him with dignity keep up his position by cherishing a good reputation. These are among the precepts of philosophy." (Vitruvius, 1960)*

Marcus Vitruvius Pollio was a Roman author, architect, and engineer during the 1st century BC and is known for his multi-volume work entitled De Architectura. Leonardo da Vinci´s drawing 'Vitruvian Man' is named accordingly due to the Vitruvian texts that accompany it. The Vitruvian triad *utilitas*, *firmitas*, and *venustas* continues to influence modern architectural assessment tools and methods (Gann, Salter, & Whyte, 2003) and even has been carried over to software architecture (Albin, 2003). According to the Vitruvius's *The Ten Books on Architecture,* an artefact should exhibit the three principles of architecture:

Firmitas (soundness or durability) – is concerned with the foundation of an artefact and its building materials and how these are chosen frugally.

Utilitas (utility or convenience) – is concerned with the proper arrangement of space so that it is correctly oriented, appropriate, and comfortable. The disposition of the space should in no way cause hindrance or impede use.

Venustas (attractiveness or beauty) – is concerned with an artefact's appearance, which should be pleasing and elegant, with proportions according to the correct principles of symmetry.

(Vitruvius, 1960; Vitruvius 1999)

Based on a similar set of starting definitions, our philosophical framework towards applied games repurposes the Vitruvian triad to fit our vision of an applied game. The following definitions have been tailored to applied games: *Utilitas* or purpose, dictates that the game should achieve a predefined purpose in relation to the player or secondary users. *Venustas* or gameplay experience, dictates that the game should provide a meaningful holistic experience (e.g. graphics, sound, game mechanics, challenges, goals, rewards, etc.) for the player. Thus, although one might expect venustas, translated above as attractiveness or beauty, to merely address the visual parts of a game, venustas in the case of games involves more. Games are more than what reaches the eye at first glance; they consist of e.g. mechanics and a rule set, as well as representational elements such as sounds and music. All these factors define whether the game is a pleasant and engaging experience to play. Therefore, the venustas of an applied game is considered gameplay experience. Lastly, *firmitas* or sustainability, means that the game needs to be solidly embedded in the context and dictates that the game be obtainable or available to users, for instance that it has a service or syllabus designed around the game, and that it aims to create a perceivable impact in the chosen domain. In the case of architecture, firmitas includes the solidness of a building, i.e. that the construction is sound. For applied games one could take that very literally: the software of the game should run properly, so that it does not crash. However, next to that, firmitas in the case of games entails more, as we will explain further below.

There are several pitfalls when considering balance and meaning in the Vitruvian triad. In the case of utilitas (purpose) there is the tendency to think that venustas (gameplay experience) needs to be sacrificed to achieve the game's applied goal ("Serious game," 2013). However this defeats the reasoning for having a game in the first place, since gameplay experience is at the core of any game. Referring to Vitruvius here, helps to show that venustas and utilitas should be in balance in one game, and neither should give in to the other.

But utilitas can also overshadow the firmitas (sustainability), as in some cases there is the fallacy of believing that if the applied game achieves its purpose (for instance rehabilitating patients, teaching math, etc.), the job is done. This is not the case, as applied games need to be sustainable. If the game contains technical bugs, is not available to the user, or the game facilitators do not know how to use the game as a tool, utilitas will then be hindered or counteracted.

Venustas on the other hand must not cause the game to lose its purpose and sustainability. For instance, too many preconceived notions of what a 'fun' game is, or basing a game on an existing game genre can cause the game to lose its purpose and/or sustainability.

Lastly, firmitas (sustainability, or soundness or durability) could easily be associated with the quality of software or hardware engineering of an applied game. However when considering video games, software and hardware are so fundamental to the venustas and utilitas that they cannot exist without the technology. Therefore we frame firmitas not only as the technological solidness, but also as thinking beyond the applied game and thinking about the larger 'game' around the game, i.e. the embedding of the game in its context. If the game cannot be embedded (e.g. in the organisation, the game is too hard to find, costs too much, etc.) or if it cannot be used within the context for which it was made (e.g. too long to play, there are technology issues on the hardware that is available, etc.), then the sustainability of the game fails and the game will not achieve an impact on the domain. Thus, firmitas includes both the technical prerequisites for the game to run, and how well the game is embedded in its context, since the latter is of great influence on whether the game is played in the long run, and thereby how sustainable it is.

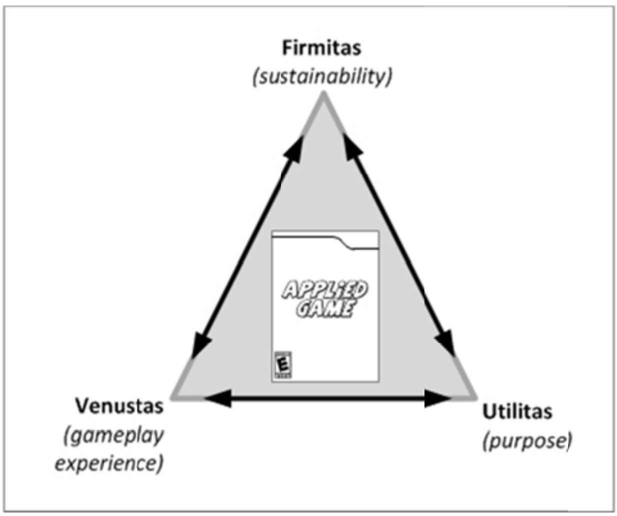

Fig. 5: The Vitruvian Triad in Applied Games

These observations are a result of nine years of experience in applied game design and development, applied game consultancy and applied game education. An important aspect of understanding our approach to the framework is to consider an applied game holistically and not as a piece of software or technology, just as Vitruvius saw architecture holistically.

Besides using our experience to reach our current definitions, they are also influenced by our partners with whom we collaborate in diverse projects, who rely on the framework to judge our performance. The framework provides us with a common language. Lastly, as this paper is the result of an iterative approach, the vision presented in this paper might have been fine-tuned after the moment of writing this.

4 Applying Vitruvius to Moodbot

So, how did we apply Vitruvius within the Moodbot project? First of all, we made sure the three principles were all represented in the consortium that designs and develops Moodbot. Secondly, we made sure the three virtues were in the game. So, we will firstly explain how the composition of the project team relates to Vitruvius, and then we will go into the actual game and how Vitruvius is integrated there.

4.1 Partners involved: utilitas, firmitas and venustas

As explained in the introduction, making applied games is a highly multidisciplinary activity (cf Winn, 2009; Harteveld, 2011; Van Roessel & Van Mastrigt, 2011). The different fields of expertise involved need each other in order to come to a unified whole. Using the Vitruvian triad helps to make this clear: each aspect should be represented by a project partner. The image (6) below shows an overview of the partners involved: Altrecht, IPPO and HKU.[4] The first partner, Altrecht, represents utilitas or purpose. They provide all the input needed to ensure Moodbot will target the right goals in terms of mental healthcare. As a large organisation in the centre of the Netherlands, they know exactly what the contemporary mental healthcare needs are in the Netherlands; They know what patients need but also what their caregivers would want in an applied game. Moreover, they bring the game designers in contact with a target audience to test with.[5]

4 Note however that the scheme is simplified and does not claim the other partners should stop caring about the other aspects of the game.

5 Whether these goals are actually met is tested in a later phase of the project, however in the design process Altrecht provides the right input considering the functionality of the game.

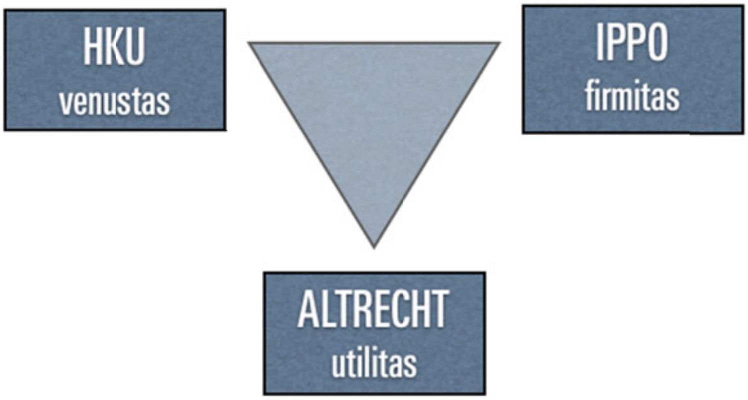

Fig. 6: Partners in the consortium and the virtues they represent (simplified)

The second partner, IPPO, represents the firmitas: they make sure the game runs as it should. In particular, they develop the back-end, which is the structure which Moodbot will eventually be played on and where the data will be stored. This back-end also provides an overview of the players' process over the period that they have played the game. This is shown by graphs and visual overviews of the values the players filled in while playing. For instance, it shows the different facial expressions of the moodbot they have chosen as well as the sliders' values. See images 7 and 8 for examples of the back-end data and the way they are displayed in the current version of Moodbot.

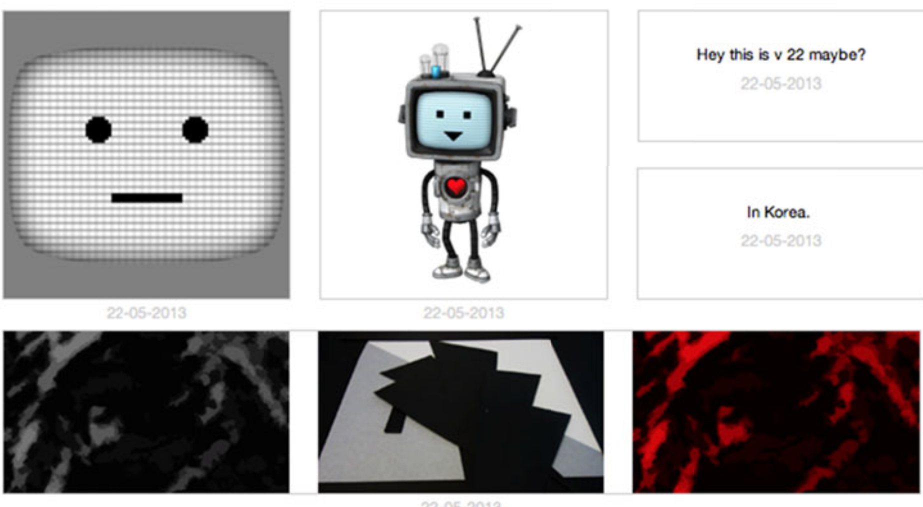

Fig. 7: Example of Back-end Data 1

Fig. 8: Example of Back-end Data 2

However, as explained in the section about Vitruvius, firmitas entails more than just technology: the game should be solid and sustainable on all fronts. Therefore, firmitas is also ensured by the other two partners. As firmitas means both the solidity of the software and how well it is embedded in its context, taking care of firmitas is split up over the three partners. Together, the partners take care of how well the game suits the healthcare institute's daily practice. This was firstly taken into account during the design of Moodbot by HKU. By analyzing the daily practice of healthcare workers and patients, and considering these findings when making design decisions, the game is developed to fit its context. Also, after the game has been developed, it is important to inform all the people that will use or encounter Moodbot thoroughly about the aims and envisioned use of the game. Training the healthcare professionals is a major part of that. The latter is done by both Altrecht and HKU.

Thirdly, venustas, or gameplay experience, is represented by the third partner, HKU. The designers and artists working at HKU's research program Games & Interaction are specialized in making games. This means, they make sure Moodbot has both an engaging and balanced gameplay and has attractive visuals and audio. HKU is also the partner that keeps an overview of the project. As the partner keeping the overview, they make sure all Vitruvian dimensions are represented in the way they should. Splitting up the partners and 'giving' them all their own dimension to take care of is not enough; without someone keeping an eye on the greater whole, the dimensions would not be in balance. In that case, the game would consist of three separate parts, while the way the come together is the crucial part.[6]

6 One can however choose to emphasize one or two dimensions when a prototype, proof of concept or other early version of the game is developed. We will go into this in the last section.

4.2 Utilitas in Moodbot

As indicated above, Altrecht is the partner primarily concerned with Moodbot's utilitas, or purpose. This is not to say that the other partners are not at all concerned with utilitas. In order for HKU to be able to process Altrech'ts input on the utilitas front into the game design, game designers needed time to familiarize themselves with the daily practice of mental healthcare, especially within the two departments Moodbot is developed for: Roosenburg and ABC.

Likewise, in order to formulate their aims in terms of gameplay, the healthcare workers and project managers at Altrecht have gained more knowledge about (applied) game design.

This is also the case for IPPO: to develop the back-end system, in which the healthcare professional will find all the useful information, an in-depth knowledge of the other partners' field was necessary. This was accomplished by several meetings, in which Altrecht explained their way of working, and gave an overview of which data would be the most important to get out of the system.

Currently, the utilitas in Moodbot consists of improving the communication between healthcare worker and patients, increasing self-management of the patient and enhancing the peer-to-peer communication, so that patients can help each other in their recovery process. The utilitas is implemented and assured roughly in two ways. Firstly, the daily practice of mental healthcare professionals was analysed in terms of: what are the current issues and challenges that could possibly be improved by a game? Questions asked here included: What does the game need to do? What should change as a result the game of being used? How is the current issue being or not being approached? Who will use the game as a tool?

On the basis of that analysis, several concrete goals, such as the aim that Moodbot should reduce recovery time and increase adherence to medicine, were set. For the full list, see table 1. These goals help to define later whether Moodbot has actually fulfilled its goals and thus whether the utilitas in Moodbot is sufficiently represented.

Table 1: Aims of Moodbot (note that these are aims on heterogeneous levels)

Patient recovers faster
Scalable to more target groups
Increase in patient's awareness of the recovery process
More patients can be treated in the same time-span
Reduced expenses
The game encourages autonomy
Higher adherence to medicine
Innovative

Secondly, utilitas is important when conducting the playtests with early versions of Moodbot. In the first, more explorative playtests, patients could give input on the desired utilitas (also on the front of venustas, but we will address this in the next section). Later on, they could more concretely state whether they would think certain features would work for them. They could indicate whether they like the features and whether they see themselves using them on a daily basis.

For instance, patients being able to give each other real world challenges, tailored to their recovery plan (e.g. going to the grocery store or drinking less coffee), was indicated by several play-testers as a feature that would support their recovery process. The designers decided to build such a feature in the game. Immediately, the healthcare professionals pointed at a number of requirements for that, such as the need for the patient to pick his/her own 'referees', who have to define whether the given task was accomplished. Thus, a constant interplay between patients, healthcare workers and game designers is necessary to implement and secure the utilitas.

Finally, in the tests that will take place after the first playable prototype has been developed, the utilitas of Moodbot will be more extensively tested, alongside its firmitas.

4.3 Firmitas in Moodbot

Firmitas, as we stated above, in the case of applied games is interpreted broader than just whether the game technically works; it has to do with sustainability. For instance, firmitas also means whether the game works on the *client's* technology. Healthcare institutions do not always have the newest hardware - or internet browsers - at their disposal, thus taking into account the system requirements of their pcs is necessary for firmitas. But firmitas also means whether the end users of the game (in Moodbot's case both the patients and their healthcare workers) know how to most effectively use the game in their daily practice. They should know its various possibilities and limitations. Firmitas also entails how well the game suits the schedule of the target group, e.g. when do they play and for how long? All these things form the sustainability or solidity of the game, i.e. its firmitas.

In Moodbot's case these contextual requirements also come out of the playtests and are defined based on interviews with Altrecht employers at the start of the project. For instance, the healthcare professionals indicated the game should be played briefly every day to obtain the right data from it. The gameplay should thus be interesting enough to play it every day, however it should not be encouraged to play longer than fifteen minutes a day, as that would collide with the patients' other activities (or worse: prevent the patients from doing other recovery oriented activities). Next to that, Moodbot should run on pcs as well as tablets so that patients can use the pcs available inside the institutions, but ambulant patients can also play while on the move. Providing the game online makes sure it is accessible from different devices and it need not be installed. Moreover, the caregivers can access the relevant data directly, also from another location.

Although all these factors of firmitas are taken into account during the design process, the real test of firmitas takes place when the first prototype of Moodbot is tested on a larger scale - and without the help of HKU and IPPO. Only then it will become clear whether the current game's firmitas meets its goals. Thus, questions asked include: Does the game run properly? Can caregivers and patients work and play with it in a meaningful way? Is the game embedded in their daily routine? Is the game available or promoted so that the domain is aware of its existence? What is the business model around the game?

4.4 Venustas in Moodbot

Venustas in applied games is all about making a good game, with an engaging gameplay experience. Balancing utilitas and venustas is not an easy endeavour, however. Applied game designers themselves indicate it is often a 'tug of war' between the purpose and the gameplay (Van Roessel & Van Mastrigt 2011). Yet, a good applied games has the two balanced, so that the motivational aspects of a good game stay intact and thereby help the player reach his/her goals.

Venustas, the virtue that makes for a good game, thus includes gameplay (rules, mechanics, goals, actions) as well as representational elements (graphics and sounds). In Moodbot, venustas has garnered much attention. As stated above, in the domain of applied or serious games, venustas is sometimes neglected. This can result in games that might reach their purpose as a functional tool, but do not leverage the added value of games. In other words, they do not motivate players to play them for another reason than their personal motivation to reach the goal, or its utilitas.

One of the aims of Moodbot is to show that applied games can have the same attraction as entertainment games. Therefore, venustas is high on the agenda. The design team at HKU consists of two game designers, one artist (supported by several art interns), a sound designer (also supported by interns) and two programmers, who together work on Moodbot's venustas - while still taking into account firmitas and utilitas.

Two major venustas elements are gameplay and art, the latter including graphics as well as sounds. With regard to gameplay, the designers draw from years of experience of both designing applied and merely entertainment games. Questions asked when designing the venustas include: What verb (game activity) could be central to the game? What could the goal of the game be? What would keep players playing the game? What kind of gameplay experience should the player take away from the game? How do the representational elements (visuals, story, music, sound, etc.) support the gameplay?

The designers start with the aimed utilitas, translate this into the behaviour that a player should display and then design gameplay that could encourage this desired behaviour, but still is interesting and engaging gameplay. However, since designing games is an iterative process, the gameplay is adjusted constantly based on playtest results and feedback from the other partners, especially Altrecht. How the target group responds to certain mechanics and rules can never be fully predicted, therefore testing and getting feedback from other partners is crucial.

For instance, the ultimate in-game goal is to make the giant airship move forward and to steer it in the right direction so that the players can explore new areas. The players can only reach this goal by collaborating and spending their dust bunnies well (the dust bunnies are in turn collected through actions like sharing a mood or filling out the dashboard). During the playtests, collaboration was identified as a motivating goal; patients liked to give each other advice and have a common goal to reach in the game. Also, according to the healthcare professionals, having patients being in an online community would be beneficial to promoting the idea of self-help in mental healthcare, and support goals such as faster recovery, patient autonomy, and better adherence to medicine. However, initially, the designers had chosen to have two teams play against each other, i.e. the gameplay contained collaboration as well as competition. The fastest of the two airships would win. Playtests indicated that this feature did not appeal to the target audience. They were not willing to compete against each other by any means, as recovering at Altrecht felt like a joint effort. A competitive element in the game - even when represented in terms of two teams and no individual competition - was against their intuition. Therefore, collaboration became the main rationale in the game to earn points.

With regard to the representational parts of venustas, the process is similar. Firstly, the artist and sound designer together with the game designers came up with a general theme of the game. As mentioned in the Moodbot section, the theme of the game is centred around a huge mechanical fish-shaped airship, which is overgrown by a giant tree. The bots own their own room in this ship. The somewhat mysterious atmosphere - not much is made explicit e.g. about why these moodbots inhabit the ship and why it is shaped like a fish - was, amongst other things, inspired by the animation films produced by the Japanese Studio Ghibli, but also by antique steam machines. After having first sketches and a preliminary art style in the prototype of the game, the playtesters could comment on it. Similarly as in case of the gameplay, the target audience gave specific input about the art style that has influenced Moodbot's venustas. The first style that was chosen, contained too little light and too many small rooms. Some playtesters indicated they felt claustrophobic, and it even reminded them of solitary confinement. After that, the art style was changed; rooms became more spacious, the player can now see lots of blue sky from the Moodbot's room and more organic elements were added (see also figure 1).

Obviously, regarding venustas, the interplay between gameplay and representational elements is highly important. In order to have a good game experience, these two should be balanced. The actions performed in the game should make sense in the fictional game world. In the case of Moodbot, part of the game consists of finding out the reasons for your in-game actions, thereby unravelling the mystery of the world. At the same time, there is the social element.

Moreover, the usability of the interface elements are part of venustas. The functions of the buttons should be clear and the number of clicks to perform should be reduced to a minimum.[7] If the interface is not intuitive, it hinders the rest of the gameplay experience, and ultimately also the utilitas. Considering these interface elements, play-testers also gave useful feedback, and optimizing this is an on-going process.

5 The Use of Vitruvius for Applied Games

Now that we have seen how the Vitruvian triad is represented in the current version of Moodbot - and how utilitas, firmitas and venustas play a part in the design process - we will show possible advantages of having a Vitruvian approach to designing applied games in general. We address three of these moments: 1) evaluation and testing, 2) acquisition and 3) defining project goals.

5.1 Evaluation and Testing

When evaluating applied games, the Vitruvian triad can be useful to pinpoint what is strong or weak about a particular game. As mentioned above, some games might have utilitas and venustas that are balanced, however the firmitas is lacking. Or the utilitas and firmitas are perfect, however the game experience is not as it should be. Vitruvius provides a vocabulary to easily name this. Thus, this framework acts a translation tool from game design experts to other people in the consortium, such as domain experts and clients.

One can also validate games on different fronts. Just testing how much 'fun' a game is, without measuring effects, can be a way to test solely the venustas. If one only measures whether a game has the outcomes that were aimed for, this would be a utilitas test. Lastly, when (a version of) the game is tested in its context over a longer time, the game is tested in terms of its firmitas. The three terms help formulating the focus of a test.

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7 Unless it is part of the gameplay to make it harder, as goes for catching the dust bunnies. Here you need some dexterity to catch the flying bunnies and collect the points.

5.2 Acquisition

Applied games are still a relatively young field. As an applied game developer, it can be hard to convince clients that it is worth their investment (EGG, 2011). Presenting the Vitruvian triad and thereby providing an analogy to a more familiar phenomenon like architecture, can help clients to better grasp what an applied game can do. Moreover, development costs are sometimes higher than a client expects, since there is currently a lack of common knowledge in this area (Van Roessel & Van Mastrigt, 2011). Therefore, Vitruvius can be used to explain which elements can be combined to obtain a (good) applied game. The Vitruvian triad can show that just investing in one of the three pillars will not yield a successful game.

Also, as the Moodbot example shows, for the utilitas, Altrecht's input as a subject matter expert is needed. The role of the utilitas representative clarifies that an applied game client - or another kind of initiator from the utilitas side - does not simply give an assignment and obtains a result a few months later. The role requires an active involvement in the project, as otherwise one of the three pillars is lacking, and the game will not be balanced.

However, not only for convincing a client, but also for gaining funding for a project, Vitruvius can come in handy.

5.3 Defining Project Goals

Many applied game projects - especially in healthcare - are pilot projects that should show the potential of applied games rather than become a commercially viable product. Their main aim is research and exploration of the field, which eventually should lead to a larger knowledge base about how to design, develop and implement applied games. In such projects, common terms are prototype, proof of concept, or vertical slice. These terms are quite loosely defined and therefore it can remain vague what parts of the game will be and what parts will *not* be developed. Vitruvius can help here. One can define beforehand where the emphasis of the design and development will be. For instance, within Moodbot, the initial emphasis was on venustas and utilitas. Firmitas only came into play later. This is also related to the tests mentioned above; identifying what to look for is easier once you know where the emphasis lies.

6 Conclusion

> *"Games are not fun because they're games, but when they are well-designed." – Sebastian Deterding (2010)*

Through this paper we have demonstrated there can be a greater value of having a manner in which to frame the qualities of an applied game. In the current era of technology and games, where games are called upon to solve real-world problems, it is necessary to consider what these artefacts consist of. Especially during the design process, it is useful to keep in mind the fine balance that (good) applied games have to maintain. Having a philosophical framework can help us describe what we value in an applied game, and it can help in terms of communicating with consortium members about it. As we have shown, Vitruvius was used for designing Moodbot. The triad has proven useful for locating the right project partners and defining their roles and responsibilities, as many applied game clients are still unaware of what they may expect from an applied game.

Moreover, when creating a game that is not fully finished or polished, the framework can serve to map which qualities will be emphasized in the prototype or first version of the game. In Moodbot, venustas - as an often neglected part of applied or serious games - plays a major part. Furthermore, Vitruvius has helped us with conducting the playtests. Here we could distinguish which quality we would (mainly) test, as well as pinpointing other unexpectedly emerging issues in terms of regarding the venustas, utilitas or firmitas.

Perhaps a philosophical framework seems a rather high-level and abstract way to approach applied game design and development. Possibly, one could think of other - more game specific or contemporary - terms to design applied games with. However, borrowing from a long design tradition like architecture - where purpose, aesthetics and solidity have ever gone hand-in-hand - strengthens the understanding of design in general and prevents us from reinventing the wheel. In other words, it lets us stand on shoulders of older and more established design disciplines. Moreover, in comparison to entertainment game design, applied game design is closer to other design disciplines, such as architecture and industrial design, since applied game design is by nature more purpose and context driven. Therefore, it makes more sense to be inspired by theories from these other design disciplines - in this case architecture.

Also, from the view of healthcare it is important to understand the possibilities as well as the hurdles and challenges of applied games. Healthcare workers need to be educated on at least a basic level about applied games and their qualities, in order to enable them to 'co-create' a game that is useful to them. Healthcare professionals need to understand that they can be and have to be critical in the early stages of the game design, because this is the moment that they can contribute to the game by securing its utilitas. It is also important to manage expectations on the side of healthcare workers involved. The purpose of an applied game for healthcare is to develop a game for patients that is not only fun to play but also - in the case of Moodbot - triggers motivation to work on their own mental well-being and is well embedded in the organisation.

7 Discussion

As we have experienced, translating Vitruvius to the context of games requires interpretation, which is not a merely objective and straightforward task. Therefore, making well-argued choices and making these explicit is crucial in order to effectively use the framework. Thus, our translation of the Vitruvian triad to applied games is not the only possible one. We need to iterate further on this way of working - e.g. in future projects - and fine-tune the approach. The findings in this paper are based on reflections on the current project - which in turn was inspired by reflections on earlier projects. However, an important next step is to evaluate the overall project when it is finished. In other words, when the upcoming tests with Moodbot in a clinical setting have been conducted, we can evaluate the whole project in terms of the Vitruvian framework and its benefits or drawbacks, also making sure to take into account the different perspectives in the project consortium. Then, in future projects, we can work with a further fine-tuned version of the framework.

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‘What Remains?’: A Persuasive Story Telling Game

Alessia Cadamuro and Valentijn Visch

Abstract

“What Remains?” is a prototype that facilitates the intake of Alzheimer’s disease suffering patients in care homes. The prototype evokes storytelling of the patient using pictorial game-elements and is based on co-creation principles involving the patient, the patient’s family-members, and a caregiver. “What Remains” consists of three interactive consecutive phases. In the first phase, family members of the patient collect pictures which are expected to be of importance for the patient. During the second phase the patient configures and connects the pictures while telling stories about them. In the third phase, the stories are used by the caregiver to enhance understanding about patient’s behavior and to personalize care giving. Additionally, the stories are used by the family members of the patient for remembrance purposes. The present paper describes the “What Remains” prototype, its design process and its evaluation from the perspective of the Persuasive Game Design model.

1 Introduction

‘What remains?’ is a design research project within the CRISP G-Motiv project that investigates how to change human behaviour by designing game elements. In *‘What remains?’* the challenge was to playfully persuade patients suffering from Alzheimer’s disease (AD) to tell stories of the lives that could be used to facilitate the care home intake procedure and to personalize caregiving.

The context of the project consisted of nursing homes for older people, which was for this project represented by nursing home Careyn in Brielle, the Netherlands. Older people typically enter these homes when they cannot live independently any longer. Often this home will be their last. Many of the older people that enter nursing homes suffer from AD, which often is the cause for the impossibility of independent living. AD is a brain disease that is positively correlated with age (Brookmeyer, Gray, & Kawas, 1998). Since aging is expected to rise globally over the coming years, the number of people suffering from AD will rise as well. AD is the most common form of dementia, and is characterized as an incurable brain disease that is progressive over time. Symptoms of AD include cognitive impairment, of which memory loss is the most notable, as well as behavioral impairment (e.g. being unable to perform functional daily life activities or, in a severe stage of AD, being unable to move or eat at all). AD impairs communication

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abilities of the patient with regard to object naming, discourse-coherence or -production (Egan, Berube, Racine, Leonard, & Rochon, 2010).

The difficulties in verbal communication between AD suffering patients and care givers affect the mental burden of the caregivers (Savundranayagam, Hummert, & Montgomery, 2005), and problematizes the care giving process as a whole (e.g. "They [the patients, red.] are unable to follow even simple directions"; "It's difficult to get them [the patients, red.] to the tub room … you have to lie" (quotes from caregivers of AD suffering patients by Richter, Roberto, & Bottenberg (1995)).

After several interviews with Marja Dijkwel, manager at Careyn, it was clear that memories play a very important role in the life of the patients living in care home. Mrs. Dijkwel experienced from observation that elderly with Dementia spend most of their life inside their own memories, completely disconnected from the present and everything around them.The sharp contrast between the patient experienced real world of the care center and the recalled fragmented memories of the patients generates very often negative emotions that can provoke feelings of anxiety, fear, aggressiveness in the mind of the elderly .From several observations at Carey Care Home it was clear that negative emotions can deeply influence the behaviours of AD's patients and that, for this reason, caretakers and relatives have many difficulties in finding a suitable communication channel with them.

Moreover, communication between the caregivers and the patients is not only problematized by the impaired communicative skills of the patients but also by the lack of available personal patient information when the patient enters the nursing home. Our pre-study interviews with caretakers revealed that they observe the patients for six weeks after their entrance in the nursing home entrance to write a digital dossier about the patient. After this observation part, the caretakers need an average time of about six months of patient contact in order to get to *'know'* a patient, to *understand* his/her behavior and to align their *communication* with the patient. We expect that when personal patient information (e.g. family, work, important life events, hobbies, etc.) is provided to the caretaker early during the intake process, the communication between patient and caregiver will be improved resulting in better care (understating of patient actions and optimizing communication) and in less burden on the part of the caregiver. In this paper, we'll present a co-creative (Sanders, 2000) user centered prototype that provides this personal information to the caretaker by persuading the patients to tell stories about their lives.

For the design process we rely on the Persuasive Game Design model (Visch, Vegt, Anderiesen, & vanderKooij, 2013). This model is constructed around the experience of the user, i.e. the older person suffering AD. This person has a socalled real world experience consisting of communication impairment during contact with the caregivers. By gamification of the communication through the application of motivational game elements, we aim to let the elderly experience a game world that is *enjoyable, engaging, safe, free, and provides direct feedback*, which motivates the patient for storytelling about his/ her life. We aim to realize transfer effects by applying the told stories in the 'real-world' care giving process – see Figure 1.

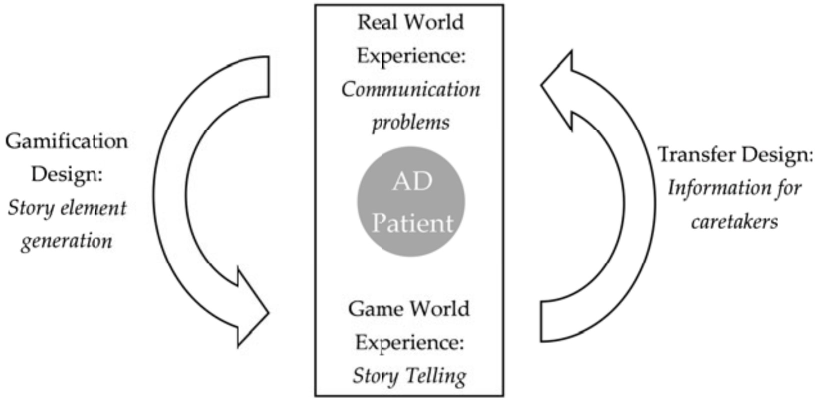

Figure 1: Application of the Persuasive Game Design model on the "What Remains?" case.

2 Design process: Workshops

For the "What Remains?" project we collaborated intensely with nursing home Careyn, design agency Monobanda, Design Academy Eindhoven, and the Industrial Design dept. of the Technical University Delft. The collaboration consisted in a series of in-depth interviews and co-creative workshops involving designers, patients, patient's relatives, and caregivers. A total of ten workshops involving five diagnosed severe AD patients, four caretakers ,the manager of Careyn and fourteen families members, were organized during the morning since the elderly were more calm and active during that time of the day. During the workshops we realized how sensible the patients were to their social environment, especially to the moods and behaviors of people who surrounded and approached them. In order to create a pleasant and comfortable atmosphere during the workshops, the number of participants was limited to the following four: one elderly with severe AD, one of the elderly's relative, a designer (the first author), and a caretaker. Every workshop started with a cup of coffee, soft delicate tone of voice and smiles, after which we slowly started the workshops. The workshops were structured as follows: in the first workshop we investigated probes for storytelling. In the second and third one, the family members of the patient collected pictures from private photo albums and from the internet that were expected to be of importance for the patients. Over the next five workshops, the pictures were printed and presented to the patient to test their motivational effect on storytelling. Participation of the elderly's family members in the workshops was crucial for the understanding of the stories based on the images combined by the elderly. In the last two workshops, the final design of the story telling game was discussed. At the beginning the workshops lasted for twenty minutes, whereas the last ones lasted almost one and half hours due to the constant growing engagement of the various patients.

Figure 2: Left: Impression of one of our participating patients configuring story elements. Middle/Right: two pictures that were used during the evaluation.

3 'What remains?' – prototype and evaluation

The prototype is a mixed-media gameful storytelling tool that involves the following three interactive and consecutive phases: (1) a computer application for generating story elements, (2) a physical table game for connecting these elements into stories and (3) a diary that captures the stories and will be used by the caretakers and relatives.

1. For the computer application, relatives of the patient were asked to collect pictures that relate to the life of the patient. 'What remains?' proposes the following pictorial categories that may be extended by the relative: *family, jobs, hobbies, pets, favorite food, religion, things they did not like to do, things they do like, holidays, memories*. In addition to the relatives, the caretakers are invited as well to collect pictures, for instance regarding objects which are frequently mentioned by the patient or which seem to provoke restlessness to their patients during the day. The software "Mindset", a digital mind-map and brainstorming application developed by Monobanda, was used to upload the pictures. All uploaded pictures are accessible by the relatives as well as by the caretakers.

2. A selection of 20 pictures is made by the relatives and the caretaker. These pictures are printed in a round shape and inserted into tangible spherical objects with a diameter of about 8 cm. The spherical objects increase attention to the pictures by enhancing their visibility and 'liveliness'. They are made of a

transparent plastic/glass material and contain a slot to insert the picture – see Figure 3. In addition to these 20, a picture of the patient is inserted into a slightly larger round transparent object. All objects, 20 pictures plus patient, will be placed on a table in front of the patient and they serve as the motivational game-element for storytelling. The images in this context becomes the game elements that motivate communication. The patient will move, group and connect these pictorial elements and this interaction motivates them to tell the stories that connect the pictures. The caretaker might prompt the patient for storytelling by asking for the reasons of the made pictorial configuration. "What Remains?" allows a high level of control to players but the stories and outcomes are unpredictable and a little bit out of control. This triggers elderly relatives and caretakers in understanding AD patients thoughts and autobiographical stories buried in the patients minds.

3. The story telling sessions are captured by the caretakers and relatives in a diary: a small booklet that is provided by the prototype. The caretakers can analyze the diary afterwards to personalize the caregiving process and diary will serve as a remembrance for the relatives of the patient.

Figure 3a: What Remains? Table game prototype.

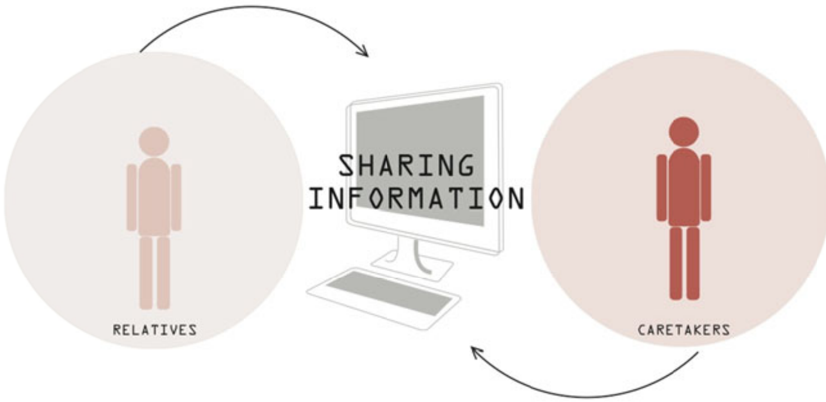

Figure 3b: Info-graphics computer application

4 What remains?' – evaluation

During our evaluation of "What Remains?" the elderly combined the same pictures over and over again. At the beginning it was difficult to understand the intimate meaning of their choices, however with the help of their families it has been possible to translate the images into real stories. The evaluation resulted in several stories.

In order to explane the value of the prototypes we present the following two stories – see Figure 2 for related pictures.

A lady affected from a severe stage of AD was restless because she was looking for a second pair of shoes that she did not have. It was very difficult for the caretakers to understand the reason behind her behavior. During a few story telling sessions the lady was combining the picture of a pair of shoes and the pictures of her father. After several days, and by the help of her sister, we finally understood that her father bought two pair of shoes for all of his children. One pair was supposed to be used during the weekdays and the other one was for Sundays and special events. Knowing this story the lady's son bought a nice new pair of shoes and placed them next to the bed of the lady. From that moment the lady stopped her nervous searching behavior and started to become calmer.

Another patient suffering from a severe stage of AD combined the picture of a guitar together with a picture of her family and a picture of her home. She was often trying to explain something about this combination but could not find a way to express her thoughts. After several story telling attempts it was possible to understand that she was trying to inform us that she did not play the guitar, but the ukulele and she was used to play it together with her family when she was a kid. With this important information the nursing *home provided a radio to the patient, that could play a playlist of Ukulele based songs at request.*

5 Conclusion

'What Remains?' shows that persuasive game design can be successfully applied to motivate people suffering from AD for storytelling which can be effectively used to increase caregiving. The used pictures represent important elements/ events of the patient's life as a kind of personal pictorial 'alphabet' for storytelling. By presenting the pictures to the patient, the patient will enter the world of memory and is able 'play' with the pictures as story elements in a Cailliosian paidiatic sense: the magnifying glass represent the pictures in a slightly hallucinating perceptual manner contrasting from the actual perceptions of the care clinic and motivating the patient to enter their world of memory. Moreover, the tangible objects containing the pictures motivate the patient to connect the pictures matching memories of life events (that can even be understood as being narrative in structure c.f. Bruner, 1991). Both design features of the 'What Remains' objects, the perceptual story world-representing magnifying glass and the tangible story connecting elements are expected to cause the found motivation of the patients to tell and share stories of their lives during the gameplay.

The co-creation aspects of 'What remains' is expected to improve the patient's self-efficacy since the patient has the leading role during the interaction: only the patient can make the correct configurations and explain them. Additionally, for the family members of the patient the processes of picture selection and story generation creates a new channel of communication with their relatives, generating a deeper involvement within the nursing home's life and caretaking process. This game is a ultimately a shared activity, designed to stimulate a physical and emotional closeness between elderly with AD, their relatives, and the caretakers.

Our evaluation showed that storytelling led to adaptation of caregiving (providing extra shoes and a radio decreased patient's restlessness) leading to a more personalized care approach. During the early stage of the project the caretakers already indicated the use of personalized care as "the best approach that Careyn was aiming at", since this enhances the patient's quality of life even in the last stage of Alzheimer. However, in order to personalize the care, the caregivers need to have personal information about the patient. "What Remains?" offers this information. Summarized, the transfer effect of 'What Remains' consists of tailored caregiving, increased social relatedness between patient, family members and caretaker and eventually increased self-efficacy.

In the present research we only tested the potential of these transfer effects which was successfully. A large scale evaluation study, involving more patients and different care homes institutions should be carried out to validate the transfer effects and the precise motivational effects of the used game-elements. We think that “What remains?” has generic applicability in that it is not limited to be used in the intake process of AD suffering patients but it can be used in any context in which shared personal information is at stake. For instance, “What remains?” may be beneficial for intake of patients suffering from anxiety disorders or trauma’s, but it might as well be successfully used to persuade children or adults with communication impairments such as aphasia to tell stories.

6 Acknowledgements:

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Professional Education

Serious game based on Clinical cases: A multidisciplinary Approach for Self-assessment in Dental Education

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Abstract

Serious games have taken up an important place in the field of health. The aim of this work was to design and to develop a serious game for students in Dental Education.

The interest is to perform a multidisciplinary approach of patients. Several clinical cases are available online and each of them concerns patients treated by students in Dental Hospitals. After choosing the e-patient, the serious gamer progresses in the game step by step. The game-play simulates the similar methodology as a dental practitioner in clinical reality. E-learners have to make a diagnosis in a limited time. Finally, the goal is to treat the e-patient deciding the ideal treatment plan.

The collaborative network between students and teacher(s) achieves an interactive learning and improves the quality of undergraduate Dental Education. The perspective is to promulgate dental education and to train young practitioners giving better dental care to patients after dental studies.

Keywords

serious game, dental education, self-assessment, clinical case reports, multi-disciplinary approach.

1 Objectives

1.1 Context

The evolution of numeric technologies is a true revolution in health professions, particularly in oral health care. Besides, learning-play and role-play games are recognized as an efficient teaching method [1]. For years, video games have invaded our daily life and serious games have taken place in all the fields [2], and especially in Health Education [3].

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Nowadays, Internet is everywhere and can no longer be ignored in Dental Education [4-5]. Indeed, prosthesis e-learning is possible thanks to web-campus pre-clinical and clinical assisting teaching (fig.1).

Fig. 1: Pre-clinical and clinical Dental Education in (a) Faculty of Odontoly with simulator and (b) Dental Hospital with patient.

Our experience shows that blended learning is better than singular learning whatever the student's level [6-7]. The online and remote learning increase self-training, self-assessment, and knowledge acquisition [8]. The concept is based on pedagogic learning paths in dental virtual courses [9]. Information and Communication Technologies (ICT) are used as word documents, PowerPoint files, photos, images in 3D, videos, recorded audio tapes, podcasts, and rich media (fig.2).

Fig. 2: Online-learning in Odontology – Virtual course of Fixed Prosthesis in undergraduate Dental Education [7].

The final goal is to develop the e-pedagogy integrating dental serious games in virtual courses [10].

1.2 Motivation

To date, serious health games have taken up an important place in oral medicine [1] and in dental training [5-9-10].

Accorting to this pedagogical dynamic, the motivation is to develop a multidisciplinary approach of the patient, to perform prosthesis assessment, and to show the interest of a global treatment plan in Dental Education (fig.3).

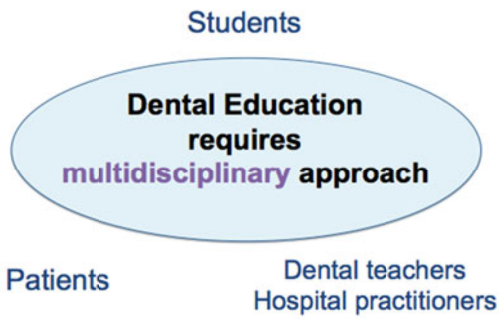

Fig. 3: Multidisciplinary approach of patients by students and hospital practitioners in Dental Education.

The perspective is to promulgate Dental Education based on simulation taking into account the ethical imperatives when a treatment is proposed to the patient [11].

To perform an interactive work, each clinical case of this serious game was treated by dental students in the Polyclinic Department (Dental Hospital in Reims).

2 Serious game design and development

2.1 Initial list of functionalities

From a functional point of view, the main idea is to allow the player (student and future practitioners) to examine and solve many cases in successive manners. For each case, the player will have to follow the classical path of a case study [12], i.e.:

- make the diagnosis (questioning of the patient, examination, etc.),
- achieve a prognosis,
- finalyse a treatment plan.

As far as the diagnosis is concerned the game will have to take into account the variety of information one can collect during the diagnosis: text answers to practitioner's questions, pictures, sounds, radiographs, videos, text documents. Furthermore, diagnosis and therapeutic choices are totally determined by the serious gamer. The e-learner evolves in the game step by step thanks to various questions to validate acquisition of scientific data and clinical knowledge.

A web page displays the player's progression along the different cases that have to be studied. Another important functionality is related to the edition of new cases or the updating of old ones. This task has to be as user-friendliest as possible, for domain experts may not have strong IT skills.

From a technical point of view, in order to assure a broad use, game and editor should be web-based. Moreover, in order to achieve multiplatform use (laptops, tablets, smartphones) the technology should be HTML5.

Consolidated budget is here limited to a few thousands euros.

2.2 Data model

The picture below depicts the data structure of the game engine (fig.4).

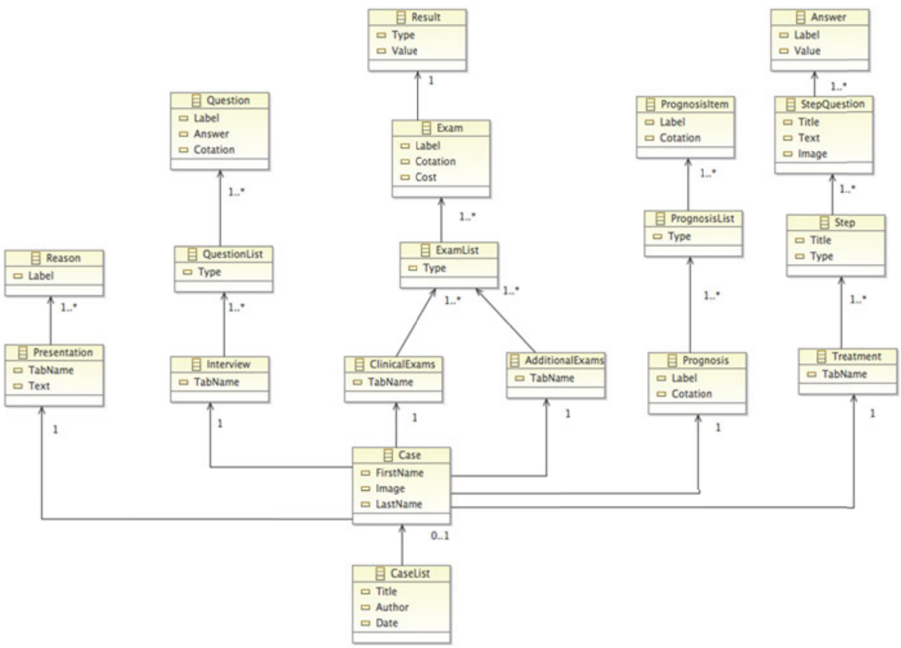

Fig. 4: Data model of this serious game.

Here, is a brief description of the model:

- an exercise is a set of cases,
- a case is related to a given patient (information, pictures, etc.) and contains several parts.

A multidisciplinary approach is necessary for each treated patient. Besides, the serious game is composed by 5 parts related clinical approach (fig.5).

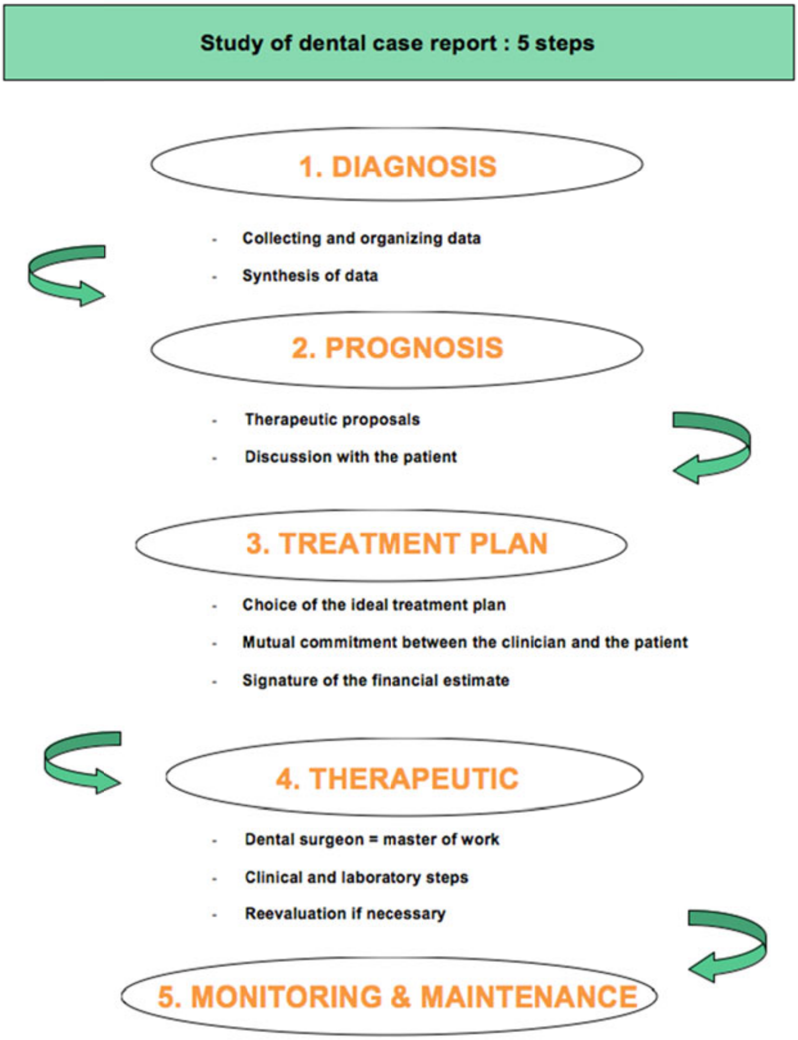

Fig. 5: The 5 steps to manage patient for a prosthetic oral rehabilitation.

Each part is composed with different points that are clinical actions (tabl.1). The gamer has to realize a diagnosis to finally decide a treatment plan for each clinical case. The aim is to choose the ideal treatment plan. Nevertheless, the therapeutic that is presented is not necessarily the only possible one because of the patient's decision in clinical practice.

Table 1: Game-play of this serious game.

Part	Title	Description	Contents
1	Patient's request	Information related to the questioning of patient: it lists several categories of possible questions that the practitioner could choose to raise	A question is described by a text, an answer and a value that reflects the pertinence of the question
2	Anamnesis	Presentation of clinical case report	A sentence said by a patient and a list of items that characterize the case more formally
3	Diagnosis - Clinical exams - Radiographic exams - Other exams	Several categories of possible exams that the practitioner could choose to perform the best treatment plan.Clinical and X-ray exams have to be realized. Complementary exams could be perform or not by the practitioner taking into account each clinical case report.	An exam is described by a title, a value that reflects the pertinence of the exam, a cost and a ressource that is going to be made available to the player if the case arises.
4	Prognosis and therapeutic proposals	For a given case, the treatment is not unique and depends on many factors (like experience, context...).	List a set of possible prognosis that the player has to select and order with respect to pertinency.
5	Treatment plan and clinical results	Devoted to the clinical treatment that was realized on the patient.	The treatment chosen by the expert is here a list of steps, each step being the occasion to ask several questions to the player. Multimedia supports all clinical steps (figures, pictures, schema, photos, videos, podcasts, courses pdf, website, etc.)

Fig. 6: Homepage of serious game online.

Different buttons of actions are proposed in each part:

- part 1: no interaction is required from the player (presentation of the clinical case)
- part 2: the player has to select among the various questions the ones that are at most pertinent, i.e. penalties come with the selection of less or non-pertinent questions and time is lost. From a pedagogical point of view this way of doing forces the player to be efficient.
- parts 3 and 4: the player has to select among the various exams the ones that are at most pertinent; again penalties come with the selection of less or non-pertinent exams and time as well as money are lost.
- part 5: a particular treatment is proposed by the expert; the player goes through a set of steps, each step being the occasion to answer a quiz

This serious game places students in a real clinical situation and forces them to make their self therapeutic choice. The aim is to treat real patients in a virtual environment but close to clinical reality and in limited time.

2.3 General architecture

The architecture of the application classically follows the architecture of an editorial chain [13-14]. The figure below depicts this general architecture (fig.7).

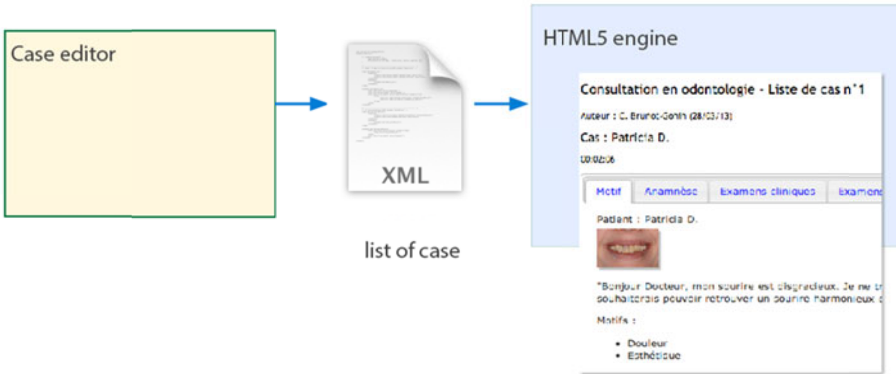

Fig. 7: General architecture of this serious game.

It is used first by the expert in an editing mode that allows to create new sequences of cases or to update existing ones. This produces an XML file containing all the information of the sequence of cases (according to the model described before) as well as a folder containing all the ressources displayed (images, sounds, videos, PDF files, etc.); the game engine loads the xml file and instanciates the sequence of cases; after each case, a result is sent to a monitoring page, which can be displayed in real time to a group of players.

2.4 Framework

The game engine is based on HTML5. This language has been chosen for several reasons. First, it becomes a new standard when developing Internet applications; moreover, for the game situations we are dealing with the development is faster and cheaper than with any other solution (like Java Applets or Flash, for example). Finally, HTML5 is now widely supported by mobile devices and does not require any plugin or add-on. This is a very important point as far as academic environments are concerned, because it warrants a good deployment of the game among the target users.

3 Discussion

This serious game performs an online self-assessment. Nevertheless, this teaching tool could be used in face to face learning to complete the self online-learning. The clinical results of treatment can be discussed with students thanks to online or in face to face forums according to blended learning.

Visualization effects, simulation, and virtual reality in 3D could increase the quality of serious game design [15]. However, we would like to show by this work that a singular serious game can be designed without a lot of high technologies and financial budget. Here, the contents are clinical case reports and the interest is to encourage a multidisciplinary approach by undergraduate dental students.

4 Conclusion

In the near future, these new teaching tools will emphasize dynamic and promising innovation of learning game, awareness game and serious games in Dentistry.

A similar approach has also been successfully studied for geriatrics ; a large of other clinical applications could be possible in the field of health care without changing game-play and design.

5 Acknowledgements

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A serious game to improve situation awareness in laparoscopic surgery

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Abstract

Safety analyses show that errors in surgery are more frequently caused by misperceptions and misjudgments than from technical failure of the surgeons. The adaptive coupling between humans and their environment, based on the perception and comprehension of signs and signals when performing a complex task, is referred to as situation awareness (SA). To date, no off-site training methods are offered to improve SA in surgical trainees. To aid the improvement of SA in minimally invasive surgery (MIS), a serious game was designed for surgical trainees. This serious game teaches surgical trainees to deal with major and minor problems in the minimally-invasive surgical theatre that originate outside of the direct line of sight. Serious games are instructional methods that allow serious skills training in a challenging environment. This paper discusses insights on design, development and evaluation of a game-based educational program for surgical residents.

1 Introduction

The application of sophisticated technology in minimally invasive surgery (MIS) has great advantages in terms of surgical outcome, but leads to increased mental strain for the surgical team[1;2]. High mental strain can precipitate errors when important early warning signs are missed. Perception by the human brain is highly selective, which is intensified by stress. The brain focuses on signals that it classifies as interesting and disregards signals that it classifies as unsuspected or uninteresting. Misclassification of signals may result in direct or delayed danger during the course of the procedure. These processes are known as *change-* [3] and *inattention blindness*[4]. It is known that surgical errors with grave clinical or economic consequences are frequently caused by misperceptions and errors of judgement[5;6].

The surgeon is ultimately responsible for the patient's safety and is therefore obliged to retain continuous overview over the equipment, the surroundings as

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well as to focus on the surgical field itself. An obvious resolution would be to educate surgical trainees to recognize and deal with adverse events associated with their technological equipment and their surroundings in order to reduce their mental strain during critical moments the surgical procedure. This adaptive coupling between humans and their surroundings during the execution of a complicated procedure is known as *situation awareness*. Situation awareness (SA) is the product of perception (what is going on?), comprehension (what does it indicate?) and projection of signals from the surroundings on the future course of the procedure (what next?)[7]. An observational study showed that a high level of situation awareness in the surgical team was associated with a better technical outcome in laparoscopic cholecystectomies[8]. Situation awareness can be improved by thorough preparation for the procedure and for non-routine events, and by practicing effective problem-solving strategies[9]. Training surgical residents to deal with two important aspects from their surroundings, including MIS equipment and (patho-)physiological disturbances in the patient, could reduce their stress and possibly improve situation awareness during MIS.

2 Serious Games in surgical training

Surgical trainees are trained to perform basic MIS procedures independently during their residency, often as early as in their second or third year. Learning MIS is thought to be more complex than conventional surgery as it requires specific visuospatial skills and technological equipment[10]. Off-site training is encouraged, to minimize patient harm during the advancement through the learning curve[11]. Virtual reality simulators train the specific MIS visuospatial abilities (the 'technical' skills)[12], but the 'non-technical'-skills, such as situation awareness, are currently educated largely 'on the job' – in the operation room.

A possible solution for non-technical skills training in medicine could be the application of game-based educational curricula. Serious games have been designed for non-technical skills training that include working in teams[13] and decision-making in stressful environments[14]. Serious games apply competitive elements, feedback mechanisms and entertainment to engage the player in an active form of learning[15]. In contrast to simulators and e-learning, serious games add an abstracted 'gaming layer' to the educational content, immersing the player in the experience to induce learning in a subtle, 'stealthy' way[16]. Multiple studies have shown positive effects in terms of appreciation by trainees[14;17] and learning effect[13;18].

3 A serious game to improve situation awareness in MIS

To optimize situation awareness in the MIS environment, a serious game was designed (Weirdbeard, Inc., Amsterdam, The Netherlands in collaboration with AMC Amsterdam). The game is intended to serve as adjunct to 'traditional' basic MIS training for surgical residents. In the game, the surgical resident is intended to learn (1) to identify important environmental elements that may influence the procedure and (2) to solve major and minor problems in MIS related to equipment and pathophysiological disturbances in the patient. The serious game is not just aimed at training surgeons, but also other members of the surgical team.

The game operates on mobile devices and web browsers and does not require any extra hardware components. The MIS equipment-related problems in the prototype were based on a genuine MIS lightsource (Olympus Exera II CLV 180, Olympus Corporation, Tokyo, Japan), insufflator (Olympus UHI-3, Olympus Corporation, Tokyo, Japan), videoprocessor (Olympus Exera II CV-180, Olympus Corporation, Tokyo, Japan), laparoscopic camera (EndoEYE HD Video Laparoscope, Olympus Corporation, Tokyo, Japan) and electrosurgical unit (Surgmaster UES-40, Olympus Corporation, Tokyo, Japan). Relevant sights and sounds were recorded and translated.

3.1 Interface and gameplay

The game interface is composed of a large central screen and a smaller side screen (Figure 1A). The central screen contains a mini-game (i.e. a game inside a game), which does not include medical content and has a mere entertaining character. The mini-game presents a challenge to the player, requiring him or her to focus the attention primarily on the mini-game. A mini-game-session endures a fixed amount of time, in which as many point should be scored as possible. Points can be scored by solving the puzzles and following instructions given by the supervisor character in the top screen.

However, during the game all sorts of problems appear that resemble MIS-related equipment difficulties and patients' physiological disturbances (Figure 1B). The signs and signals associated with the problems are comparable to reality. These signals influence the mini-game screen, (e.g. blurred screen) or have an auditory nature (e.g. specific alarm going off). The player needs to recognise these signals timely and react by stopping the mini-game. A troubleshooting mode appears, containing a simulated MIS environment with all relevant equipment (Figure 1C). The equipment-tabs can be selected individually, allowing the player to check parameters (e.g. intra-abdominal gas pressure) and correct them by selecting appropriate actions. After the troubleshooting phase, the player receives extra points and returns to the session.

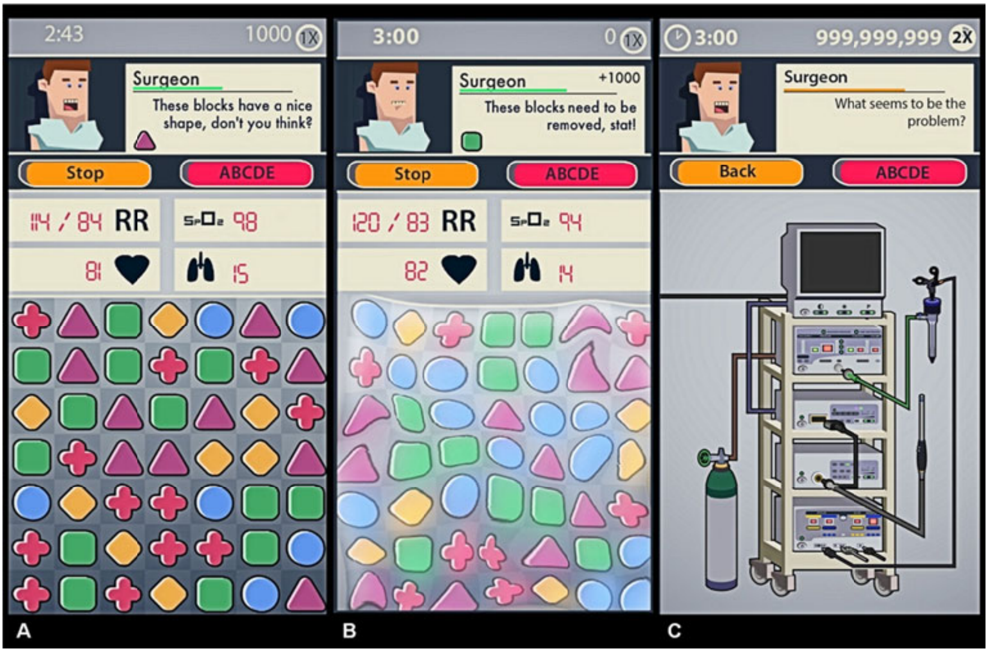

Figure 1: Overview of the serious game.

A) Main screen with the mini-game (below), the patient's vital signs, and a supervising surgeon (above);

B) When playing the mini-game, the player encounters problems that resemble problems encountered in real MIS, such as a blurred screen.

C) After acknowledging that a problem has occurred, the player enters a troubleshooting mode that resembles the MIS environment.

3.2 Content, learning and assessment

The content was selected in cooperation with licensed surgeons, anaesthesiologists and MIS equipment technicians. Common, equipment-associated problems include vision-related problems (Table 1), insufflation problems (Table 2) or malfunctioning electrosurgery (Table 3). Rare, yet major pathophysiological problems related to MIS include accumulation of gas in the venous system or right atrium (gas embolus), pneumothorax, or major bleeding when creating the pneumoperitoneum (Table 4)[19;20]. The player encounters all types on regular basis. The content was evaluated by three independent surgical referees (licensed laparoscopic surgeons) and five MIS equipment technicians through an online questionnaire. Faulty scenarios were removed during the design process.

Through familiarization with relevant signals and malfunctions that can be encountered during MIS, the trainee increases his awareness and learns problem-solving strategies. The trainees receive direct feedback in the form of a feedback screen after the actions in the game, followed by a debriefing score sheet after each session.

The players' performance is objectified by different parameters, not directly visible to the player. Problem recognition and problem solving scores are calculated. The time necessary to identify the problem is measured, as is the time necessary to solve the problem. The amount of steps the player needs to solve a problem is measured, correct steps as well as incorrect steps taken. This allows an accuracy percentage to be calculated.

3.3 Development and evaluation

To develop the game, an iterative design process was followed[21]. The serious game concept was developed by the game designer and approved by a multidisciplinary focus group containing surgeons, anaesthesiologists, game designers, psychologists and scientists. The game was developed in several phases, in which the design, content, and game mechanics was systematically extended by the game designers and a panel of content experts. One phase contained an evaluation by a group of surgical residents (the target group), specifically directed at the user experience.

The prototype should be evaluated scientifically to prove its validity. Validity research is a multi-step process that is preceded by a reliability test, proving that the system proves similar outcome assessments on the same performance over time[22]. The validity process usually includes content-, face-, construct-, concurrent- and predictive validity research[23;24], although these criteria are currently under discussion[25]. If the game content adequately covers the medical construct it aims to educate, content validity is achieved. Face validity is regarded as the games degree of resemblance with reality assessed by trainees and experts. If groups of independent experts and trainees play the serious game and positively evaluate the construct, this signifies resemblance to reality of important medical concepts. Acceptance of trainees and educators seems to be especially important among potential users of serious games. Construct validity is achieved when the serious game is capable of measuring an inherent difference in outcome of experts and novices on gameplay outcome parameters. If two cohorts with different levels of skills in reality perform differently on the serious games outcome parameters, conformity with the construct is likely. Concurrent validity is regarded as the concordance of study results between game and established instrument or method. Finally, predictive validity is the concordance of game outcome and task performance in reality. Situation awareness in the OR is influenced by many factors, such as stress and fatigue. Outcome measures should therefore be chosen as concrete as possible to prevent these confounders.

4 Conclusions

Surgical societies call upon the development of new methods for acquisition and maintenance of skills, and certification of the surgeons' competency[26]. Surgical societies call upon the surgical community to determine if new methods are safe and effective. Although virtual reality simulators have been implemented in surgical residency training curricula to teach MIS visuospatial ('technical') skills and relevant procedural knowledge, no methods currently exist to train situation awareness in the MIS environment[11;26]. High technological dependency and unusual pathophysiological conditions of the patient lead to additional complexity in MIS. The serious game described in this paper provides an off-site training environment with the potential to improve situation awareness in MIS.

The games content could be further extended to cover different types of MIS equipment. New mini-games could be created to increase the players challenge and motivation. Furthermore, the game could be made attractive to more experienced surgeons by adding more complex problem-solving scenarios. Before the game is implemented in training programs as teaching and assessment instrument, its validity should be formally evaluated to prove its learning effects. A prospective cohort study is currently being conducted, aimed at evaluating face- and construct validity. The next step will be to perform a randomized controlled trial comparing the effect of the game-enhanced MIS training curriculum with the standard MIS training curriculum.

5 Disclosures

Contributors: MG, MS drafted the article and revised it for important intellectual content. Both authors approved the final version. The authors had full access to all of the data in the study and can take responsibility for the integrity.

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7 Tables

Table 1: Visual problems related to MIS equipment with possible causes.

Problem	**Possible Causes**
Blurred screen	Filthy camera lens Image contrast set too low Cracked camera lens
Condensed screen	Condensed camera lens Condense inside camera due too defected insulation
Flashing screen	Video cable not tightly connected Monitor cable not tightly connected Video cable defective
Moving image on screen	Friction between camera head and cable
Yellow screen	Filthy camera lens Colour settings incorrect White balance off
Green screen	Colour settings incorrect

Red screen	Colour settings incorrect Filter settings abnormal
Blue screen	Colour settings incorrect
Darkened screen	Light Intensity set too low Iris mode set abnormal Monitor brightness set abnormal Xenon Lamp defective Light cable defective or not connected Video cable worn out
Light screen	Light Intensity set too high Iris mode set abnormal. Monitor brightness set abnormal. Condense inside camera due too defected insulation
Black screen	Monitor / Light source / Videoprocessor set off Videocable / Light cable not connected Light source set 'standby'
No signal on monitor	Monitor set on different channel Monitor not connected
Smoke in screen	Smoke caused by diathermia

Table 2: Insufflation problems related to MIS equipment with possible causes.

Problem	**Possible Causes**
Intra-abdominal pressure too high	Insufflation tube kinked Trocar valve closed Extraperitoneal positioned trocar Insufflator filter obstructed Patient improperly sedated
Diminished gas supply	Gas tank empty Gas tank placed horizontally Gas tank valve sealed Gas tube kinked
Failed insufflation	Pressure set too low Insufflation tube leaks Insufflation tube not connected Instrument not properly capped Small-diameter instrument in large-diameter trocar

Table 3: Electrosurgical problems related to MIS equipment with possible causes.

Problem	**Possible causes**
Diathermia alarm	Patient plate not connected
Diathermia dysfunctional	Instrument not connected to diathermia Diathermia cable defective Foot pedal not connected to diathermia
Diathermia too weak	Power set too low Current leaks away through capecitation Current leaks away through interconnecting instruments

Table 4: Pathophysiological disturbances related to MIS.

Problem	**Possible causes**
Desaturation	Tube dislocation Pneumothorax Obstructing embolus (Gas, clot, etc.) Atelectasis Etc.
Hypotension	Pathophysiological - Obstructing Embolus (Gas, clot, etc.) - Anaphylactic drug reaction - Myocardial infarction - Undetected blood loss - etc. Physiological - Decreased venous return by pneumoperitoneum - Vagus nerve stimulation by pneumoperitoneum - etc.

Games for Care, Cure and Medicine Adherence

Patient follow-up using Serious Games. A feasibility study on low back pain patients.

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Abstract

Low Back Pain (LBP) is one of the most frequent pathologies related to musculoskeletal disorders. Patients suffering from LBP must perform rehabilitation exercises in order to avoid chronic disorder. At the beginning these exercises are performed with physiotherapists during rehabilitation. A major part of the treatment need to be performed at home by the patient himself. Serious Games (SG) could be used to increase patients' motivation and to be sure that patients are performing these exercises and most important that they are doing it in the right way. A specific SG was created for LBP patients. Motions performed during the game are recorded and parameters (range of motion, speed, coupled motion) are processed. The aim of this feasibility study was to evaluate the intra and inter day reproducibility of this system to evaluate whether or not it can be used in daily practice for following the evolution of the patient and for scoring the severity of disorders.

1 Introduction

The musculoskeletal system (MSS) is essential to allow the performance of everyday functional tasks, to have a professional life or to develop social interactions with our peers. MSS pathologies can therefore have a significant impact on our daily life. MSS disorders can lead to severe impairments of the MSS normal physiology and seriously disable patients in their daily routine. It is therefore not surprising to find MSS-related health problems at the top of global statistics on professional absenteeism or societal health costs [1]. The most frequent pathology

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of MSS is low back pain, approximately 22% of active people experienced low back pain at least once a year [2]. There are lots of different therapeutic approaches: medication [3], physiotherapy [4], surgery [5],… depending on the causes (disc hernia, arthrosis, muscles weakness, inflammatory disease…) and the severity [6]. The best approach seems to be a follow-up by a multidisciplinary team composed by doctors, physiotherapists, occupational therapist [6]. Rehabilitation exercises, first performed with the physiotherapist, must be trained as much as possible. Unfortunately these exercises (e.g. stretching, posture, and strengthening) are quite boring and it is estimated that approximately 80% of the patients does not perform any exercises at home because they are not motivated enough. Lack of motivation is one of the most frequently cited reasons for patient failure to comply, dropout and other negative treatment outcome [7]. Serious Games (SG) could be used to motivate these patients. SG are games that have been designed and are used with a different purpose than pure entertainment [8].

Previous studies have shown the potential beneficial aspect of SG on motivation [9-14]. Development of SG is closely linked to the development of new technology related to the video games industry. In 2006 the Wii™ (Nintendo®) was commercialised and some of these games have been tested for rehabilitation: bowling game to decrease risk fall risk for elderly [15], reduce limb hyperactive behaviour for children with deficit hyperactivity disorder [16], during burn rehabilitation [17], for rehabilitation of people suffering of multiple sclerosis [18]… In 2008 Microsoft® commercialized a markerless camera to control the game: the Kinect™. The Kinect™ is recording the entire body and thus seems more interesting for rehabilitation. Despite this potential advantage, there are few studies on the use commercial games and Kinect™ for rehabilitation. One study has tested the possibility for physical rehabilitation for patients with motor disabilities [19]. Another study evaluated if it is possible to decrease fall risk for elderly [20]. The use of games for patient suffering from neurological disorders (degenerative ataxia) has also been tested [21].

In parallel to the research on the clinical effectiveness of SG, important work is performed in order to evaluate the validity of these devices used to control games: the Balance Board™ [22-23] and the Kinect™ [17-19]. The conclusion of these studies is that these devices are precise enough to be used to assess posture [22, 23, 19]. Concerning motion evaluation, the Kinect™ can be used only for some well-defined situations [20-21]. One of the major advantages of this device is that the motion of the patient can be recorded and corrected during exercises. This is important to be sure that the patient performs the right motion. Two studies have shown that it is possible to correct posture during exercises [44] and lateral trunk lean during gait retraining [42]. Although these studies compare the Kinect™ sensor with a gold standard laboratory device (optoelectronic device), and conclude that the results are acceptable, there is a lack of knowledge about the reproducibility of the measurement recorded during the game. The aim of this study was to evaluate the intra and inter day reproducibility of measurements recorded during SG rehabilitation exercises performed by low back pain patients. These measurements and scores were computed from the skeleton while playing the revalidation games and express clinically meaningful information for patients suffering from spinal impairment: we focus on the reliability of the automatic computation of Range of Motion (ROM) of the trunk in a lateral bending task and on the analysis of rotation of the lumbar segment as a coupled motion during the same task [30-31].

2 Material and method

2.1 Participants

Ten adults (51±8 years old, 5 women) with chronic low back pain (Visual Analogue Scale = 1.2±0.4 reflecting a moderate pain, range of this scale varies between 0 (meaning no pain) to 10 (meaning the worst pain)) participated in this study. Participants were recruited in a special program for low back pain patients at the hospital (so called "back school"). Patients are included in this program after medical examination; this program lasted for three months and included three sessions a week.

2.2 Material

The Kinect™ was used to control the game and as a Markerless Motion Capture (MMC) system to record motion performed by the patients (frequency: 30 Hz). A skeleton model (i.e., a stick figure composed of 20 points, Image 1) was directly obtained from the Microsoft Kinect SDK software. This model was used to further estimate relative segment orientation. Prior to data collection, the MLS camera was placed on a tripod at 1.5 meter above the floor. Subjects stood at 2 meters from the camera, as recommended by the manufacturer [32].

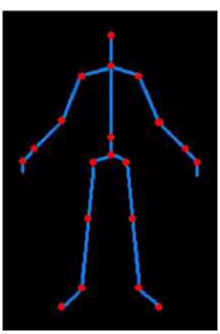

Image 1: Skeleton model obtained with MMC.

The game used in this study is a flight simulator specially developed for revalidation purposes (Image 2). The plane is controlled by trunk bending. The goal of the game is to collect as many stars as possible while avoiding meteorites.

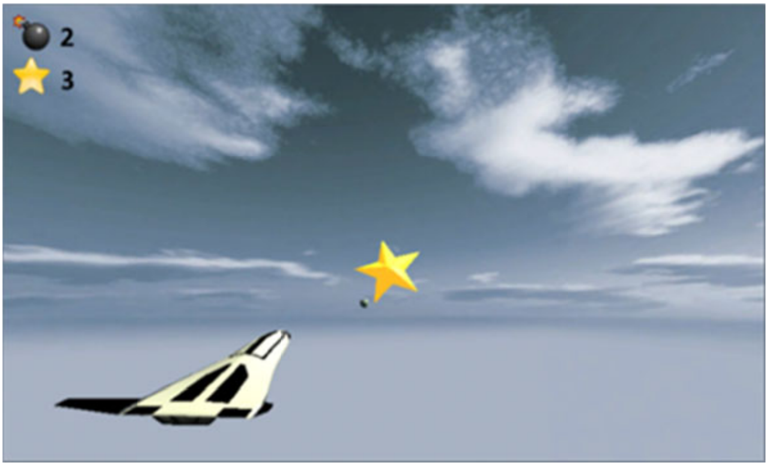

Image 2: Flight Simulator used in the study

2.3 Protocol

Before the first recorded session patients were first invited to play the game to be sure that they are performing the right motion. During one session patients were invited to play the game during two minutes then one minute rest and then two minutes of games to test the intraday reproducibility. The same protocol was repeated one week after to assess the inter-day reproducibility. A total of four sessions were recorded. During this protocol patients attended the same physiotherapy treatment as usual.

2.4 Data Processing

From the skeleton model (20 points) two angles were computed: lateral bending angle and rotation (see Image 3 for details). Angles were processed during the games and Range of Motion (ROM = maximal - minimal values) were computed. Although ROM is an important parameter to evaluate patients [33] and to quantify follow up, expressing only ROM seems quite poor to describe a two minutes exercise. To control the airplane, trunk motions are supposed to be in the frontal plane (lateral bending) thus rotation is not supposed to be important. To express the relation between lateral bending and rotation during the games a coefficient was processed. First right and left lateral bending were separated, then both lateral bending and rotation were plotted. The surfaces under both curves were computed and expressed in percentage (100% is the mean absolute area under lateral bending curve) this variable is called Coupled Motion (Coupled Motion= mean absolute rotation / mean absolute lateral bending angle) (Image 4) [34].

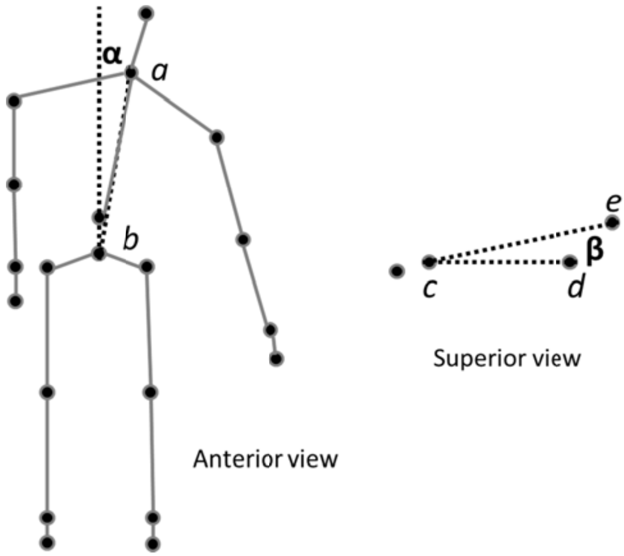

Image 3: Definition of the angles. For lateral bending the angle (α) was defined as the angle between a vertical line and a line between mid-shoulder (a) and mid-pelvis (b). For rotation the angle (β) was defined as the angle between a line between right (c) and left pelvis (d) and a line between left pelvis (c) and right shoulder (e) (for right rotation)

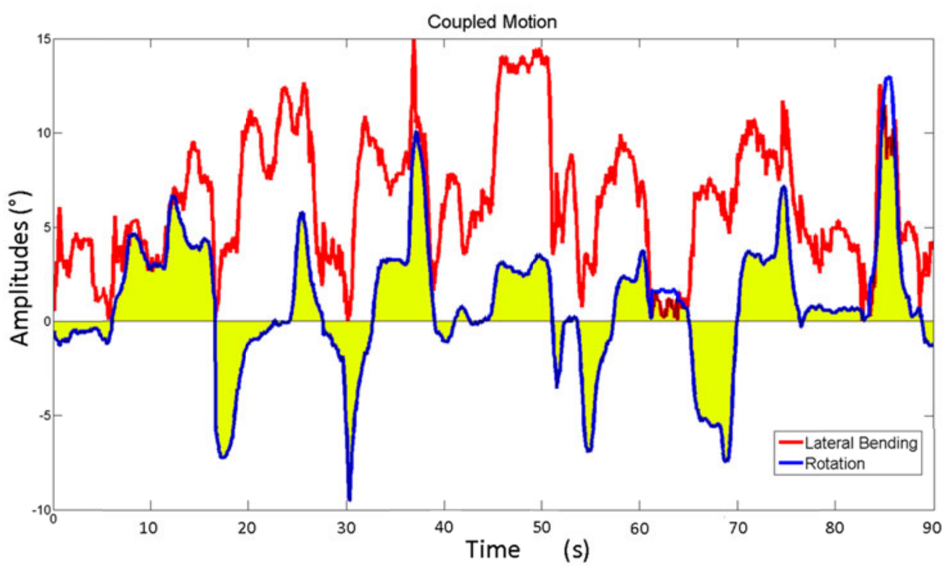

Image 4: Example of results obtained during the game Right bending is in red, blue is used for rotation coupled to lateral bending, and positive values are for right rotation (homolateral coupled motion). The filled area is used to represent coupled motion.

2.5 Statistics

Normality of the data was checked using Kolmogorov-Smirnov. To compare results obtained during the four sessions of play a one-way analysis of variance (Kruskal-Wallis) was used. To evaluate consistency and reproducibility of the results Intraclass Correlation Coefficient (ICC) were used [35] for intra and inter-day reproducibility. For inter-day ICC were computed between mean of Session 1 and 2 and mean of Session 3 and 4.

3 Results

Table 1 summarized results for ROM, coupled motion and results of Kruskal-Wallis tests (between the four sessions).

Table 1: Mean (std) of the studied variables and results of Kruskal-Wallis (p-value). As no difference was found between the sessions, mean results of the four sessions are presented.

Variable	Mean value	Kruskal-Wallis
Lateral bending right	32 (17)°	0.65
Rotation right	27 (5)°	0.28
Coupled motion right	37 (16)%	0.59
Lateral bending left	29 (12)°	0.32
Rotation left	29 (6)°	0.46
Coupled motion left	42 (13)%	0.58

Results of intra and inter-day reproducibility are presented in Table 2.

Table 2: ICC results

Variable	Intraday	Inter-day
Lateral bending right	0.68	0.75
Rotation right	0.78	0.50
Coupled motion right	0.65	0.57
Lateral bending left	0.69	0.54
Rotation left	0.84	0.68
Coupled motion left	0.79	0.58

For the intraday reproducibility, the ICC's indicate strong agreement for all studied parameters. Concerning the inter-day reproducibility, values are a bit lower indicating moderate to strong agreement.

4 Discussion

The industry of video games is a huge market (more than 100 billion of dollars of benefit for 2012). This huge amount of money leads to important development and innovation. Although these developments are initially for fun and entertainment, this technology could be transferred to rehabilitation for helping patients. There are many potential advantages of using computer games for rehabilitation. The most important one is the motivation of the patient [9-14]. Another positive aspect is that playing games allows patients to perform more repetitions of movements before getting bored, especially when there are rewards in the games [36]. In rehabilitation the more the patient is repeating the motion the more important will be the benefits [37]. Currently there are two problems related to exercises that patients need to perform at home. The first one is that due to low compliance only very few patients are regularly doing these exercises and the second one, more vicious, is that some patients are doing at home exercises but they are doing them in a wrong way (because they did not understand/remember the instruction, because they cannot do it,…). SG coupled to motion analysis could be the solution for these problems.

During this study, four sessions of play were recorded, no difference was found for parameters recorded during each of them. Results are strongly consistent when measurements are repeated the same day. For the inter-day reproducibility results are not as good as for the intra-day but remain acceptable for a rehabilitation use (moderate to strong agreement). These results indicate that motions recorded during rehabilitation exercises with fast and easy to use MMC are reproducible. Implications for both patients and clinicians are various: curves can be visualized in real-time to correct the patient while performing the exercises [42]. Clinicians can follow the evolution of patients, be sure that they are doing the exercises, and get the score from the games. The fact that these scores are reproducible is of course very important. If the clinician notices that the score of the patient is increasing, he can modify the parameters of the games: speed, number of meteorites, increase the range of motion required to get from one side of the screen to the other one... On the opposite, if he observes a decrease in the score, the clinician must analyze the curves to understand the problem and try to solve it. Note that having a highly configurable game is needed to maximize the chance of success. Indeed, patients often present some very heterogeneous clinical symptomatology; the games must be adapted towards each patients' specificity.

The game used in this study is built on top of a very highly configurable platform that allows modifying a lot of parameters (Image 5) [38].

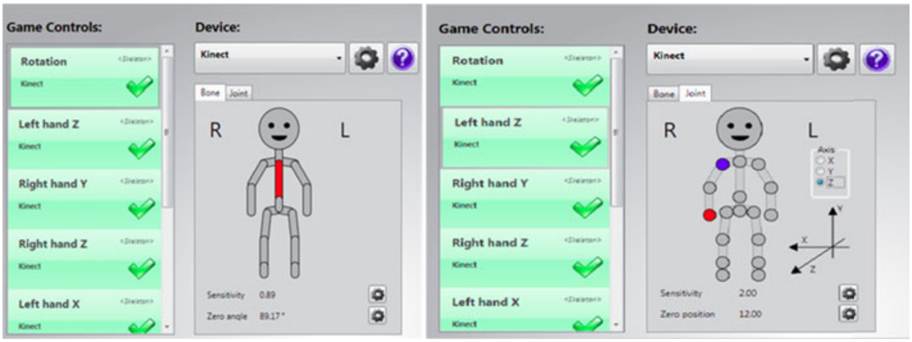

Image 5: Platform used to configure the game (visual background, joint to control the game, speed, range of motion …) www.ict4rehab.org/users

Some people may be tempted to believe that SG can substitute physiotherapists or that SG are developed by physiotherapists to get rid of some patients. Of course both of these possibilities are wrong. In order to obtain positive results both clinicians and patients must be in close interaction (Image 6). Based on our knowledge, success of SG for rehabilitation is depending on the quality of this loop.

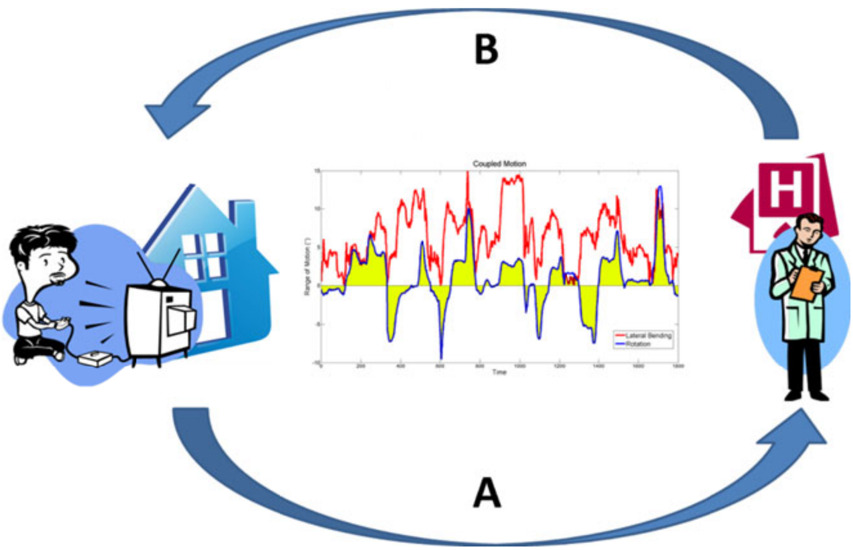

Image 6: Close interaction that needs to exist between patients and clinicians. *A* Information from games to clinicians (e.g. ROM, score of the games, Coupled Motion). Based on these results clinicians can modify game parameters ***B*** (e.g. increase ROM required to drive the plane to the right part of the screen, decrease the speed …)

This is a feasibility study with some limitations: there is a limited number of patients included in this study (ten participants), the games are played for a short period of time (four session of two minutes) and finally we did not compare results obtained with the Kinect with gold standard devices used in motion analysis (e.g. stereophotogrammetric device) [39].

5 Conclusion

The use of video games for rehabilitation (either commercial mass consumer games or specially dedicated to rehabilitation) is relatively new and thus lots of research is needed to explore the new possibilities offered by this technology. Although some papers focused on the validity and reliability of the Kinect™, to our knowledge, no study has investigated the reliability of the data captured during rehabilitation exercises. ROM and coupled motion are measures used in the analysis of spinal impairment even if the use of these parameters is still controversial in clinics [31]. Thus therapy models are often based on the concept of improving ROM and having a better control of coupled movement. The game has been developed to improve these parameters. Results of this study indicate a good reproducibility of the measures obtained during this game with LBP patients. Therefore future work must focus on long term evaluation and follow up of these games for the management of low back pain from the clinical point of view.

6 Acknowledgments

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Designing Kinect games to train motor skills for mixed ability players

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Abstract

Children who have special needs when it comes to motor skill development, for instance as a result of developmental coordination disorder or cerebral palsy, need to undergo long bouts of physical therapy. This can often be considered boring, to the detriment of the efficacy of the therapy. One way to improve the engagement of physical therapy is to embed it into a video game, e.g. with the aid of Kinect. However, very little is known scientifically on how to design these serious games for mixed abilities in order to be both fun and efficacious in terms of motor skills development or attitude change. In addition, contemporary entertainment games often revolve around competition based on mastery of skills to be engaging, something special needs children feel left out in. In this position paper we survey the field and propose a number of ways to approach mixed ability game design.

Keywords

serious games, game design, motor skills, special needs, mixed ability design

1 Introduction

In the last few years a lot of new gaming technologies have been developed. Some of the games for these platforms aim at stimulating physical exercise or training motor skills, such as Wii Sports, Just Dance and Kinect Sports. More often than not, these are targeted at the mass market, in which the average child develops his or her motor skills according to a normal pattern. However, these relatively cheap and widely available entertainment technologies also make it possible to be utilized towards helping special needs children with their therapy. Motor skill therapy can sometimes be arduous and considered boring. The addition of a game environment can make this process more motivating [1]. The effectiveness of long term therapy but especially of physiotherapy is directly associated with the engagement, effort and commitment during the rehabilitation process [2].

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Within the group of children with special needs however, problems often extend beyond a delayed motor development. In real life, but also in the context of playing competitive games, special needs children may feel segregated from those with a normal development, due to being picked last at sporting events or scoring worse in activities. The most effective way to deal with these feelings is by stimulating interaction between the child and his surroundings [3]. In this context it is important to not only focus on mitigating the motor problems associated with the disorder but also on the child's perception of his or her abilities [3]. This will increase their self-confidence and feeling of equity. In addition, a more positive outlook on one's own abilities has been shown to improve motor learning itself [4].

We are interested in examining how to create a more effective and appealing way of therapy for children with mixed abilities, and how this can contribute to creating more understanding between children through cooperative elements.

2 Related work

Gaming technologies have already been applied for health and motor purposes for a long time, ranging from stimulation physical exercise with games like Wii Fit to games that train motor skills such as Motion Explosion for the Microsoft Kinect. Whilst some of these games offer monitoring capabilities and aim to motivate their users, they are not developed for rehabilitation purposes [5].

One step beyond this principle is Superpop from Georgia Tech in which children can do therapeutic exercises by popping bubbles [6]. The system is able to monitor progress and allows the therapist to adjust the game. While this project rests on the principle of using a well available technology to be able to move the therapy setting to children's homes whilst being able to monitor their progress, the focus is on therapy rather than game experience.

In the research of Voxar labs, UFPE Brazil [7], user game experience is more of a focal point. They conclude that the effectiveness in therapy goes up when the gaming experience improves. Although this research links the concept of using the Kinect to therapy (while monitoring progress) to the gaming experience, it does not address the social aspect of children with special needs.

An example of a game where children with mixed abilities are encouraged to socially interact with one another is the pOwerball [8]. Although this is a good example of how to design for a user group with mixed ability it focuses on the social interaction and bridging the gap between the physical and virtual world; not on therapeutic goals.

A game consisting of a number of minigames to help children with Cerebral Palsy exercise more, was made by Hernandez and colleagues [9]. In this game, called

Liberi, the player has to pedal on a recumbent bicycle, and through this control characters in minigames. Hernandez et al. found that the majority of the target group actually prefers to play action games, even though they have difficulties playing them. Therefore, they propose a number of usability guidelines, such as, among others, avoiding a fast pace, not requiring precision timing and not requiring multiple simultaneous inputs in order to mitigate some of their weak performance [9].

3 Game design and playful experiences

In this paper and subsequent research we want to extend that approach by investigating how games for children with motor disabilities should be designed a priori. This is furthermore motivated by two additional problems we discerned. Firstly, while it is undisputed that many children find entertainment games engaging, there is as of yet little evidence that serious games are more motivating than other forms of instruction, something that is compounded by a lack of knowledge on how serious games should be designed to be more engaging [10]. Furthermore, while games have been found to improve feelings of self-efficacy [11], and improving self-efficacy is also conducive to increased engagement [12], much of the boost in self-efficacy is precipitated by a game offering difficult challenges and competition [13], [14]. This can be problematic for children with delayed motor development, as losing out to friends will likely lower their self-efficacy instead of increasing it, and therefore nullify (some of) the engaging qualities of a game.

One promising way to base one's game design on in order to improve the engagement of a game is Self-Determination Theory, which states that humans (and in fact game players) are intrinsically motivated to satisfy basic psychological needs of competence, autonomy and relatedness [15], [16]. Designing games with Self-Determination Theory in mind should improve the intrinsic motivation (or engagement) of the activity, which in turn has been shown to improve persistence on a learning task [17]. This is a different approach than appealing to extrinsic motivation as is the case in some regular physical therapy. Although existing games already integrate these principles in variable ways, focusing on autonomy, competence and relatedness reveals a design problem, especially concerning the latter two. It is important to stimulate multiplayer in order to enhance intrinsic motivation, but we noticed earlier that the competitive nature of many games has an adverse effect on the feeling of competence of special needs children. Consequently, we contend that games for special needs children should incorporate cooperative instead of competitive multiplayer, but in such a way that the disorder of the child is not apparent, or in fact a bonus for successful completion. Focusing on cooperative play has the added benefit that it has been shown to improve motor learning in other settings [18]. Designing games for players with mixed abilities can in such a way not only support the motor development of children with special needs, but can also support family and friends in getting a better understanding about each other.

Other research has examined how to design for different playful experiences [19], such as exploration, fellowship and curiosity. Applying these playful experiences in the design of games for mixed abilities may further contribute to increasing the appeal of such games.

4 Implementation

The aim of our work is to examine how we can design Kinect based games using full body interaction, for children with mild motor disabilities. The different groups of children that could benefit from our approach could be very diverse. The test bed for this research will be children with a mild form of Cerebral Palsy (CP) and children with Developmental Coordination Disorder (DCD).

Children with CP suffered a lesion in their brain at birth or closely after. Which most of the time results in spasticity, meaning that the muscle tension of some muscle groups is permanently too high. Children with DCD suffer from congenital problems, leading to difficulty with both gross and fine motor skills. In contrary to CP the motor problems are not caused by an inability to make certain movements, but rather the inability to properly plan, coordinate and moderate motor aspects such as speed, place and force [3]. Although the motor problems in CP differ from those in DCD, the exercises and therapeutic approach are often quite similar. Ability and difficulties differ greatly from child to child.

Therapists often use a task/activity based approach in which they analyze the child’s current state of development and the complexity of the task after which exercises will help the child reach their goal [20]. Common exercises for these groups would be ball skills (aiming, throwing, catching), balance, climbing, running, jumping; basic skills in both the gross and fine motor area. In addition, children with DCD have greater difficulties in coordinating actions when limbs have to cross the body’s midline, e.g. moving an object with the right hand on the left side of the body.

The main focus of this project is to support social interaction between people with mixed abilities while at the same time helping the child with a disorder with his/her therapeutic goals.

5 Requirements

Through three expert interviews with one physio and two ergo therapists, and two exploratory therapy sessions, and in addition to the considerations stated in sections 2 and 3, we have collected several requirements for the design of Kinect games so far.

- Simple and fun game that intrinsically motivates and encourages child
- The game should heed usability considerations for motor skill disabilities [9]
- Cooperation element in game in order to increase empathy and self confidence
- On a therapeutic level the child should be able to plan, act and reflect on their actions
- Adjustability of the game to child’s abilities and problem task/activity
- Monitoring capabilities so the therapist can objectively keep track of progress
- Game should take involuntary movements of player into account

Furthermore, we have examined why games on existing platforms do not meet the requirements of these user groups. The platform that is currently in use at the two therapeutic centers we visited is the Wii. The most apparent problem is the difficulty in holding the Wii remote, let alone simultaneously press buttons and specifically pointing it. This easily evokes ‘cheating’ behavior; for example, holding the remote in an unaffected hand or with both hands, cancelling out the exercise’s therapeutic effect. For both the Kinect and the Wii the largest problem still, is the inability to adjust games to the affected skills or area of each specific child [21], [22]. This means there is (great) inequality in the ability for different children to play a game, which can have a negative influence on a child’s motivation and effectiveness of possible therapeutic effects.

6 Initial game scenarios

In order to determine how Kinect games can be designed to aid in motor skill therapy for children with a coordination disorder, we performed a number of game design investigations together with students of industrial design. We will highlight three of these games to illustrate concepts of how games can tackle therapeutic problems associated with these disorders, in line with (some of) the requirements stated above.

In order to train gross motor coordination, in one game players have to guide a ball across platforms, pickup bonus items and guide them into a goal, by letting the ball roll over their outstretched arms (figure 1). This is a relatively simple concept that nonetheless can easily be made progressively more difficult with more complex level layouts. A more taxing coordination task is shown in figure 2, in a game where players have to guide benevolent fictional creatures with one hand, and simultaneously fend of hostile creatures with the other.

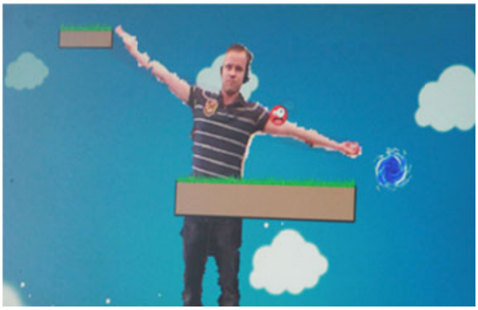

Fig. 1: Roll a ball over your outstretched arms

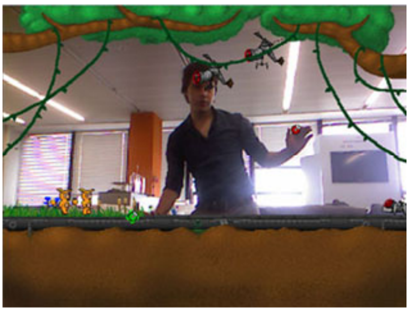

Fig. 2: Guide and fend off creatures with both hands

Earlier we mentioned that children with DCD have difficulties coordinating movement across the body's midline. One approach for training this can be seen in the game in figure 3, where players have to fend off colored meteors by touching them with their similarly colored hands. As the game progresses, meteors will more often show up on the other side of the person's body.

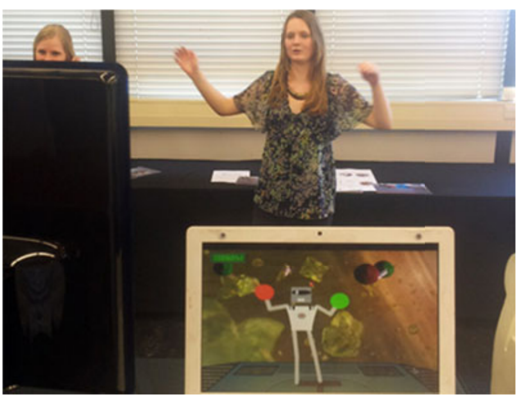

Fig. 3: Fending off meteors on both sides of the body

In order to design for persistence of play, this game also lets the player 'earn' different suit upgrades to customize his or her avatar, and show it off on a scoring board for children with DCD or Cerebral Palsy. Ultimately the most ardent players will have the nicest looking custom avatars. Another example of how one can hypothetically design for persistence is by including an adventure story that spans many hours of therapy.

The upgrading of an avatar is an example of rewarding persistence instead of performance. Scoring performance is more often used in entertainment and serious exergames but, as we contended earlier, could be detrimental to the self-esteem of less able players. However, this approach does not mitigate the possibility that a more able player could start competing with the child with a coordination disorder, negating any perceived gains in competence.

In order to tackle this, one could for instance make the game exclusive to children with a coordination disorder, although this could also potentially serve to highlight the child's disability. Another approach is to provide the competitive or cooperative multiplayer mentioned earlier, with markedly different roles for the players. For instance, a game where one player is King Kong and has to make large arm movements to fend off attacks, and the other player controls the attacking forces and has to make small movements to e.g. pilot the airplanes. Lastly, we are experimenting with a game where there are no scoring mechanisms or win-states, but players are rewarded with increasing and pleasurable audiovisual effects. However whether this stays fun for longer periods of time is still very much unclear.

7 Approach and Future Work

In addition to continuing on with the investigations such as described above, we intend to vary the amount of 'relatedness' and 'competence' embedded in the game by varying the extent to which the two players depend on each other in reaching the overall goal of the game. By performing controlled trials on these variations, we aim to discern design guidelines that improve the efficacy, engagement and player persistence of serious motor skill games for mixed abilities.

We are in the process of developing Kinect games for this user group. During the iterative design process we will incorporate regular input from diverse stakeholders such as parents, therapists and children.

8 Conclusion

Most commercially available games are not specifically suited for children with special needs, but there are already games in development for this group; some of these games also incorporate a therapeutic angle. We will examine how to integrate in a game design process a combination of children's therapeutic goals with a design for mixed abilities. In this way the game should both support motor skill training as well as providing a positive social experience.

On a therapeutic level this means being able to adjust the game to a child's ability level, providing meaningful tasks in which the child has to plan, act and reflect on their actions, and being able to monitor their progress. On a social level this means increasing self-confidence and empathy through cooperative playing between players with mixed abilities.

Through design research we intend to develop design guidelines for how to design full body interaction games for children with special needs, and how to design mixed ability games.

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Gaming at the dentist's – serious game design for pain and discomfort distraction

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Abstract

Virtual reality (VR) techniques have proved effective in distracting patients from perceived pain in a variety of studies. These results, partly due to the visual impact and immersion achieved, encourage investigating the purposeful design of games for deployment in a variety of dentist treatments. In fact, a large group of patients, particularly youngsters, experience a strong resistance or even aversion to visiting a dentist's practice, often due to previous distressing and painful experiences. We argue that, to solve such situations, distracting a patient with just an attractive virtual environment is less efficient than with an interactive game expressly designed for this context and purpose. This paper presents the first results of a pilot project in this direction. We discuss the various requirements gathered throughout the project, and describe several technological challenges, involving e.g. user experience, interaction, content, graphics, which we faced throughout the game design and development phases. Although the project is still ongoing, the preliminary results of the prototype game evaluation in a controlled environment were very encouraging.

Keywords

serious games, dental treatment, pain distraction, virtual reality

1 Introduction

Virtual reality (VR) techniques have often been deployed with considerable success as a method for distracting patients and reducing their perceived pain, as well as in helping overcome anxiety [4, 2]. Several studies report on the successful application of VR distraction to reduce pain associated with e.g. cancer-related treatment [10], intravenous placement [5], and burn injuries [8].

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Specialists point out as main reasons for this success the visual impact of a virtual world, the freedom of navigation, the high-degree of interactivity, and the consequent high-level of immersion experienced. In short, a patient can get so deeply immersed when experiencing the virtual world that much less attention will be spent in processing the pain being suffered.

There have been various experiments on exposing patients to VR environments during dental treatments [11]. For example, a study concluded that VR immersion had been very successful in increasing the "amount of attention drawn away from the 'real world', allowing patients to tolerate painful dental procedures" [7]. More recently, a randomized controlled trial showed that "virtual reality eyeglasses can successfully decrease pain perception during dental treatment" [1]. In the commercial product Isla Calma, the patient could even have some active roles, as e.g. picking collectibles or making choices [3]. However, these simple actions are rather isolated and unlikely to keep the patient's mind busy for a contiguous period. Moreover, the VR environment and experience they describe, no matter how attractive and immersive, were designed for generic pain distraction, not for specific treatments in the context of a dental clinic. This has a number of disadvantages, as we will see in the next section.

Dental clinic patients with a critical discomfort often develop a mild anxiety of being exposed to the pain associated with even routine treatments. This discomfort, if not overcome by children, might lead to aversion or even avoidance of any treatment at all, which would only increase the damage in the near future.

How anyone becomes afraid of a dentist, is best explained by Pavlov's theory. If, for example, you experience pain while drilling, you learn that drilling will hurt. The brain remembers this and, with the next dental drilling experience, one is reminded of the pain and that makes you anxious. In other words, at a next treatment one is afraid because of the fear that it will hurt. This is called classical conditioning.

Fortunately, both this anxiety and the associated pain itself can be overcome by a proper use of distraction. We believe that, to solve such situations, distracting dental patients with just an attractive virtual environment is less efficient than with an interactive game expressly designed for these purposes. This paper reports on our pilot project in that direction. For this, we set up an interdisciplinary research team consisting of dentists, computer scientists, game designers, and user experience experts. As far as we know, this is the first pain distraction game purposefully designed from the outset for deployment in a dentist context.

In this paper, we first discuss the various requirements gathered throughout the project. We then describe several technological challenges, involving e.g. user experience, interaction, graphics, which we faced throughout the game development phase. We also discuss the results of the preliminary game evaluation in a controlled environment and, finally, we draw a few conclusions.

2 Requirements

In this section, we elaborate on the two main types of requirements that we collected at the beginning of this project, and drove the whole game design and development process. First, from the dentist specialists in our team, we gathered a variety of requirements from the perspective of their work circumstances and of the treatments for which the game could be deployed. Second, from a game designer's perspective, we identified a number of requirements that greatly influence the game genre, the gameplay and its pace, the type of content, etc. In this section, we summarize both types of requirements and indicate how we got along with them. This exercise plays a crucial role in clarifying how to solve the various conflicts among the different requirements and domains involved. In this task, we applied recent serious game design methodologies [6].

2.1 Dentist domain

Regarding audio-visual technology, there are two main constraints to be concerned about: on the one hand, the visualization should not be hindered by the dentist at work; on the other hand, the dentist should be able to stay in permanent contact with the patient, e.g. to ask questions and receive quick and intelligible answers. In particular, the use of music or any other game sounds should never cause the patient to lose contact with the dentist. These constraints quickly converge to the deployment of (some type of) VR goggles. In that case, an important factor is the size and the weight of the goggles. Working in the mouth of the patient requires a certain clearance area for treatment: the goggles may not interfere with it, nor limit the operation space. Wires and cables should in general be avoided, both on the floor and around the patient's head, in order to avoid any accidents, and to facilitate manipulating dental instruments in the mouth without any hindrance. So a wireless system should be preferred. Furthermore, whatever the setup, the system should not hinder nor burden dental personnel in any way: it should be easy to set up and technically not complicated.

Regardless of the kind of game controller, its use should be very simple, requiring e.g. only one or two controls, and intuitive. The bottom line is that the patient has to quickly get used to it without ever needing to look down at the controller, when lying in the dental chair. To facilitate this, the possibility should be considered of having (new) patients start playing the game outside the dental chair, for instance in the waiting room, so that they get prior experience with the game, controller actions, etc.

Regarding safety, additional measures may be required due to the co-location of electronic cables, the use of water and of rotating instruments with water cooling. Furthermore, disinfection of all devices used for the game (e.g. goggles and controller) will have to be performed using swabs with alcohol, as usual in dental clinics. So device materials must be resistant for this kind of fluids.

Due to the large variety of dental treatments, the duration of the game would better be flexibly adjustable by the dentist; so ideally, the player will, say, neither 'finish all levels' too early nor ask to continue a while after the dentist is done with the treatment. However, this should be achieved without damaging the challenge level with abrupt variations, so that the game will remain challenging for both short and long treatments, without leaving a feeling of frustration when it is 'game over'.

Regarding the kind of game environment and actions, the player should always feel comfortable and relaxed, without unexpected, startling or violent events. In particular, it is important to avoid any sudden movements of the patient, especially of their heads, while lying on the chair. For this reason, for example, we consider that head tracking should never be used in combination with the VR goggles in a dental clinic setting like ours, as it would encourage moving the head around, with all sorts of associated risks.

2.2 Game design domain

For the game design process, the two main drivers identified are the constraints just mentioned above: *relaxation* of the player, and the *physical setup* at the dental clinic. All other aspects, including *gameplay*, although important, are secondary.

Relaxation: early during our design process, we felt that the key to relaxation would be immersion. With this, we mean offering players a compelling presentation, including visuals and narrative, that instantly draws them in. Keeping in mind the target audience for our initial pilot project (10 to 16 year olds), we investigated a simple yet powerful concept: players would navigate their airship through a series of caverns. Later, as development had already started, we adapted the theme to a submarine navigating through underwater caves.

Physical setup: since players should move as little as possible during the procedure, we chose to use VR goggles and a wireless controller. The game is controlled using only the left joystick, and therefore should be easy to 'pick-up and play'. Furthermore, we expect that giving players something tangible to hold in their hands helps to distract them as well.

Gameplay: the experience features a balanced mix between player control (freely moving the submarine in all directions) and computer-driven events (gravity, steady forward panning of the animated camera), forcing players to actively keep up. Within the game environment, seen from the side, players must avoid hitting the cavern ceiling and floor, as well as evade hostile objects floating around in the water. However, they may also pick up certain items to score points, offering moment-to-movement mini-goals, and requiring from the player proper risk/ reward considerations.

Currently, to increase accessibility as well as replayability of the game, we added two difficulty levels. On easy mode, most players should have little trouble reaching the end of a level. On hard mode, extra obstacles offer bigger challenges. In our upcoming test sessions, it will be interesting to investigate to which extent this additional challenge will be beneficial or detrimental to relaxation and immersion.

Eventually, for final deployment, we intend to implement high-scores into the game, so that players may compare their achievements with each other. Such a sound competition might even stimulate them to try and improve their results, increasing the longevity of the game within the dental clinic, as well as keeping players distracted for longer periods of time.

3 Prototype development and evaluation

The development of our first prototype followed the requirements gathered from the dentist domain, and their corresponding interpretation from a serious gaming design perspective, as introduced in the previous section. We consider the content, the learning curve, and the user interaction among the key points for our game implementation, to which special attention was given in order to fulfill all the above requirements.

Starting from the content, our focus on player's immersion led us to the design and incorporation of engaging graphics such as the underwater environment and the submarine itself, as shown in Figure 1. Moreover, we made a selection of comforting colors featuring shades of blue, which reinforces the other requirement of maintaining the player calm and relaxed.

Concerning the learning curve, the submarine theme was found to be very suitable, as it turns out that most people rather intuitively can anticipate how a submarine behaves under water, subject to a constant gravity force. Although intuitive, there is still ample room for learning since, due to a careful level design, the navigation in increasingly narrow caves is still hard to master. This makes the game more intriguing and challenging for the player.

The requirements described in Section 2 also set new challenges in terms of human-computer interaction. As mentioned before, they almost necessarily lead to the use of some light VR eyewear and a wireless game controller. In our current prototype, the equipment setup consists of the following components:

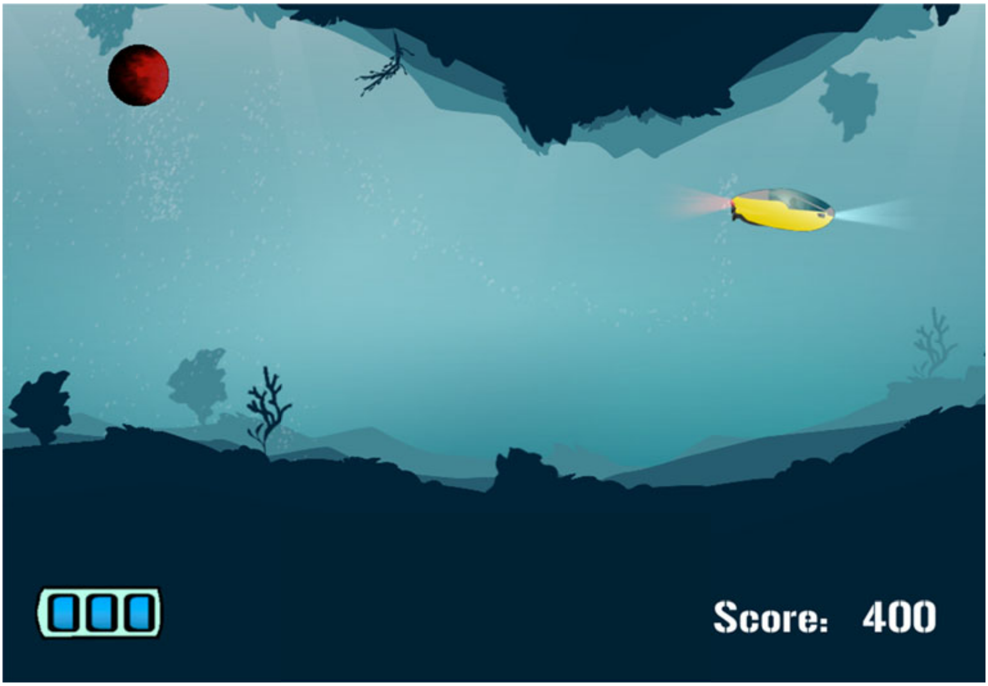

Fig. 1: Screenshot of the first game level

Display technology: we have been using Vuzix 1200VR goggles, but without making any use of its head tracking nor of its stereo imaging for the reasons explained in Section 2. This eyewear reaches a resolution of 1280 x 720, and provides a relatively dark environment without total enclosure of the users sight. This effectively helps patients keep focused on the gameplay, and avoids distractions from the surrounding environments but without depriving them from the crucial audio-visual perception of, and communication with, the dentist.

Controller: the game is played with a wireless XBox 360 controller. Only the left stick is being used and has been programmed to carry out the submarine's movement in all four directions.

In order to make the game more interactive and immersive we integrated a variety of visual elements and audio effects; see Figure 1. A life bar is used to display the submarine's health, represented by three bars on the lower left corner. The health is calculated based on the rewards retrieved by the submarine and on the damage caused by hostile objects, like the red ball shown. Additionally, a scoring system based on the number of rewards is permanently displayed on the lower right corner. Other visual effects include small air bubbles that follow the movement of the submarine, and moving air bubbles around hostile objects (e.g. the red balls). In order to keep the user aware of successful actions (e.g. retrieval of a reward item), we have sporadically added some subtle sound effects. In the future, we plan to investigate whether other audio forms could potentially enhance the immersion without hindering communication.

Our prototype was developed using the Unity game engine, which very much facilitated the integration of components like the environment, the navigation, the graphics and audio effects, as well as the artificial intelligence and scoring mechanisms. In addition, Unity permits running the game both as a standalone executable and online, on the browser, by means of the Unity Web player.

We made some preliminary tests of the current prototype game in a controlled environment, to have an early sense of how it was performing relative to the two crucial issues of player relaxation and physical setup. These resulted in very encouraging outcomes.

Fig. 2: Preliminary evaluation tests during STEM Girls Day

The occasion was given by a STEM (Science, Technology, Engineering, Mathematics) demo day, nationally organized for school girls, aged 8 to 15. For this, we set up a booth featuring a deep-leaning chair, simulating the dentist chair, the VR goggles and controller, and, of course, the computer running the game, with a large screen where all bystanders could follow the 'patient' playing, while lying on the chair; see Figure 2. Sitting beside the chair was the dentist, who talked to the playing child, putting questions and giving various instructions, 'as if' a real treatment was going on. As mentioned above, using these goggles the child was able to play the game as well as perceive the dentist's presence.

The game environment was considered attractive and relaxing, and the gameplay, very successful: all children were eager to get to the next level and were very concentrated on getting higher scores. Nevertheless, in all cases, it was remarkably surprising how easy the communication was between the dentist and the children as they played on the chair. For example, they promptly followed commands for 'opening the mouth wider', 'turning their head aside', etc. whilst continuing to play the game, without any perceptible disruption of the gameplay. Even more, outside those explicit dentist commands, it was noteworthy that all children held their heads very still throughout the whole session. We mainly attribute this to the fact that our game features a steady, slow-paced side scrolling.

Eventually, all children were quite enthusiastic about the game and wanted it to be available at their own dentist. They also commented, for example, that 'they now had something cool to do in the dentist chair' and that 'going to the dentist would become a lot more fun'.

4 Conclusions

Many patients, particularly youngsters, experience a strong resistance, at times, utter aversion, to visiting a dentist's clinic, often due to previous distressing and painful experiences. We pose that distracting a patient with an interactive game expressly designed for this context can be very helpful and effective to solve those and similar situations. We discussed the first results of a project in this direction, and identified a variety of requirements, from both the dentist's and the serious game designer's point of view.

Various technological challenges, which we faced throughout the game design and development phases, were discussed and solved, involving e.g. user experience, interaction, content, and graphics. For example, we concluded that slow-paced, steady side scrolling is a very appropriate and successful game progression mechanism that very well fits our dental clinic setting requirements.

We expect that a compelling gameplay, with its calm but steady attention focus, should help to better distract patients from the dental treatment and its associated pain. Even more, for long dental treatments (e.g. root canal or orthodontic treatments, which can easily last 30-60 minutes), an immersive game like this, is very likely to improve the patient's sense of elapsing time.

Still, we argue that there is no pain distraction game, VR environment or system that is 'good-for-all-situations', due to the large variety of circumstances and constraints across specific domains. For example, fully enclosing goggles with head tracking have the undesired consequence, for dental treatments, of inducing patients to unpredictably turn their head, to look around in the environment. From our preliminary project experience and prototype evaluation, we concluded that the best approach is a careful, ad-hoc game design, taking into account problem and domain-specific constraints and requirements.

Among the next steps in our project, we will, very soon now, perform actual test sessions in a dental clinic, followed by the investigation of adaptive gameplay mechanisms, in order to strengthen the flexibility of gameplay duration and enlarge the target public of this game [9].

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Cognitive and Mental Health

A Taxonomy of Serious Games for Dementia

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Abstract

Serious games for dementia (SG4D) hold their own, unique and significant space within the Games for Health domain. However, the SG4D field still has not been fully mapped out and classified. In this work, we present a generic taxonomy of serious games for dementia, based on the health functions and the health purposes they serve. Firstly, we classify dementia games based on the health function they serve, in: cognitive, physical and social-emotional games. Each of these functions serves a variety of health purposes, leading us to a second, lower level of classification in: preventative, rehabilitative, assessing and educative games. Furthermore, we provide an ex-post evaluation of the proposed taxonomy by exploring whether the existing serious games for dementia can be validly classified, based on the proposed taxonomic characters. To this end, we collect and analyse a set of dementia-related serious games (e.g. WiiSports, Big Brain Academy, Cognifit, MinWii, et al.) by performing a literature review. The results show that the taxonomical system covers a sub-field of "games for health" and indicates areas which are under-explored by current games.

Keywords

Alzheimer's disease; dementia; mild cognitive impairment; serious games; taxonomy;

1 Introduction

Video games can be developed for the purpose of changing player's attitudes and behaviours, being both an expressive and a persuasive medium [3, 14]. With a persuasive strategy in consideration, for purposes other than pure entertainment, the long existing field of "serious games" has found broad application in the video games industry, attempting to educate, train, and inspire the players [28, 32, 36].

One of the key areas of application of serious games is the health domain, targeting changes in health-related behaviours. Games for Health (G4H) provide opportu-

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nities for players to improved rehabilitation, disease prevention, assessment, diagnosis and education/training [15, 30].

Within the wider health area, there are areas with particularly strong game development activity. One of these is the issue of dementia. Part of the motivation for research in this area is the current and predicted increases in the cost of dementia, both to the social welfare system, and to the wider fabric of society [22, 26].

However, the serious game for dementia (SG4D) field still has not been fully mapped out and classified. Sawyer and Smith [31] imply the need for top-down game taxonomical approaches ("You can't have a serious Serious Games Taxonomy without developing a taxonomy of all games"). The fact that an all-games taxonomy, a serious games taxonomy, and a G4H taxonomy have already been presented [31], opens the way for focusing on more specific parts of the G4H domain. The SG4D field, a part of the G4H domain, contains enough games and research studies and it is mature enough for analysis as a clear and *consistent* taxonomy, which could be further utilised for obtaining *predictive* abilities over the efficacy and efficiency of SG4D.

1.1 Contribution & paper organization

In this paper, we present a new taxonomical scheme for serious games for dementia and we apply it on existing systems for evaluation purposes. The contribution of this work is to:

- present a generic taxonomy of serious games for dementia, based on the health functions and the health purposes they serve.
- present an up-to-date review of dementia-related serious games (i.e. games targeting dementia, Alzheimer's disease, or Mild Cognitive Impairment), accompanied by their related research studies and classify them according to the proposed taxonomy for evaluating its validity.
- acquire an overview of the SG4D field - based on the proposed taxonomy and the literature review of dementia games – thus identifying the field's problems and potentials.

The rest of the paper is organised as follows. Section 2 examines the related work and Section 3 describes the motivation behind this study. Next, Section 4 describes the proposed taxonomy, Section 5 presents the application of the proposed taxonomy to existing dementia-related game titles and discusses the observations that came out of the application of the taxonomy. The paper concludes in Section 6.

2 Related work

The work of Sawyer and Smith on serious games' taxonomies [30, 31], under the Serious Games Initiative and Games for Health Project, is of significant value for the scope of this study. Sawyer and Smith in [30, 31] present a games-for-health taxonomy (Fig. 1) based on the type of health uses the games have and the stakeholders they involve. We also extend the work of McCallum [22], categorising the games for health according to the health area that they affect. Finally, our previous work on reviewing the existed dementia-related game titles and the research studies that accompany them [23], provides the basis for the ex-post evaluation of the proposed SG4D taxonomy. In [23], we presented a total of 12 video games targeting dementia-related health problems (dementia, Alzheimer's disease, and mild cognitive impairment), all of them supported by published, experimental studies.

	Personal	Professional Practice	Research/ Academia	Public Health
Preventative	Health Assets: PERMA, Exergaming, Stress, Nutrition	Patient Communi-cation	Data Collection	Public Health Policy & Social Awareness Campaigns
Therapeutic	PT/OT Sensimortor Rehabitain-ment; Disease Management	Pain Distraction; CyberPsycholo gy; Disease Management	Virtual Humans	First Responders
Assessment	Self Ranking	Measurement	Inducement	Interface/ Visualization
Education & Training	First Aid, Patient Education; Health Literacy	Skills/Training	Recruitment	Management Sims
Informatics	Personal Health record (PHR)	Electronic Medical Record (EMR)	Visualization	Epidemiology
Production	Personal Data Collection; Quantified Self	Biotech Manufacturing & Design	Biotech Manufacturing & Design	Large-scala Data Collection & Monitoring

Fig. 1: The Games for Health Taxonomy developed by the Games for Health Project [30].

3 The motivation for the SG4D taxonomy

The SG4D is a gaming field of high significance, due to its serious target. The variety of the SG4D game titles and the various health purposes they serve make the need for a classification scheme imperative. The motivation for proposing the SG4D taxonomy is twofold:

- to establish a classification scheme within which the position and, thus properties, of games relative to one another can be understood, and
- to act as a foundation for constructing a SG4D field knowledge base as part of the SG4D design and development process.

More specifically, since SG4D target specific types, stages or symptoms of the dementia disease and they also fulfill various purposes, their classification is of great significance for having a clear understanding of how the games and their properties are related to one another. Furthermore, a clear taxonomy on the field of serious games for dementia will stand as an assistive tool for SG4D developers by enabling them to focus on a specific, distinct research areas and target more accurately the dementia-related purpose that are trying to achieve.

Therefore, the motivation behind developing the current taxonomy further requires that it satisfies three distinct characteristics: *validity*, *consistency* and *predictive power*. The validity element allows the taxonomy to be an acceptable and accredited tool for the researchers and the game developers' community. The consistency of the proposed taxonomy will offer high taxonomic resolution and comparability of game datasets [8]. Finally, the predictive power of the taxonomy, given that a game A belongs to taxon x in category y, will allow us to infer that A has a set of X properties [10].

The validity and the consistency of the proposed taxonomy will be ensured by providing an ex-post evaluation of the proposed taxonomy based on the existed game titles (in the current study) and by collaborating with expert researchers from the "games for health" field for further evaluation. The predictive power will be assessed by documenting the correlations between the dementia game traits and their effectiveness' traits, as part of future work which will be based on the current preliminary study. The process will require breaking down each game into its attributes, and extracting the various aspects of the effects on patients. Having created a finer grained matrix of potential relationships, we will be able to examine their relationship, thus creating a potential training set for providing attribute predictions for instances/new SG4D titles that enter the system.

4 The SG4D taxonomy

The proposed taxonomy of SG4D is built on purely dementia-related taxonomic characters. The classification of dementia games is based on the dementia-related health areas they affect and the health purposes they serve. At the end of the proposed taxonomy we identify the user groups affected by the dementia-related games to provide a clearer overview of the health impacts. Schematically, the proposed taxonomy of serious games for dementia is shown in Fig. 2, following a circuit-schematic approach. A serious game for dementia might perform more than one health functions and also serve more than one health purposes simultaneously.

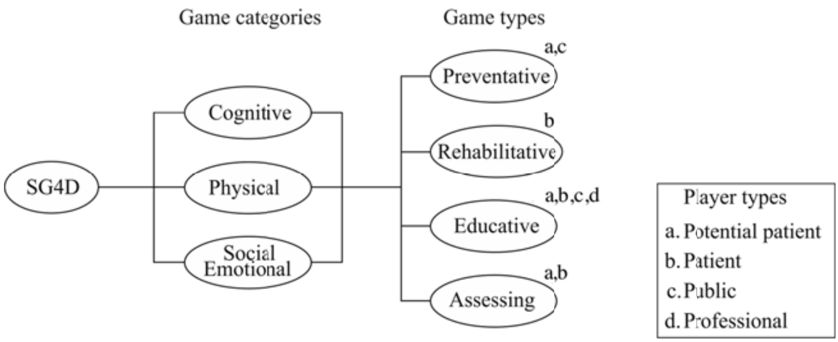

Fig. 2: The taxonomy of serious games for dementia.

4.1 Towards the SG4D taxonomy, taxonomic categories, characters and nomenclature

Dementia is a disease that affects the cognitive, physical and emotional abilities of the patients. The most common symptom of dementia is impaired memory; however it also results in impairments in thinking, communication, orientation, and coping with everyday tasks. Other symptoms are personality changes, anxiety, depression, suspiciousness, delusions and compulsive behaviours [26].

With this in mind, and based on the categorisation of health games presented by McCallum in [22], the broadest taxonomic category of the proposed taxonomy is associated with the dementia-related health function that the SG4D affect. Therefore, the upper "layer" of the proposed taxonomy is the "game category" dividing games into *cognitive games*, i.e. games that trigger the cognitive and mental abilities of the player; *physical games*, i.e. games that are developed for physical health, promoting physical activity; and *social-emotional games*, i.e. games that encourage players to link with their friends, providing shared experiences and discussion opportunities which enable the development of a sense of community.

Each of these dementia-related health functions/game categories serves a variety of health purposes. From a gaming point of view, we refer to this taxonomic category as the "game type" based on the nomenclature on the games-for-health taxonomy of Sawyer and Smith [31] and Sawyer [30]. Consequently, the SG4D can be *preventative*, i.e. games that keep the player physically, cognitively and/or emotionally active and slow down dementia's symptoms; *rehabilitative*, games that have therapeutic functionality and restore player's/patient's health; *assessing*, i.e. games that provide direct and accredited health data to the player about his/her health status; and *educative*, i.e. games that educate the player about the dementia disease, raise awareness or train the player to cope with dementia-related situations, thus containing informational and/or training aspects.

The core of the proposed taxonomy is two-dimensional, based on the aforementioned two intrinsic game-related characteristics (game categories and game types), however the identification of the SG4D health user groups/players is a useful representation of how the SG4D are connected with society and the disease itself. Therefore, Fig. 2 includes the "player types" categorisation, as an extra layer of significant dementia-related information, on top of the proposed taxonomical scheme. This categorisation is analysed further in Section 4.2.

4.2 Dementia-related health user groups

In our attempt to classify the SG4D based on dementia-related criteria, the need of identifying the health user groups that are affected by SG4D has emerged, in order to explore a more user-centric focused approach for the proposed taxonomy. The health user groups are categorised based on their relationship with the dementia disease and they are presented as the "player types" of SG4D.

There are four player types:

- *potential patients:* people who have not had a dementia-related diagnosis but their health status is at a critical point,
- *patients:* people who have been diagnosed with some type of dementia,
- *public:* meaning the part of the population who does not have a first hand relationship with dementia, and
- *professionals*, i.e. people who are not patients themselves but whose lives are directly affected by dementia in a professional way (e.g. academic researchers, professional practitioners, public health workers and caregivers).

The relationship of each player type with the dementia disease is visualised in Fig. 3. This diagram emphasises the distinction between the first hand experiences (patients and professionals) and second hand experiences (general public and potential patients).

The categorisation of the player types derives from the generic categorisation of healthcare stakeholders, presented by Sawyer and Smith in [31] and Sawyer in [30]

(Fig. 1), having undergone a number of adjustments to fit the dementia-oriented nature of the study.

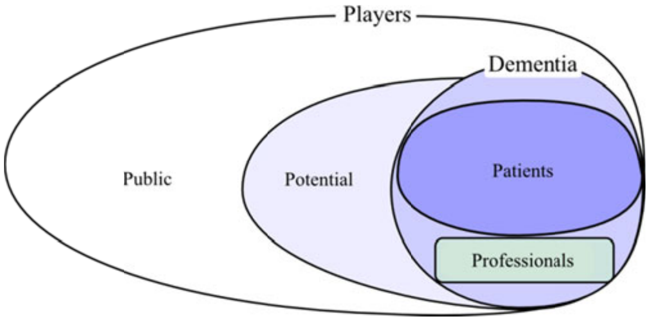

Fig.3: The proposed player types and their relationship with the dementia disease.

5 Applying the proposed taxonomy

To assess the practical value and validity of the proposed taxonomy, we turn our attention to its application to existing systems. In essence, we are interested in exploring whether the existing serious games for dementia can be validly classified, based on the proposed taxonomic characters. To this end, firstly, we collected and analysed a set of dementia-related serious games by performing a literature review [23]. The methodology for developing the dementia games literature review can be summarised in two stages:

- Scan the games which have been associated with general health and filter those to extract the dementia-related game titles.
- Narrow these games down to the ones that present a documented, peer-reviewed, and published effect on dementia-related health issues.

The motivation for the second stage is that we are dealing with a sensitive and serious health issue and the reviewed game titles have to be accompanied by credibility and validity. For a publication to pass stage 2, it has to be peer-reviewed, published and to examine the efficacy of a video game on dementia, MCI or Alzheimer's disease patients. We include a "games to be considered" section (Section 5.1), which includes games with promising potential but that lack studies supporting their effectiveness on players [23].

The reviewed publications were collected during November and December 2012 via a library database search, Google Scholar and Web of Knowledge search tools, scanning through academic databases including IEEE Xplore, ACM Digital Library, ScienceDirect, and Springer Link. The keywords used were ["dementia" or "mild cognitive impairment" or "Alzheimer"] and ["serious games" or "video games"]. Furthermore, the Google search engine was used to find commercially available cognitive training game titles.

Table 1 presents the games that are associated with the dementia games literature review. It contains a short description of each game, general information, as well as the supported gaming platforms and input methods. The final column presents all the related research studies [23].

Table 1: The games of the dementia games' review.

Game title	**Game description**	**Platform**	**Distri-bution**	**Input method**	**Dementia-related studies**
Big Brain Academy	A puzzle video game by Nintendo, testing the player's mental acuity in a five-category quiz: thinking, memorization, computation, analysis, and identification.	Nintendo Wii, Nintendo DS	Commercial	Wiimote & movement (Wii), Contro-ller (DS)	[12]
Complete Brain Workout	A collection of braining training games by Oak Systems, with 40 activities to stimulate and exercise the brain in an entertaining way.	Comput-er	Commer-cial	Type & click	[33]
Lumosity	An online brain training platform using personalized training to harness brain's neuroplasticity.	Compu-ter, Mobile	Commer-cial	Type & click (Compu-ter), Tap (Mobile)	[9, 13]
MasterQuiz	A tablet-based reminiscence game for mild dementia patients. The core of the game is a quiz with an image displayed on the left and text-based answers on the right.	Tablet PC	Academic	Tap	[22]
MinWii (MINDs)	A serious video game targeting Alzheimer and demented patients, working as a simple music therapy tool, which allows the player to improvise or play predefined songs on a virtual keyboard.	Computer	Academic	Wiimote & movement	[5]

Game title	Game description	Platform	Distri-bution	Input method	Dementia-related studies
Posit Science	Cognitive training gaming software that effectively address cognitive issues related to healthy aging as well as a broad range of other conditions.	Computer	Commercial	Type & click	[1, 29]
SmartBrain Games	A collection of brain training games by Educamigos, for youngsters, adults or seniors, to exercise the intellectual skills and to prevent their loss in a practical and entertaining manner.	Computer	Commercial	Type & click	[34]
Wii Sports	A sports game by Nintendo, which is actually a collection of five sports simulations: tennis, baseball, bowling, golf, and boxing.	Nintendo Wii	Commercial	Wiimote & movement	[11, 19, 35, 37]
WiiFit	An exercise game for the Wii console, with more than 40 activities and exercises including strength training, aerobics, yoga, and balance games.	Nintendo Wii	Commercial	Wiimote & movement	[27]
Xavix Hot Plus	A collection of twenty-four physical/sport games, offering rehabilitation support to the elderly.	XaviXPO RT	Commercial	Control-ler & move-ment	[38]

5.1 Dementia-related games to be considered

Supplementary to the literature review, we covered those dementia-related games, which present promising potential; however they have not been evaluated by studies, testing their effectiveness on dementia-related patients [23].

The brain training game *Brain Age* by Nintendo was developed based on the previous findings of the study of Kawashima et al. [18], which examined the effect of reading aloud and arithmetic calculation on elderly people diagnosed with dementia.

KiMentia is a Kinect-based Windows application, developed to help cognitive stimulation for individuals with dementia and presented in the study of Breton et al. [6]. The tool focuses on therapeutic aspects of both cognitive and physical stimulation by allowing the player to perform mental activities and physical exercise at the same time.

Using the paradigm of a serious game as a therapeutic tool for dementia, the *eMotiva project* introduces a collection of cognitive games for dementia, attempting to stimulate different cognitive processes such as memory or attention, trying to keep the patient motivated at all times [2, 7].

Another serious game, specifically designed for treating dementia/Alzheimer patients is an *untitled cooking game*, proposed by Imbeault and Bouchard et al. [4, 17] where a prototype has been developed, taking advantage of artificial intelligence techniques to create an accessible tool for cognitive training and allowing in-game estimation of the patient's cognitive performance.

A recent development in the dementia gaming area is the educational game *Into D'mentia* by Ijsfontein. The game consists of a physical, interactive space where the world of a person with dementia is visualized using Virtual Reality and players are able to experience the limitations and obstacles that a dementia patient faces on his/her daily life [16]. The game uses a simulation platform and it takes place inside a specifically customised truck. The goal of the game is to stimulate empathy for people with dementia and to raise awareness for the difficulties faced by these people.

5.2 Categorising the selected games

Table 2: Applying the proposed taxonomy.

Game Types / Game Categories	Preventative	Rehabilitative	Educative	Assessing
Cognitive	- Brain Age - Big Brain Academy - Lumosity - Posit Science - CogniFit - Complete Brain Workout - SmartBrain Games	- MasterQuiz - MinWii - Cooking game - eMotiva	- Into D'mentia	N/A
Physical	- WiiFit - Wii Sports	- MinWii - eMotiva	- Into D'mentia	N/A
Social/ Emotional	- WiiFit - Wii Sports - Big Brain Academy	- eMotiva	- Into D'mentia	N/A

Table 2 presents the application of the core proposed taxonomy (Fig. 2) on the games described in Table 1. The player types' categorisation (Fig. 2 and Section 4.2) can be consistently applied to the classified games of Table 2, according to their types (e.g. the game Brain Age, being of preventative nature, can be played by potential patients and the public).

5.3 Observations made from applying the proposed taxonomy

After applying the proposed taxonomical system on the existing research-supported dementia game titles, we can reach some interesting conclusions about the form of the SG4D field, as well as about the performance of the proposed taxonomy. At first glance, it is obvious that the majority of the existed dementia-related game titles are focusing on the cognitive and physical categories, serving preventative and rehabilitative purposes. The social-emotional function of the SG4D is mostly operating as a secondary element, coming from the multiplayer function of the games.

The educative type of games presents a small number of titles, presumably because of the difficulty to clearly define and cover the varied nature of the dementia disease within an educational game. However, there are informational and training programs and games that are currently being developed, and this space will hopefully fill out over time [20].

The most important observation is the complete lack of assessment games. The fact that there are no games in this category could mean that it is unnecessary and out of the scope of the proposed taxonomy. However, this type of game is being developed and there are already several dementia-related screening tools, like the Mini Mental State Examination [21], Montreal Cognitive Assessment [24], Neurotrack [25] et al., which could be gamified in order to keep track of the player's cognitive status and keep him/her motivated. Consequently, we consider this game type to emerge in the near future and we consider its inclusion to the proposed taxonomical system necessary for the system to be complete and up-to-date.

6 Conclusion & future work

The proposed taxonomy is able to give us an overview of the current SG4D field, classifying the dementia-related game titles according to dementia-related criteria. Having based the current study on previous knowledge, helped us to create a complete taxonomical system that focuses further inside the "games for health" field.

As future work, the proposed taxonomy will be evaluated by expert researchers of the field, with the goal of creating a collaborative, updated and validated tool, creating a synergy between game developers and dementia professionals. The ultimate goal - as described in Section 3 - is to develop a SG4D taxonomy with predictive power, aiming to provide attribute predictions for each new game title that is introduced.

7 References

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BKI: Brain Kinect Interface, a new hybrid BCI for rehabilitation

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Abstract

In this paper we propose the creation of a novel hBCI, which combines biomechanical signals acquired by the Kinect sensor with signals from the BCI system Emotiv EPOC through the strategy of selective attention, using SSVEP signals. The combination of these signals (MoCap and EEG-BCI) is used for interaction in a rehabilitation game for patients with motor and/or cognitive impairments. The system, providing a long and fluid interaction time, enables effective data collection that is aimed to objectively describe body movements through software developed for this purpose. The interaction with the BCI system is performed by the SSVEP which allows the user to explode objects in the air, through the controlled focus in a particular visual stimulus; the EEG signals are processed in the OpenVibe software. The Interactive Room for Rehabilitation, a real space plus a digital environment in which patients with neuromotor disabilities interact through their movements and thoughts, allows specialists to perform objective assessments of motor and/or cognitive aspects. Previous results suggest that acute exercise may enhance cognitive control through the management of visual stimulus.

1 Introduction

One of the most significant and promissory applications of brain computer interfaces (BCI) is used in the therapies to recover the loss of motor control caused by diseases and conditions such as strokes [Tan & Nijholt, 2010]. BCI have turned into a new and effective system for controlling applications such as video games (BCI games) and platforms of virtual reality (VR). One of the first investigators who contemplated the idea of combining simulations or games in VR with the BCI was Nijholt [Nijholt & Tan, 2008] who described the first games controlled by these interfaces focused in the diagnosis of cerebral signs in aspects as the measurement of the attention of the user or the relation of affective components with the games. To achieve the interaction of people in immersive games with BCI systems they are trained in the habit of using a mental strategy known as selective attention where, among others, visual predetermined stimuli (videos, images, animations on a screen) can be used to generate in the user Visual Steady State Evoked Potentials (SSVEP). In a typical configuration of a BCI video game the sign of every stimulus

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is associated with a command that controls a specific action inside the video game. In order to select a command the user has to focus his attention in the corresponding stimulus generating the intended mental intention [Graimann & Pfurtscheller, 2010]. The combination of motion capture sensors with BCI systems within a videogame could become a novel methodology for therapies with patients with brain problems that affect directly their motor skills, such as a stroke, Parkinson's disease, sclerosis, hemiparesis, neuropathies, squeals of trauma or surgery interventions, among others. In this paper we propose a new paradigm for immersive videogames where we use a combination of gestural and brain commandos to achieve a unique gaming experience. The resulting system supports the fundamental goal of the ubiquity: make the user (in this case the patient) move away from the classic desktop scenario of the computer-assisted rehabilitation, demanding physical mobility and mental dynamism to improve his/her evolution.

1.1 Kinect like tool for rehabilitation

Inside the context of the serious games there is a specific type that seeks to promote the physical activity by means of different roles in gameplay: the Exergames. These stimulate the mobility of the entire body by using interactive environments with immersive experiences that simulate different sensations of presence. The Kinect sensor allows a perfect integration with a computer beyond the console Xbox-360; in rehabilitation, the characteristics of follow-up and automatic assignment of points of interaction (Joints) to the users have turned this sensor into a powerful tool for the objective analysis of the movement. The Kinect allows performing motion capture (MoCap) and saving this in the standard format BioVision Hierarchical (bvh) [Parent & Ebert, 2010], that can be used later in software designed for biomechanical analysis. Comparative investigations of the Kinect have been made by other systems of capture of movement that need big assemblies and costly equipments [Chang & Lange, 2012, Fernández & Susin, 2012]. These works conclude that though the Kinect sensor is less precise, the measurements are inside a reliable range of measurement in aspects like positions and angles of movement. There are also works that aim to measure user's coordination and balance [Kayama & Okamoto, 2012], whereas others make an extraordinary combination between entertaining video games and capture targets of information to generate a more accurate diagnosis [Lange & Koeing, 2012]. The main reasons why the Kinect sensor is considered to be a successful tool for the rehabilitation are the following:

- The low cost of the sensor compared with the most economic system of motion capture in the market.
- Portability and comfort. This feature has pushed the researchers to propose systems of online therapies, which can be used by the patients in house or can be taken to places of difficult access. The information of capture can be

processed in a remote way by the specialist to generate a diagnosis without the need of a physical displacement of the patient to a specialized center. At the moment of using the Kinect sensor there are not any necessary specific lighting conditions or complex configurations neither in hardware nor software to carry out an information capture procedure.

- The perfect integration with tools of animation and video games allows the generation of interactive activities using virtual environments, virtual reality, augmented reality and immersive experiences across the use of corporal gestures and real time interaction. This allows breaking with the classic paradigm of a therapy where the specialist indicates routines and specific procedures in every session to the user.
- The possibility of recording patients' information in real time turns Kinect sensor into a powerful tool for the biomechanical analysis of the joints. Thanks to the depth camera of the sensor and its ability to trace points on the body of the patient in an effective way, there can be made mathematical calculations of movements relative to a system of reference in 3 coordinates, as well as the estimation of the Euler angles of each joint in each moment of the session. This type of information can be registered in graphs that record a log-book of the evolution of the patient in a specific period of time.

Platforms like IGEN of the University of Milan, VirtualRehab of the company VirtualWare and SeeMe [Sugarman &Weisel-eichler, 2011] are clear examples of robust systems for the managing therapy of rehabilitation through the Kinect sensor. The integration of the Kinect sensor in engines of video games like Unity3D is the point of convergence where the BCI systems like the Emotiv EPOC can be used as a whole by simple systems of movement capture as the Kinect or the Asus XtionPro. This type of technological mixture can be classified within what is known today as the hybridization of the Brain-Computer Interfaces.

1.2 Biomechanical analysis across Euler's angles

In the human body every segment is joined to its adjacent one forming joints that are fixed points in which the changes of position of the segments take place. For example when a forearm flexion is made, both the forearm and the hand with any weight that might be bearing are rotating on the articulation of the elbow. As the movement of the bodies in the space has six degrees of freedom, to be able to study the dynamics of the movement of the human body six independent coordinates are needed. Three variables correspond to the centers of mass of the body members, coordinates XYZ and three coordinates of movement, which are three angles of movement known as Euler's angles. Given these systems of coordinates with common origin, it is possible to specify the position of a system in terms of another using three angles α, β and γ . Euler's angles constitute a way of giving a numerical description of any rotation in a three-dimensional space using three numbers. Nevertheless, this approach has been widely criticized as a method for describing the possible articulated movements, since the use of this method imposes a very strict order of sequence in the description of the rotations that cannot be altered [Woltring 1991]. Due to this problem with the goniometric description of the angles in 1983 Grood and Suntay introduced the concept of a coordinated system of a joint to describe Euler's angles in the joints of the human body [Grood & Suntay, 1983]. To present Euler's angles in a form that is much easier to understand for a biomechanical clinical investigator, they determined the angles using vector analysis from a system of articular coordinates of the position of every joint, not with a fixed axis but with a floating or movable axis in the frontal, sagittal and rotational planes, describing three natural movements of the joints of the human body in spatial coordinates that allow to determine the Euler's angles or rotation of each of them in a most successful way.

1.3 Steady State Visual Evoked Potentials (SSVEP)

SSVEP are neural signals that occur in response to visual stimulation of certain frequency, they can be captured by BCI systems to generate an interaction through the selective attention of the user. The SSVEP have three distinct components: a primary component located in the gamma band (25-60) Hz, with little inter-subject variability and a latency of (30-60) ms, a secondary component in the range of (15-25) Hz with high variability between subjects and latencies ranging between (85-120) ms and finally a rhythm component of 15 Hz below with a mean latency of 250 ms. The paradigm of using SSVEP to handle the BCI system was introduced by Regan in 1979, the idea is to control interfaces of buttons with visual evoked potentials [Vialatte & Maurice, 2010]. The robustness of the SSVEP-BCI systems controlled by external visual stimuli has become a more manageable tool for the implementation of these interfaces since their ratio signal/noise is becoming more reliable. Accuracies within SSVEP games have been measured according to each player's correct responses to the stimuli. SSVEP games had a high average accuracy of 92 %. This suggests that the paradigm is accurate and works well within BCI games. Subjects within SSVEP game trials were given little training in comparison to subjects of motor imagery mental strategy, within certain trials the subjects learned to control the game and were tested within the same session. This suggests that SSVEP is an excellent paradigm for BCI games (high accuracy and short training periods) [Marshall & Coyle, 2013].

1.4 Hybrid BCI

Despite impressive advances in the industry of BCI systems, product diversification and globalization of the study of this area of neuroscience, the state of the art in multiple applications shows that effective interaction with BCI applications and assistive devices is not usually maintained for long periods of time without the aid of an expert [Millán & Rupp, 2010]. This statement is not intended to delegitimize the great moment this technology is experiencing; it simply seeks to bring closer the BCI community to a possible solution: using the BCI systems as an additional input channel for the application. A hybridization using a combination of multiple signals, including at least one BCI channel, called a hybrid BCI (hBCI). The combination of signals coming from BCI systems with other biosignals, e.g. electromyography (EMG) signals or particular biomechanical signals obtained through motion capture systems (MoCap), may allow more stable and durable control of an application or device. As additional input signals electrocardiographic signals (ECG), or external signals of other control devices such as cameras, proximity sensors, accelerometers, pulse oximeters and other electronic sensors can be used. Hybrid BCIs, like any BCI, must fulfill four criteria to function as BCI [Pfurtscheller & Allison, 2010]:

- Direct: the system must rely on activity recorded directly from the brain.
- Intentional control: at least one recordable brain signal, which can be intentionally modulated, must provide input to the BCI (electrical potentials, magnetic fields or hemodynamic changes)
- Real time processing: the signal processing must occur online and yield communication or signal control.
- Feedback: the user must obtain feedback about the success or failure of his/her efforts to communicate or control.

2 System Overview

The proposed hybrid scheme for testing videogames for rehabilitation in this work is one that involves the motion capture data from a non-invasive Kinect sensor, which allows a natural interaction through body gestures and real-time avatars, objects and virtual environments, a BCI system that works with visually evoked potentials which allow to establish a relationship of the concentration level of the user in a particular action within a game role. The system has been called BKI (Brain-Kinect Interface) and image 1 shows a general scheme of it:

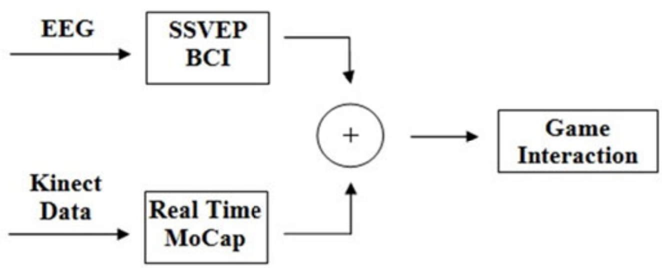

Image 1: Scheme of the Hybrid BCI system proposed (BKI)

The resulting hBCI system actively involved patients with neuromotor diseases in video games with motion capture and BCI interactions, significantly improving the dynamics of the classic BCI game systems through the change of traditional systems of data input such as the keyboard and the mouse, for a real time motion capture system which enables the movement of the body parts assigned to an avatar as hands, feet, knees, head and trunk (among others), allowing the interaction with the BCI system more punctual actions such as the levitation of objects, the collision of an object with another, among others. The system is completely wireless, which greatly facilitates the comfortable interaction of the user with the videogame, also uses a large video projection, subdued illumination and sound effects to make the experience more immersive.

The final platform is implemented in an Interactive Room for Rehabilitation (SIR) where assessment of motor and cognitive aspects of the patients is done through video games, using the Kinect and Emotive EPOC sensors. This room is located in a rehabilitation center where therapies and sessions are conducted for the recovery of patients who have suffered motor damages and/or cognitive/neuromotor diseases. It is an interactive space where we use Exergames specially designed to improve motor skills such as balance and dissociation. Recently, the inclusion of the EPOC and the study of BCI systems have opened up the range of variables to be analyzed by the medical community in the rehabilitation center: cognitive variables that range from the attention and concentration level of the user to the objective measurement of emotional states. Although studies in patients are still ongoing, this paper seeks to fathom into the technology assembly and proposed hybridization to expose the previous results obtained from the study in patients. These video games projected on an immersive room allow specialists to work on variables such as balance, coordination, dissociation, the recovery of mobility and strength. Once identified the pathology, the required type of exercise and other parameters of the session, the patient is located approximately 200 cm from the Kinect sensor and the projection and is ready to interact with the game through his/her gestures and movements.

Now, one of the most common weaknesses in research and implementation of serious games for health, as reported by the psychologist and world expert Pamela Kato in [Kato 2012a] is that appropriate or objective measures are not performed while conducting sessions with video games. The incorporation of standardized measures in the research project usually facilitates comparison with other studies looking for increasing the amount of objective results and reducing the anecdotal [Kato 2012b]. However, in order to generate objective measures relating to displacement and the angles of precession, nutation and rotation of each joint, we have created the Bio-Cirac v.1.0 software, which allows the quantitative analysis of the user’s movements session by session.

The inclusion of BCI interaction requires a prior training of the user, which is to perform an initial calibration of a state of "neutral" thinking of the user 10 seconds approximately, after this, using a specific animation action that is required to be controlled in the game through the BCI system. Afterwards, the animation produces in the user an SSVEP, which is registered in the EPOC software. This training allows the system to distinguish between the so-called neutral state of the user and his/her reaction to particular visual stimuli, which are evoked within the dynamics of the game. Once registered, the user must concentrate to perform the levitation of the object (for example) just at the moment where instructed to do so, if this fails, the user is re-trained using the same procedure previously described. This is done in order to obtain the maximum level of control over the BCI interaction to generate a dynamic fluid interaction as is done with the Kinect sensor; this aspect keeps the patient entertained throughout the whole proposed session, making more efficient the therapy. This methodology allows the inclusion of interactivity through the BCI system using visual evoked potentials within Exergames. Generally, the movement of the user tend to cause the so-called *artifacts* into the EEG signals, to avoid this, we used the *Temporal Filter* tool with a 1 Hz – 60 Hz pass-band filter in OpenVibe software for EPOC signal preprocessing. OpenVibe is a free and open source software platform for design and implementation of BCI experiments (http://openvibe.inria.fr).The game engine used is Unity3D in its free version, which enables a complete integration with the Kinect sensor motion capture data; the *Cognitive Suite* of the EPOC is used to achieve the BCI interaction within the virtual scenario through the effective generation of SSVEP by training performed.

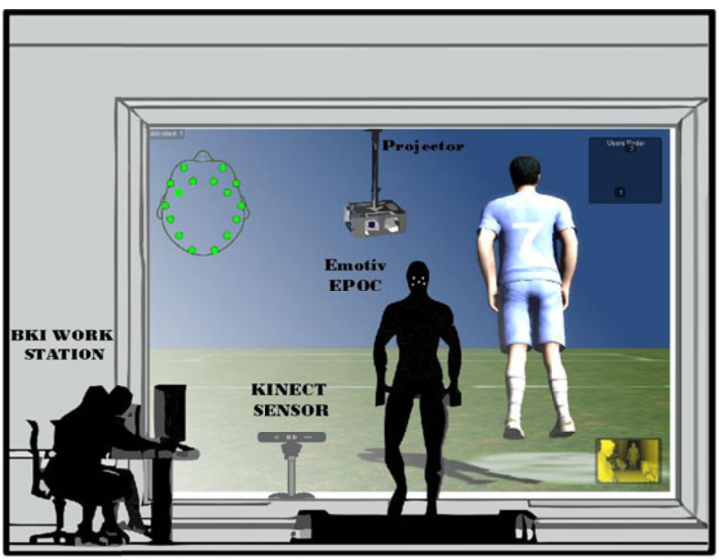

Image 2: Proposed BKI System assembly.

The complete system includes a workstation for the BKI system, the Kinect sensor located at the bottom of the enclosure, a video projection and the BCI system connected to the patient. Image 2 shows a diagram of the SIR assembled in the "*Unidad de Acción Motora*"of the *Clínica del Dolor del Eje Cafetero*.

The interactive system used by the patient and the specialist can be divided in three fundamental parts.

2.1 Interaction

The test begins with the video projection of the game. It is important to mention that the lighting conditions and the quality and size of the image are important elements at the time of achieving an immersive experience. The games must be a simple dynamic in which the specialist seeks to introduce the patient in a role playing game of a trivial level of competitiveness. Grasp elements, jump obstacles, move, bend and swing with balance are the active parts of the interaction proposed by these games. The time of interaction can be programmed by the specialist according to the patient and the characteristic of the game, often the user can use elements such as weights, ribbons, strips and any other physiotherapeutic elements that do not obstruct widely the space between the user and the sensor. In the interaction with the BCI system, the user, after being trained, uses his mental-control skills to perform an action over a specific object of the scene (levitation, destruction, removal, etc.) when the game requires him to do so. Usability and fluidity tests are performed in the interaction with the whole system in order to verify the relevance of hybridization in the field of rehabilitation. Generally the user takes an average of 3 trials in the concentration required to generate the signal in the first interaction with the game after the training session, however in the following sessions and to the extent that the user increased their physical activity within the game, the mental action control improved and only needed a single attempt to reach the goal, which suggests that acute exercise may enhance cognitive control through the management of visual stimulus.

2.2 Data Capture

In parallel the specialist can run the application of motion capture BrekelKinect (www.brekel.com) which is a powerful free tool for capturing Kinect sensor data to a bvh file. This standardization of monitoring data from the user's skeleton has allowed a more dynamic integration with the medical community in the rehabilitation area with this technology, as it allows transforming a measurement process that is usually done in analog way through goniometers in a fully automated, user-friendly way, without annoying connections, portable, easy to install and with reliable measurements. In [Khoshelham & Elberink, 2012] is shown that the random error of the depth measure in the Kinect sensor is directly proportional to the distance between the sensor and the user, ranging from a few millimeters up to a maximum of 4 cm in the maximum range of the sensor (about 4 m). The user registration is organized in the form of log-book segments each session for review at any time by specialist.

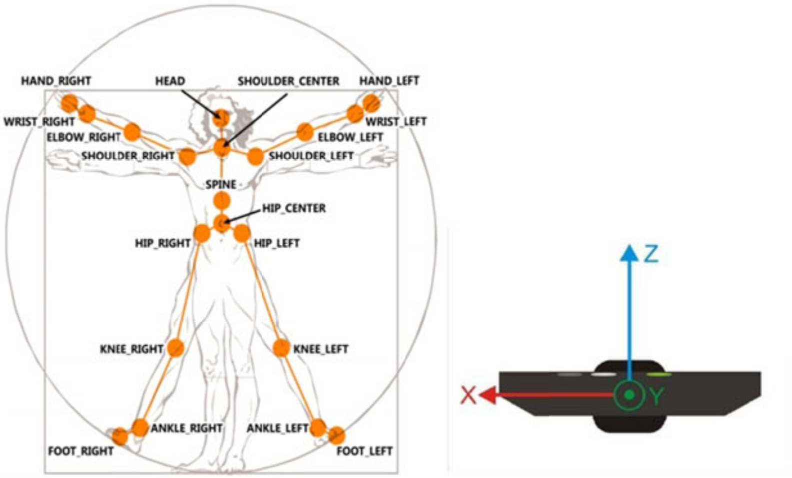

Image 3: Left: convention of Joints handles by BVH file captured by the Kinect sensor. Right: Kinect sensor coordinate system.

At this stage, the specialist must ensure to capture the user's movement at the right time; an extensive capture can yield a file of great weight that often becomes difficult to manage in the analysis stage. The convention managed by the file format and the Kinect sensor is as shown in image 2-3. The specialist chooses the right time to start capturing data as well as to stop doing it. This stage ends with one or more records of the movement of users through bvh extension files, for example "capture_0000.bhv", which are the raw material for the analysis stage. Data from the BCI system is captured using OpenVibe through the acquisition of the Emotiv EPOC Research Edition Pack and these data is labeled when the user has to perform the mental task to continue the game. Monitoring by OpenVibe to generate topographic maps in 2D, 3D and voxels while the user is playing, this tool allows correlating movements and mental intentions of users with sensorimotor rhythms throughout the entire game.

2.3 Data Analysis

At this stage, the specialist after completing the session with the patient and having obtained the corresponding MoCap file will have to use the Bio-Cirac v.1.0 software developed by the team to load the file into a proposed user interface. This software uses libraries developed by Neil Lawrence for the use of MoCap files with bvh extension. Bio-Cirac allows visualization of the BVH files, the software shows a graph relating the joints (each element of the skeleton) with the skeleton of the user in three a dimensional space and shows also each joint axes (X-red, Y-green, Z-blue). Image 4 shows a preview of the software developed for the analysis of motion capture data obtained through the Kinect sensor, Bio-Cirac v. 1.0.

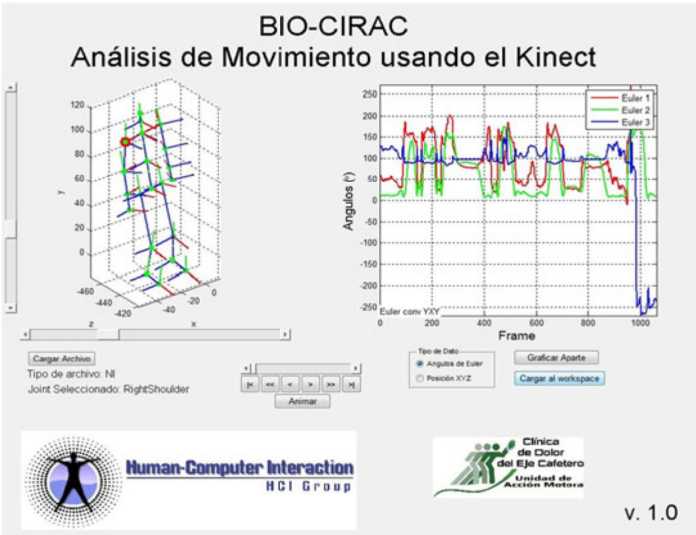

Image 4: GUI designed for Bio-Cirac v.1.0 software, which allows loading the motion capture file and generating graphs for analysis.

Now, in order to obtain the graphs of the Euler angles of each joint, the desired articulation is selected in the 3D skeleton of the user. There are two types of graphics that the software makes; the first is the Euler angles which is a two-dimensional graph that contains information concerning the frames vs. the Euler angles, which are calculated according to the ZXY convention. This graph shows the behavior of the precession angle, frontal plane (α: Euler 1, red), the angle of nutation, sagittal plane (β: Euler 2, green) and rotation angle, transversal plane (γ: Euler 3, blue) vs. total catch in frames, this graph can be analyzed separately through the graph apart button, allowing the use of graphical analysis tools such as zoom and cursor data and export of the graph in an image as JPEG format. For easier analysis, it is recommended not to take more than 1 minute captures, because the volume of data contained in these files requires a significant processing capacity for analysis. The software has a very simple user interface, where no prior knowledge is required. The second type of graph is relative to the XYZ position of each joint, these are captured according to the coordinate system of the Kinect sensor although the origin is relocated to the initial body position (in line with the spine, but at the level of the floor).

For analysis of data from EPOC we use OpenVibe where *scenarios* are designed using the concept of *box*, blocks or elementary components that contain algorithms that help to reduce the development time of BCI experiments. The proposed design for the analysis of signals containing an acquisition stage, filtering and removal artifacts (temporal filter), windowing and signal averaging and finally create 2D/3D topographic maps. With these maps we perform pre and post analysis of neuronal plasticity of users and previous results show a significant increase of activity in the occipital cortex measured at O1 and O2EPOC electrodes. A figure of the *scenario* on OpenVibe with maps is shown below:

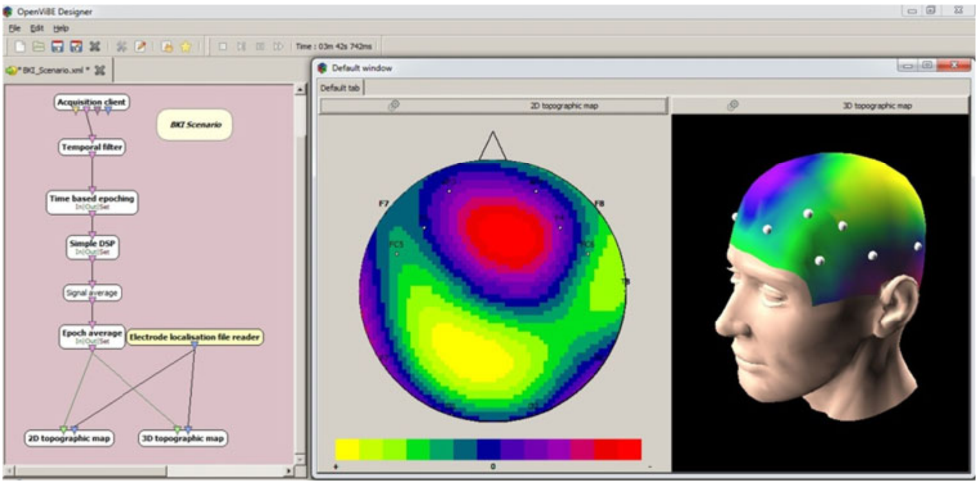

Image 5: BKI Scenario designed for EEG-BCI data analysis using OpenVibe

Deeper analysis of the platform may lead to correlate the duration and type of stimulus to exercise-induced changes in variables such as the latency of the SSVEP signal.

2.4 Cognitive Balance Game Description

To test the operation of the interactive system we made a video game to improve the ability of balance, arms movement and the concentration of the user. The game consists of an avatar that skates over a fixed virtual trunk, the user must try to remain standing through balancing while following a proposed route. When the user starts to lose his/her balance, the avatar is inclined to one side, moment in which the user must compensate this inclination with movements (light or exaggerated) towards the other side. Even there, the game works like a traditional Exergame, however every 15 seconds an object approaches towards the user in the trunk line from the virtual sky, at which time the user must gaze the object and evoke the prior-trained mental command to explode the object in the air before it collides with the avatar. In the case that the user achieves to explode the object before the collision, the avatar can follow its course by the infinite trunk, however if the user fails to concentrate to produce the required SSVEP signal for the object explosion in an approximate time of 8 seconds, the object will collide with the avatar making it fall from the trunk and forcing it to start again. The explosion of the objects is counted within the game as well as the duration of the avatar without falling from the trunk in order to generate positive stimuli and encourage the patient to continue efforts to get better scores after each session [Adams & Marshall, 2009]. The user must have an optimal control of the BCI system, i.e., must be able to generate the signal dynamics trained to continue playing. The game ends when the user reaches a determined score by exploding a number of objects.

The integration between the medical staff of the Unidad de Acción Motora and engineers of the Universidad Tecnológica de Pereira has allowed the creation of this hBCI system, which despite being in its implementation stage, promises to be a robust tool for a comprehensive analysis of the rehabilitation processes of motor and/or cognitive diseases of patients across the country, providing not only an outstanding interactive dynamics for the patient but also accurate and reliable movements and cognitive intentions specialist referral.

3 Conclusion

We developed a new hybrid interface that combines the signals of motion capture acquired by the Kinect sensor with the obtained by a system BCI to combine in a video game for the rehabilitation of motion and/or cognitive impairments; the system BKI is a new hybrid approach of the BCI systems, which offers a significant improvement in the naturalness of the interaction of these interfaces specifically in video games. We developed a video game based on the combination of an Exergame with a BCI game, in which there used the real time motion capture of the Kinect sensor and a methodology for the interaction across SSVEPs taken of the neuroheadset Emotiv EPOC for rehabilitating patients with neuromotor injuries or disease. The system besides offering a entertaining therapy to the patient, allows the medical specialists an objective analysis of the movements of the user across the developed software Bio-Cirac v.1.0, which shows graphs of the movements of up to 20 joints in the body sensed by the Kinect, as graphs that relate frames to the 3 Euler's angles used in biomechanics to describe the angular movements of every joint in the frontal, sagittal and transverse planes. Finally, the use of OpenVibe software allows recording and processing of EEG data captured from the user while playing for measurement of concentration, relaxation or SSVEP signal latencies, as well as the impact that physical activity can have on the control of BCI system. We think that this hBCI allows enriching the therapies of users' rehabilitation with multiple disabilities, at the time that it allows to save a log-book of the evolution of the patient in cognitive aspects and proper mobility. Probably one day in the future we manage to have an ideal connection between our movements and our thoughts in a physically real avatar, in the best of James Cameron style.

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Development of a theory-based applied game for the treatment of Post-Traumatic Stress Disorder: proof of feasibility

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Abstract

Post-traumatic stress disorder is a potentially debilitating psychiatric condition causing severe distress and significant loss of productive employment years. In a recent experiment we developed a therapeutic virtual reality protocol based on already proven successful non-pharmacological theories for treatment of this disorder. The initial immersive virtual-reality sequence was developed on the Computer Assisted Rehabilitation ENvironment (CAREN) and is called 3MDR: military motion-assisted memory desensitization and reprocessing. Furthermore the 3MDR sequence uses principles of cognitive behavioral therapy and eye movement desensitization and reprocessing. After performing a proof of concept the 3MDR-sequence was translated into an applied game called "Achilles Initiative: the Battle for Sector 1". Central in the applied game is that subjects, prior to playing the game deliver pictures of high emotional affect, that are loaded into the game. As such the game uses principles of augmented virtuality. In the game the participant passes several distinct phases: preparatory, therapeutic and mental cooling down phase. Afterwards a debriefing with the therapist is performed. The game can be run automated, but a therapist is always present. The development process and the feasibility of this game for therapy, based on preliminary patient experiences are discussed.

Keywords

PTSD, 3MDR, CAREN, Serious Game, EMDR, Military

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1 Introduction

Posttraumatic stress disorder (PTSD) is a potentially debilitating psychiatric disorder. The functional impairments and disability patients suffer can be tremendous. In the military the patients are usually young men who still have a large working potential ahead of them. Therefore, the costs accompanying this disorder, both personal and societal, are very large when paid work is not possible for years [1]. The non-pharmacological treatment of PTSD consists usually of cognitive behavioral therapy (CBT) and/or eye movement desensitisation and reprocessing (EMDR) [2]. Both therapy forms appear to be effective, but adherence to therapy is a problem [1,3].

EMDR is a form of imaginal exposure accompanied by saccadic eye movements. The eye movements (e.g. elicited by following a oscillating finger) are introduced as a form of dual task processing for the high emotional load so that it can enhance desensitization for the disturbing memory. It is generally believed that the limbic system plays an important role in the memory formation and desensitization of the stressor. We have used principles of CBT and EMDR and translated those into a therapeutic virtual reality sequence (3MDR; http://www.youtube.com/watch?v=3rmJ4ySMAcY) on a motion platform with a 6 m 180 degree field of vision [4,5]. Integrated in the platform is an instrumented treadmill. Prior to the start of the session subjects deliver 5-7 deployment-related pictures with a high emotional affect. The pictures are loaded into the routine and as they virtually walk towards a picture it slowly enlarges to about 3 meters. The therapist facilitates maximizing the stress level, after which a desensitizing stimulus in the form of an oscillating ball appears on the screen. This process repeats itself 5-7 times, depending on the amount of pictures delivered. It is expected that in general 6 weekly sessions should suffice, but this will have to be substantiated in further research.

An important problem with conventional therapy is that the therapy is intrusive, intense and in general experienced as boring. Hence the therapy adherence is quite low [6]. Virtual reality in combination with gaming principles might offer an engaging, compelling and challenging therapeutic environment that enhances therapy adherence and therefore also better therapeutic results.

It was hypothesized that translating the 3MDR sequence into an interactive game would create a truly interactive and engaging therapeutic environment, enhancing therapy adherence and a sense of control. In this study the process of translating the sequence into the game "Achilles Initiative: The Battle for Sector 1" is described and also the feasibility of using the game as a therapeutic instrument.

2 Method

Research group. The research group consisted of people from the medical, art, game design, sound engineering and computer programming disciplines.

Hardware. The CAREN-extended version of MOTEK Medical was used. This system is a 6 degrees-of-motion platform with an integrated instrumented treadmill, real-time motion capture system, a 6m 180 degrees visual projection system and a 5.1 Dolby Surround audio system.

Software. The game engine used was the D-FLOW 3.10.0 and the scripting language LUA 5.1.4.

Game. During the development of the game the 3MDR sequence was to be respected, which means people had to deliver pictures with high emotional affect that had to be loaded into the program. Furthermore people had to familiarize themselves with the virtual environment by walking on the treadmill. The therapeutic sequence consisted of 5-7 runs, depending on the amount of pictures delivered. Afterwards a mental cooling down period was initiated where the subjects had to walk for several minutes and let their stress levels decrease and also a debriefing with the therapist took place. For the game it was decided to use a science fiction environment, as those kinds of environments are not present in daily life and would not result in a potential negative conditioned response when encountering similar situations. Also when using principles of the 'theory of presence' life-like situations are not necessarily needed, but the willingness to suspend disbelief of being in a mediated environment is considered essential [7]. It is therefore a cognitive concept and in layman's terms best described as a sense of 'being there'. To enhance a sense of accomplishment it was decided to make the game circular, the subjects starts and ends the game in the same virtual space.

Subjects. One subject who had been diagnosed and treated for deployment related PTSD for more than ten years ago, volunteered for initial game testing. Distress levels were measured by asking the subject to rate them on a scale of 0 to 10.

Time span. The game development and feasibility testing was done in a period of three months.

3 Results

3.1 Development

The game design team familiarized themselves with the 3MDR sequence at the Military Rehabilitation Center. Furthermore they had to learn about PTSD. This was facilitated with a lecture by the Military Mental Health Unit and a conversation with two patients who had been diagnosed with PTSD. After this period a brainstorm session was planned with the program leader from the Military Rehabilitation Center. Game concept selection was based on the 'Scope Model' by M. Hrehosvcik [8]. In this model several concepts are made iteratively and after review a final concept is selected.

Eventually a science fiction adventure game set-up was chosen. The core of the storyline is that the subject is in a wrong timeline and has to return to the past to fix the present. Much like the analogy of CBT and EMDR.

A total of four environments were created for the game, namely *A. The control room.* This is where the game starts. The subject finds himself in a control room where he is asked to start a mission. If he accepts the games commences. *B. The Nexus.* This is a safe environment to where he is initially transported. The sounds in this area are clear, peaceful and whale-like. The environment is white, blue vivid and has a broad horizon. The subject can walk there for several minutes to familiarize himself with the treadmill, but also to give a final 'go' for start of the therapy. In this environment he will encounter "Reva", a flying robot, a companion who will accompany and help the subject. *C. Game space.* In the game space the subject walks in a hall of a space ship and is surrounded by flying robots which he has to destroy by hitting them with his fists. The environment is narrow and has side corridors in which 50% of the time the picture for that specific run is presented. Also the end of the hall is closed by doors that will open automatically when close enough. In this environment the sounds are threatening, abrupt, unpredictable. *D. Reprocessing space*. After having walked through several corridors, the subject enters the reprocessing space. This environment is dark, looks shattered and has electric sounds. In this space the subject walks towards the picture and when the picture size is about 3 meters, 'Reva' takes the role of a desensitizing oscillating object (analogous to EMDR therapy). After 45 seconds the subject is allowed to (but not necessarily has to) destroy the picture by hitting it. This latter is done to enhance the patient's feeling of control over the situation. Environments C and D are then looped according to the number of pictures delivered.

The complete sequence looks like: A-B-C-D-B-A. The second time the subject enters environment B, there are also positive pictures present of for example family members. This is done to replace the possible negative emotions and to help the patient get back into the real life. Afterwards a debriefing with the therapist takes place.

The video-footage of the game can be seen at http://www.youtube.com /watch?v=Ba8r8p0qNzE.

3.2 Feasibility

There were two play testing events with the patient. In the first neutral pictures were shown, this was done to distinguish the influence of deployment related pictures on the sequence. In the first event the experienced distress level was 7/10. In the second event where context specific pictures were used the distress level was maximal. The subject thought the game was engaging and although the stress levels were maximal, he wanted to go for another session. Het told us he felt a sense of mastery over the situation.

4 Discussion

This feasibility study shows that a theory based approach of PTSD, by first taking as a starting point regular therapy, translating those principles in a virtual reality therapeutic sequence and then into a game is a potentially successful approach. During the development phase an iterative approach seems necessary. The developed environment on its own was able to give a significant rise in distress levels, pointing towards a good game design. Adding context specific pictures in the game further increased the distress levels, showing that adding augmented virtuality into a game facilitates exposure. Further research is needed to determine whether the concept is viable as a therapeutic instrument in adjunct to regular therapy and/or on its own. Preferably, a clinical trial should be performed where the Achilles Initiative is compared in terms of effectiveness, engagement and therapy adherence to the 3MDR sequence and regular psychotherapeutic intervention. Similarly, a study can be designed where the Achilles Initiative is an adjunct of regular therapy where this therapy scheme is then compared to for example regular therapy alone. This should give satisfactory information on the ability of virtual reality and serious games to potentially augment or even replace regular therapy for post-traumatic stress disorder.

Although the use of virtual reality for the treatment of PTSD is relatively new, the results however seem promising [9]. This research project shows that it is potentially possible to use game mechanics for the treatment of PTSD and to our knowledge this is the first serious game specifically developed for the treatment of PTSD. Furthermore, besides incorporating CBT, EMDR and exposure in one gaming session, the patient is not sedentary but walks. We have not come across any other study where walking is an integral part of a PTSD treatment session. Therefore, it is not known what the potential benefit for the patient might be, but what our (military) patients have told us after the 3MDR sessions [4,5] is that they like being active during 3MDR and that walking during the sessions gives them a sense of control.

In general, virtual reality based therapies for PTSD focus on recreating the stressing environment. This is a time-consuming process as every situation is different [1,9]. The “Achilles Initiative: the battle for sector 1” shows that instead of recreating patient-specific virtual environments the use of context-specific pictures in a predesigned virtual environment is highly effective in maximizing distress levels and this is in accordance with our previous work [4,5]. The process we have developed takes less than 5 minutes to load all the pictures into the game and a session is completed in 45 minutes. This makes it suitable for daily practice as outside the scientific realm, therapists have time-constraints regarding allocated therapy time per patient.

As a final remark, although the CAREN system is a high-end motion platform with superb analytical possibilities, the principles in this game are generic and, if validated in larger studies, can be easily translated to a low-end game console/pc as long as a treadmill is present.

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Children's Health

DYSL-X: Design of a tablet game for early risk detection of dyslexia in preschoolers

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Abstract

The goal of the DYSL-X project is to develop a tool to predict whether a preschooler (5 yrs) shows high risks for developing dyslexia. This tool is a tablet game that incorporates tests to take specific performance measures that allow for this prediction. The game will thus serve as an assessment tool to be used in school psychology services and clinical diagnostic and rehabilitation centers. In order to design the optimal tablet game for preschoolers, during the first phase of the projects several existing games for preschoolers were evaluated in order to derive design guidelines for games targeted at preschoolers. These design guidelines are presented in this paper and next, we show how these guidelines were used to develop the final game of the DYSL-X project.

1 Introduction

Dyslexia refers to specific problems to acquire reading and spelling skills despite adequate intelligence and instruction. It has a prevalence of 5-10 % in the population [1, 2]. The first signs of dyslexia are typically observed during the first year of formal reading education (age 7 yrs), but very often the diagnosis is only made at an older age. However, dyslexia is a developmental disorder that should be detected and treated as soon as possible. The younger the age of the child at the start of a therapy, the larger the long term effects. Early risk detection allows for taking preventive measures, which has been proven to be effective, even at preschooler age.

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Recent scientific studies provide us with a better understanding of predictive variables for dyslexia that can be measured, even in a preschool population [3–8]. The aim of DYSL-X is to integrate these predictors in a computer game, an aim to similar [9]. The underlying motivation of the DYSL-X project however is twofold. First, by using a game, preschoolers will display a higher motivation, a longer attention span, and as a result a more accurate measurement can be taken. Consequently, incorporating these measurements into a game will improve the quality of the tests and result in a more reliable and more valid prediction. Secondly, the DYSL-X game-based application will come with automated measurements and scoring. Therefore, no qualified personnel is needed to administer and score the tests. This allows for the deployment of DYSL-X at a wider scale, increasing the utilization potential. However, in order to develop the optimal assessment of the onset of dyslexia we need not only to understand how to measure the predictive variables, but equally how to design an optimal game experience for preschoolers, based on a thorough understanding of what constitutes fun for preschoolers. In this paper, we will describe the design process of the DYSL-x game based assessment tool, with the aim of achieving a high play motivation of preschoolers. We emphasize that in this paper we will not focus on the validation of the game, this will be the focus of forthcoming papers.

2 Rationale of the project

Existing dyslexia tests with preschoolers[4, 6–9] already aimed at gamification [10]. Researchers made the user interface more attractive and added animations in order to increase the motivation of the child [5, 11]. However, the researchers conducting the gamified tests mentioned that it was still difficult to keep the child's attention at a high level throughout the test. It was suggested that a higher accuracy can be achieved by finding better ways to motivate the child. The challenge remains how to elicit a 'rich game play experience' and not just [12] coating while offering a reliable and valid test platform. It is important for game designers to address the true gratifications of this new gaming audience. As existing theoretical frameworks on meaningful gameplay for preschoolers are rare, dated and lack a comprehensive validation [13], we conducted a User Experience study (i.e. UX) Laddering [14, 15]) to unveil the gameplay preferences of preschoolers. This study resulted in a list of meaningful and useful guidelines for future game designers, directed at this specific target group. In this workshop paper we present these design guidelines, and next, we demonstrate how we applied these to our own tablet game.

3 Method

UX Laddering is an interview method that aims at unveiling the underlying motives for preferring one product over the other [14]. A comprehensive explanation of the method is besides the scope of this workshop paper, however, we refer the interested reader to the paper of Celis et al. [13] for more information. In short, 25 five-year olds were invited to play eight different games.

These digital games were selected in view of some predefined research questions that seemed interesting in the field of game design for preschoolers. For each element of interest, two games with contrasting features were selected. The first item related to the applied input device. Do preschoolers prefer to work on a tablet on the one hand or a laptop on the other hand? For this comparison, the child played the same game, i.e. Angry Birds, on both devices. Next, two different fantasy worlds were compared. In order to avoid gender biases, two comparison pairs were formulated. The first pair contained a dress-up game i.e. Dora Dress-Up, and a game of skill, i.e. K3 and the Ice Princess – Frog Game: Catching Frogs. These games were in the first place marketed at girls and were both performed on a laptop. The next comparison pair contained two tablet games, that might appeal more to boys: a construction game, i.e. Toca Robot Lab, and a race game, i.e. Drawrace. Finally, we wanted to elucidate which narrative progression structure children prefer. Therefore two laptop games with a similar fantasy world were compared: a more linear adventure game, i.e. Putt-Putt, and a learning game with a hub world of different mini-games, i.e. Clifford. Consequently, four comparison pairs were obtained, which invited the child to make relative comparisons and judgments between two technologies.

The games were offered in pairs and preschoolers had to rank which game they preferred and explain why (Figure 1).

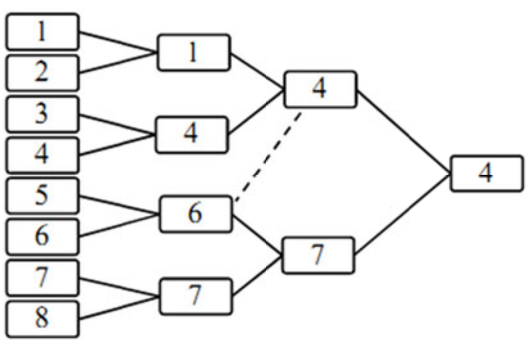

Fig. 1: Illustration of the preference ranking: eight different games were offered in pairs, preschoolers had to indicate which game they preferred. The preferred games were again paired, and preschoolers had to indicate their preference again. This

procedure was repeated until the most favorite game was indicated, in total 7 pairs were offered.

4 Results

The following guidelines were derived from the study.

4.1 Collecting Things >> Rewards/Winning >>Challenging

Typically, for preschoolers the way to introduce challenge is by implementing goals and obstacles that require some form of problem solving (e.g. matching shapes, learning words, arithmetic's etc.). However, in our study this was not preferred. Instead, challenge was most favorably offered by 'collecting things'. Collecting things provided preschoolers with a sense of reward and victory and ultimately realized a challenging gameplay-experience.

4.2 Touch Input vs. Mouse Input

One of the contrasts we presented in this study related to the preferred input device. Consequently, preschoolers were offered games with touch input (via an iPad) as well as games with traditional mouse input. The test group preferred the touch input, in general, over the mouse input.

Furthermore, touch input was also linked to physical interaction. This shows that preschoolers like the intuitiveness of the physical interaction with their hands and fingers. Additionally, they simply seemed to like the physical movement.

Hence, implementing a mechanic of intuitive touch based control can contribute to achieving some kind of 'Sense-Pleasure'.

4.3 Character Creation

Character creation appeared to be the second most dominant element in our study (next to collecting things) and is found to be preferred by almost all children (22 out of 25).The children linked character creation to a relaxed, easy playing style, which implies that the preschoolers are not always looking for a 'challenging' gameplay. Other links with character creation were the opportunity for self-expression, and an aesthetic sense.

5 Humorous, Destructive, Absurd and Visceral Effects

Lastly, we would like to discuss the action-reaction effects that some games implement, i.e. the mouse is used to click on an object and in reaction something 'surprising or spectacular' happens. Effects like this are usually enjoyed by preschoolers, because they are perceived as humorous or satisfy curiosity. Destructive elements in effects are also perceived humorous, e.g. cutting out the enemy by destroying the castle in Angry Birds, as well as absurd elements (e.g. a dog with dresses). Below an overview of these findings is listed, translated into design guidelines.

Table 1: An overview of design guidelines

Aesthetics/gratifications	Mechanics/attributes
Challenge	Implement the collection of different items through the game. This can equally serve as a reward system and provides preschoolers with a sense of victory.
Sense-Pleasure Arousal Body and senses	Implement intuitive touch based controls that rely on physical movement of the fingers, with natural mappings (i.e. analog to movement in real life). Implement visceral effects and visual gags, destructive elements (exploding items, breaking walls,…).
Expression Creative and constructive expression	Implement character creation, providing a standard avatar, which can be outfitted with different clothes and accessories. This can be extended to the customization of all kinds of objects, e.g. vehicles, houses etc.
Humor/Curiosity	Implement humour via 'surprising or spectacular effects' (e.g. deviating from the norm, preschoolers already have a strong sense of how things should be in reality.)

5.1 Resulting design of the DYSL-X game

The Diesel-X backbone story is about a robot dog with the name Diesel, who needs to get rid of the criminal gang of cats in the city.

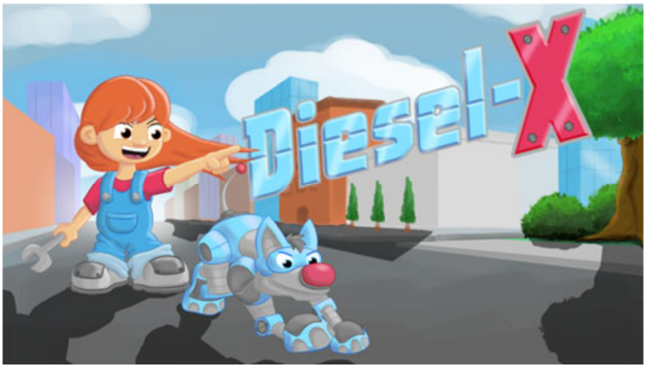

Fig. 2: Concept art for the Diesel-X story concept.

With the story of the game known, the actual game design started. The core of the design is a series of mini-games, each containing a performance test.

5.2 The mini-games

Diesel-X contains three mini-games at the moment: 1) a high-speed chase, 2) a lineup and 3) the search for lost objects. Each of these three mini-games incorporates one specific measurement related to the onset of dyslexia. Further details of these measurements are beyond the scope of this paper, however we refer the interested reader to [3–8] .

In the chase mini-game, Diesel is chasing cats that just robbed the bank. Each cat is holding a big bag, but only one contains the stolen goods. By stopping the cats and scanning the bags the player needs to catch the cat with the stolen goods.

Fig. 3: Screen shot of the chase mini-game

The lineup mini-game is situated in the police office. Here a citizen comes to identify a criminal cat. Each cat holds a board with a letter on it and the citizen identifies the cat by calling the letter it is holding. The player then needs to select the right cat.

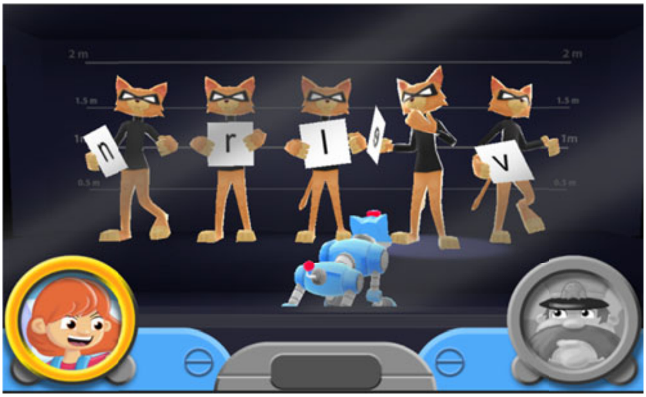

Fig. 4: Screen shot of the lineup mini-game.

The lost objects mini-game has Diesel searching for stashes of stolen goods. He needs to find specific items for Alex and she is playing a game with him. He needs to find an item that ends with the same letter as the item Alex is telling him about.

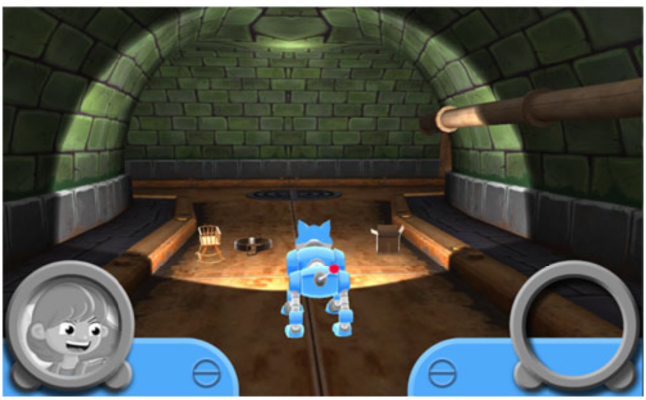

Fig. 5: Screen shot of the lost objects mini-game

The game design implements the design guidelines created by our previous study (Table 1).

5.3 Collectible items

The game implements collectible items in multiple ways.

Firstly, in the chase mini-game, the child can collect gold and even diamonds when chasing down the cat. Additionally, collecting things is also implemented through rewarding the player after each mini-game with an item that can be used in the character creation part. This way the player is rewarded for playing the performance tests by receiving more options for customizing Diesel.

Another implementation of collectible items is by rewarding the player with parts of a rocket after completing a series of mini-games, so that the cats can be sent to the moon at the end of the game.

Fig. 6: Example of the money reward in the chase mini-game

5.4 Touch-based intuitive control

Based on the outcome of the study, we also decided that the target device of the game should be a tablet, which allows for touch-input. Although certain gestures can add value to the touch control, i.e. swiping or dragging, the complexity of the gestures in the performance tests is kept to a minimum, i.e. a simple tap. This is due to the fact that the results of the performance tests cannot be influenced by the experience the user has with the device.

5.5 Character creation

In between mini-games the player is able to customize Diesel in a character creation suite. Here it is possible to give Diesel a new paint job, customize him by adding a jet engine to make him fly, giving him a flash light for dark places etc… These customizations are earned by playing the mini-games.

Fig. 7: Example of the character creation

5.6 Humor via deviating from the norm

In the game, visual gags are used like big dust clouds and a screaming cat when Diesel is fighting with one of the criminal cats. Also when Diesel finds a bag with stolen goods, it can contain an item that does not belong there, thereby fooling the child player.

6 Summary

To summarize, the final goal of DYSL-X is the use of the game as an assessment tool for detection of children with high risks of developing dyslexia, in all school psychology services and clinical diagnostic and rehabilitation centers in Flanders. For the design of the game, we first conducted a study to create some design guidelines for our target audience (preschoolers) and used these to base our design on. During the workshop, we will present the intermediate results of the project.

7 Acknowledgements

We like to thank the teachers and preschoolers of Heilig Hart Heverlee, Scholengemeenschap De Kraal and Sint-Jan Berchmanscollege Diest who participated in our experiment with great enthusiasm.

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Playfully Conquering Performance Anxiety

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Abstract

Despite its significant impact on concentration and learning process, performance anxiety is an under represented topic in today´s primary schools. Even slight extents influence one´s cognitive, behavioural and physiological performance and - if untreated - might manifest and grow into clinical forms for some pupils. We present a serious game prototype for primary schools to introduce this sensitive topic and open discussions with pupil in class. Playing the game raises awareness to the topic and teaches a possible counter strategy in a playful way as a preventive strategy. As such, the game implements a broad base of cognitive psychology research and clinical knowledge in child-oriented way. It was designed in an iterative, user centred design process, using the Serious Games Assessment Framework as a design lens and closely supervised by a psychological therapist. First results of a focus group test are promising and prove accessibility and usability for children. The game seems to fulfill its central purpose, conveying information about performance anxiety and effective counter strategies.

Keywords

Serious games, performance anxiety, cognitive behavioural therapy, cognitive restructuring, game design, children, school

1 Introduction

A significant amount of today`s school children are suffering from performance anxiety (PA). While slight extends of anxiety usually raise arousal levels and sharpen the mind towards a better performance, those affected with PA are likely to experience deterioration in learning and gradually less performance in exam situations. Recent studies have shown the considerable frequency of anxiety towards negative consequences, such as repetition of an examination not passed during school. PA was diagnosed for 20% of the 8 to 18-year-olds of a representative sample [1]. Furthermore the negative correlation between anxiety and performance was substantiated within a meta-analysis of 126 studies from different countries between 1975 and 1988 [2].

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Cognitive-behavioural therapy has proven to be effective, as children learn about the reasons for anxiety disorders, reduce levels and acquire self-help coping strategies. In this paper, we present the serious game prototype "Gedanken-suche"(Mind Quest), an approach to allow eight to eleven year-olds to playfully explore the topic of performance anxiety and learn about basics of cognitive restructuring as a counter strategy. The game addresses the player to help the bear Simo in finding encouraging thoughts during an exam situation. A mentoring owl-character was designed to transport the story and reflect on the players choices. As a preventive tool, the game is meant to raise awareness with teachers and children and to constitute a base for further discussion in classroom.

2 Performance Anxiety and Counter Strategies

2.1 Performance Anxiety in School

Performances are behaviours and result of activities that are subjected to specific quality criteria. Anxieties towards performance situations constitute unique fear reactions, which manifest themselves through the perception of a threat of one's self-esteem and negative appraisal of one's own performances [3]. Symptoms resulting from Performance Anxiety (PA) affect the cognitive, behavioural and physiological level [4].

School typically represents the primary starting point of stressful experiences for children. In a study of Silverman et al. on general worries of children aged between seven and twelve years, school was declared as the second most common fear-inducing subject, directly after concerns about personal health conditions [5]. Corresponding results were found by the national PAK-KID study of Döpfner et al., based on the judgement of parents. A fear of school was noticed in 3.7 % of all boys and in 3.8 % of all girls [6].

The phenomena of fear induction at school is explained by a broad scale of heterogeneous stressors, such as failings in tests, parental performance pressure, insufficient knowledge to do homework, educational design of lessons and the teacher-pupil relationship. Furthermore, the typical performance-based daily routine covers a successive, three-phase learning process of preparation phase, test phase and evaluation phase. Accordingly, to define PA a process-oriented approach is advisable in order to postulate meaningful explanations in terms of school context [7]. For those affected, preparation also means forthcoming performance situations, such as tests. Those situations are interpreted as future events with negative outcome, which is perceived as a potential threat to self-esteem and causes negative emotions. As a result, children undergo cognitive interferences in the actual performance situation. The cognitive capacity is divided into task-relevant and task-irrelevant cognitions, lowering the overall capacity for the task at hand. During evaluation, former negative expectations are often confirmed. Moreover, cognitive errors occur in the causal attribution of failures. Consequently, these self-depreciating attributions could lead to critical deficits in one's motivation.

Despite its significance and impact, most schools have no working strategy against PA. Moreover, the topic is no subject for open discussions and remains below surface. Usually teachers would recognize kids suffering from PA by observing behaviors described earlier or performance difficulties and inform parents and possibly school psychologists. "Gedankensuche" therefore was also designed as a tool helping teachers to open a discussion on performance anxiety in a playful way by talking about the game and its characters and not pupil.

2.2 Relief with Cognitive Restructuring

Cognitive processes can be divided into so-called functional and dysfunctional cognitions. Functional cognitions include positive gift concepts, high expectations of self-efficacy and other healthy cognitive schemes. In contrast, dysfunctional cognitions, such as cognitive errors in terms of content and logical mental biases significantly support the development of anxiety disorders. However, research and therapeutic practice have shown that dysfunctional cognitions can be restructured towards functional ones through cognitive restructuring, which according to Wilken [8] defines three major approaches: The rational emotive therapy of Ellis, anti-stress training by Meichenbaum and cognitive therapy by Beck.

The present game design is based mainly on the ABC - Theory of rational emotive therapy by Ellis. The aim of this approach is to change irrational appraisals and to help people achieve healthier viewpoints and cognitions. The (A) symbolizes an activating event, usually consisting of external and internal psychological processes or thoughts. For example internal anticipations such as failure in a future test situations or external incidents, like the death of a relative. (B) defines belief and belief systems that evaluate the activating events (A) and evoke conscious and sub-conscious beliefs. (C) stands for consequence, the emotional reaction caused by the interaction of (A) and (B). It is particularly important to notice that the central assumption of the ABC-Theory is that (C) is not directly caused by (A) but develops through the following appraisal processes [8].

The transfer of the techniques of the cognitive-behavioral therapy, such as the cognitive restructuring, to virtual game worlds in the context of serious games is a relatively new research field which indeed seems promising. On the one hand those games are implemented as therapeutic tools to support therapists during their daily work and on the other hand they are used in the area of prevention of psychological disorders.

One example for a serious game used in the therapy of children and adolescents is Treasure Hunt[1] of University of Zürich. It immerses the patient to help the captain of a sailing boat to read a treasure map, by solving riddles and minigames. The game supports the therapeutic work by presenting examples of cognitive behavioral therapy. Because of its non-specific design, the authors suggest to use the game for a variety of related therapy programs, namely anxiety disorders, depression and aggressive behavior [9].

Another recent example for the use of serious games in therapy is the 3D fantasy game Sparx. The third person 3D-Adventure is divided into seven levels, each representing another aspect of depression. The player's task is to save the world from dominating GNATs (Gloomy Negative Automatic Thoughts). The game is meant to serve as help for self-help for adolescents with first symptoms of depression and is meant to be played over four to seven weeks. It includes strategies of cognitive restructuring in some of the levels and was successfully evaluated [10].

3 A Playful Approach to the ABC-Theory

3.1 Considerations of Serious Game Design

Designing a serious game for a preventive approach to performance anxiety in class has one major challenge: Especially children with an (unknown/unconscious) tendency to PA may find such a game more challenging than others, because of a cognitive tendency towards dysfunctional thoughts. Moreover, alike school exams, playing games usually results in a quantifiable and therefore comparable outcome. Players therefore are also likely to experience games itself as performance situations. Consequently, a main design task is to create a game that is inviting, challenging and rewarding enough to be played, but avoids widely used game mechanics such as restraining or negative consequences, time pressure and bold presentations of performance feedback. "Gedankensuche" only reflects carefully chosen text feedback and character mimics, as well as random compilations of the tasks contents to avoid comparisons.

1 http://www.treasurehunt.uzh.ch/

In addition, the role of the player needs careful consideration. On the one hand, a strong identification with and control over a player character and its internal and external journey in the game might foster learning of transferable knowledge. On the other hand, it will also render unwittingly evoking performance situations even more likely. In "Gedankensuche" the non-player character Simo, a little bear, therefore is chosen to experience exam situations while the player takes the role of an active observer. The setting allows players to explore the ABC-Theory and learn from observing the bear`s reactions and thoughts, instead of being put in a performance situation directly. The motivation to play is created by a cover story, leading into a social plea to support the bear in finding functional cognitions and win back his courage.

Besides these major considerations, "Gedankensuche" was consequently built along state of the art cognitive theories and principles to engage players and allow for a maximum of concentration and learning.

Limited working memory & cognitive load reduction: Humans working-memory is limited to three to four chunks. The games story and elements, such as animations, interactions, sounds and especially texts are mostly sequenced (one at a time), clearly focused and fulfill a functional purpose within the design mix. This way, we also prevent the player from extraneous cognitive load [11]. To raise challenge, the player is presented with a rising number of cognitions during play. The game therefore will be more difficult to play but also build upon experiences to support schema acquisition over time.

Arousal and Attention: According to current knowledge, humans may selectively focus or divide attention across different foci [11]. The Yerkes-Dodson-Law furthermore postulates that a certain arousal is necessary to focus attention and reach optimal performance levels [12]. However, with performance anxiety being powerful stressor and situational parameters of play out of design space, resulting arousal levels during play might quickly defocus the player and prevent cognitive schemata acquisition. The game therefore only presents low arousal levels from additional audio-visual stimuli. It also does not implement time pressure situations, performance scores or other forms of potential player-to-player comparison. A necessary but limited level of arousal is created through the stimulating nature of the social plea to help the bear and the mentoring owl-character.

Elaboration and Equilibration: The learner should be able to elaborate the content by contextual information and different approaches. Equilibration describes an optimal level between appliances of knowledge and chances to acquire new knowledge [12]. Therefore the game closely connects the story and explanations to the player's tasks: Selecting functional cognitions. Explanations given by the owl character introduce the topic of performance anxiety as well as the ABC-Theory as corresponding counter strategy. The textual and visual feedback given during play shows players causes and effects of their choices. Of course, playing the game alone does not guarantee learning, but it prepares for further discussions and reactions in class.

3.2 Game Overview

Fig. 1: Simo in a test situation. The player needs to choose a helpful thought for the bear which is followed by Simo`s direct, positive reactions. The owl reflects the player`s interactions and gives hints, if necessary.

The game`s story introduces Simo, a little bear just before his important bear-exam and Lilo, and old and wise owl. During the first dialogues, the player learns about Simo´s anxieties and courage problem while the owl explains the situation and coping strategies based on ABC - Theory. The characters then ask the player to help Simo with his exam by selecting encouraging thoughts. The player is in full control of the game`s speed. Every action does have a textual or audio-visual response. Especially each correct or incorrect selection of cognitions is followed by qualitative feedback and audio, in order to clarify the impact of cognitions on emotions according to the ABC-Theory.

3.3 Design Framework and Game Design Description

As a guideline for design, the serious game assessment framework (SGAF) of Mitgutsch & Alvarado [13] was used. The authors argue that the purpose and aim of a serious game is of fundamental importance and should, as a holistic design guideline, reflected into every aspect of the game. In other words and alike to core rules of other media productions: Every audio-visual, textual or interactive element of the game should have reason and contribute the games central purpose. The qualitative assessment framework, or as the authors put it, a "constructive tool for critical discussions", differs from other, more technical or interaction focused game frameworks. It describes six main categories for serious games assessment that constitute the overall game system. For example and in contrast to e.g. Fullerton`s structural game model [14], "mechanics" cover the complete set of rules, game mechanics, goals and rewards. Because of special importance for serious games, the SGAF also adds categories of "content" and "framing', which includes target group and play literacy.

If to be measured by the framework, it only seems logical and indeed renders helpful, to already consider those categories during design and production of a game. With "Gedankensuche", the authors therefore took SGAF for a design lens, leading every design decision along a clear defined purpose. In addition and in accordance to a user centered approach, the visual design, interaction concept and game design was presented in school two times during early development stages.

Furthermore, regularly consultancy of an expert therapist ensured the relevance and correctness of decisions regarding the implementation of the relations between cognitions and emotions in the game world as well as the relevant cognitions used in the game. The following paragraphs describe the design decisions taken for the game.

Purpose: The main takeaway of the game is to learn that thoughts do have influence on emotions, the experiences as well as psychological and physical conditions during exam situations. As negative thoughts towards a performance situation will lead to counterproductive feelings, the individual also has the power to use positive thoughts to prepare for exam situations. The idea to consciously influence ones thoughts may therefore be used as part of a preventive concept for pupil and indirectly teach children between eight and eleven years about the well-established ABC - Theory as a counter strategy. Furthermore, the game and the reactions of the games characters provide a hook to open up the sensitive topic of performance anxiety for discussion.

Content & Information: The games content is structured in introducing the setting, building up the central exam situation and call for action, action and feedback cycles conducted by the player as well as reflection on the bear`s overall performance. During the exam situation, players are asked to choose the functional thoughts out of a number of options. After each action, textual and visual positive or explanatory feedback is given to show the player consequences of his selection. After the exam, a dialogue between bear and owl reflects the exam situation and thoughts selected by the player as a whole, ending with a renewed call for action if errors were made

Fiction and Narrative: The story of "Gedankensuche" takes place on a wood island to associate feelings of being somewhere far off school and create the "magic circle" of the gaming situation. The story introduces the two main characters, Simo the bear and Lilo the owl with the latter being the wise mentor of bear, as well as the bear's family. Simo has lost his courage because of dysfunctional thoughts about an upcoming exam situation. The owl then helps the bear understand the impact of functional and dysfunctional thoughts on his feelings about the exam, before asking the player to help Simo win back his courage by finding the "good thoughts". We used a bear character for two main reasons: Bears are usually seen as calm and strong animals. If a bear shows weaknesses, it may support player`s to emotionally connect to the bear and understand that anxiety has nothing to do with size or strength. On the other hand, bears are also believed to grow strong and leave weaknesses behind. An owl is attributed with wisdom, seriousness and experience and therefore represents an authentic mentor character to guide and support the player in his task to support Simo.

Mechanics: Only simple interaction patterns were implemented to maximize cognitive capacity for learning and with respect to the target group's age. The game can be played by mouse or track pad only and uses only one mouse button for necessary move, choose/recognize and select actions. The game`s core action-feedback loop consists of players choosing one out of several possible cognitions such as "Others are better than me" or "I'll start with what I know", followed by multiple intermediate feedback. The owl rates the selection as functional or dysfunctional while the bear`s mimics and thoughts shows encouraging or discouraging reactions and thoughts. After seven levels with an increasing number of options, the exam is finished. Owl and bear reflect the exam in conjunction with the number of functional/dysfunctional answers chosen: All correct results in a very positive exam feedback; half and more than half result in average feedback and asks the player to try again and get better; less than half is an exam failed and leave the bear anxious, enforcing the player to try again. In general there is no really negative feedback or consequence given to allow players explore the character`s reactions with different selections.

Fig. 2: Main character Simo in various emotional conditions

Aesthetics and Graphics: The visual design goal was to find a good compromise between an attractive but not visually distracting and complicated style. The graphics therefore are dominantly flat, minimalistic 2D graphics with few colors in different saturations. With regards to the story, the dominant colors are green and brown. Texts are presented differently in the game. Explanations and dialogues are kept in brown, rectangle boxes, while cognitions are presented as clouds that may form storms but also go away [1]. Graphics, sounds and music are kept simple, too. We implemented one ambient sound, supporting the atmosphere of being in the woods, feedback sounds supporting button actions as well as two sounds differentiating functional from dysfunctional selections.

Framing: "Gedankensuche" was built for young children, between eight and eleven of age. To our experience from the user centered design process and latest studies, basic computer literacy and experience with the computer mouse is present in the target group as 90+% of primary school children use computers at home [15]. As mentioned in the mechanics chapter, only simple move and select actions are necessary and therefore should not influence the game experience with most of the audience. The game is a tool to open discussion on the topic of performance anxiety in schools and should be backed up by further discussions or material in class. We expect the game to have a preventive character for those not affected but also may bring attention to kids already suffering from performance anxiety. Thus, teachers should know their pupils, create an open and trustful atmosphere and if necessary follow up in private with some kids and parents. From our discussions with a therapist, the game might also render useful for the first hours of a cognitive therapy as these are usually experienced as stressful for kids.

3.4 Focus Group Evaluation

The development of the game focused on an iterative, user-centered design and thus ran through several rounds of expert interviews (with teachers, pupils and therapists) as well as a small focus group testing at the end of the first project development milestone. The prototype was tested with small focus groups of three to four, with 15 children (7 female, 8 male) in total. The setting consists of an approximately ten minutes free play part followed by a one-page questionnaire, which was introduced only after play to prevent the notion of a test situation. Main goals of the play part were to find major usability issues and monitor children`s understanding and reactions, such as, mimic and body language during play. The questionnaire was created to tests the children`s comprehension of the games story and the purpose of the serious game. It consists of two comprehensive questions (free text), six yes/no items out of a standardized anxiety questionnaire for pupils [16] and one multiple choice question of the ABC - Theory, with two correct answers out of four. The game features a hidden score that was linked with the questionnaire to find tendencies of correlations. All data was collected anonymously and according to standard ethics guidelines. The corresponding ethics proposal was approved by the University's Ethics Board. In summary, our focus group test showed the following results.

Usability: None of the testees showed problems in starting and interacting with the game. However, there were significant differences in computer literacy as well as precision and proficiency of mouse usage. Further observation gave clues to rethink the layout of the game screen regarding a clearer contrast of text feedback and buttons. The amount of text to read was adequate and not demotivating.

Attention/Focus/Challenge: All children seemed to be quite focused on the screen during reading the story and play. Some played three to four times, even if they already scored maximum in the first round. In total children scored an average of 6.2 out of 7 points (89.5%), which suggests to carefully raising the overall challenge level of difficulty.

Performance Anxiety: The game was deliberately designed to avoid an ingame PA-Situation, but this fundamentally contradicts to the use of challenges in the game as discussed above. Our results show a tendency trend to lower scores of testees with a tendency to PA from the items of the standardized anxiety questionnaire (AFS). This may be explained by present cognitive schemata or an inner mental state that biases thinking towards dysfunctional cognitions. Comparable notions can be found for depression [17] and as theoretical background of the cognitive bias modification treatment [18]. Yet, this hypothesis does need further detailed and thorough investigation and evaluation as only few selected items of the AFS were used.

Comprehension: Results of the first comprehensive question showed, that all children were able to describe Simo`s problem of performance anxiety in their own words. The second question about how Lilo the owl tried to help the bear resulted in ten correct and five wrong or misleading answers. For example, one child answered that Lilo tries to reason with the bear, while others noticed that Lilo helps the bear to find positive thoughts. Despite the somewhat open question (In what way does Lilo try to help the bear), the results indicate possible clarification in the game’s story and dialogues. However, most children seemed to understand the subject of the game with thirteen children (out of 15) selecting the correct cognitions out of the multiple choice question. In summary, the findings indicate that the game fulfills its central purpose with most of the children but also leaves room for improvement in explaining the mechanics of PA to the children. After playfully opening the topic in classroom, the game experience should be combined with further material and discussions in class, too.

4 Conclusion and Outlook

"Gedankensuche" was created to open discussion on the sensitive topic of performance anxiety in primary school. By playing the game and observing the characters, children encounter PA in a lightweight and playful way. As such, the game offers a chance to learn about coping strategies for personal performance anxiety tendencies. It also represents and anchor for further and fruitful discussion in class as pupil get the chance to discuss the players characters problems and experiences rather than their own and therefore avoiding possible embarrassment. As such it holds general potential to reflect children in their own internal thoughts as well as to teach first steps towards coping strategies for daily school life. Due to its lightweight and opening character, the game might be part of a preventive concept in schools.

The design of the game explicitly follows a consequent easy entry and casual gameplay approach to reduce players cognitive load and foster thinking and learning about the game´s content. An appealing story and the non-player characters´ help request draw players into the game and introduce the task to be accomplished. At its core, the game implements the basic idea of the profound ABC - theory of cognitive restructuring through active observation. The design deliberately avoids ingame PA situations by a careful use of design patterns and by putting the NPC Simo in the testing situation rather than the player.

First results from focus group tests were promising. The game seems to transport its content and conveys information about PA and counter strategies, with regards to the bear Simo. However, the evaluation did not focus on the utilization of knowledge in daily school life, which is an interesting future question. Same counts for the question whether players with a tendency towards PA experience the game to be more challenging than others? The next version of the game therefore should support a more differentiated scoring and levels of difficulty and a more extensive anxiety questionnaire (AFS) to examine that question. Further improvements concern the button design of the examination screen, as well as the owl’s role and texts as only two third of the children were able to tell the mentors task in the game.

The use of the Serious Game Assessment Framework as a design lens, combined with an iterative and user centered design process proved to be a refreshing, useful and effective way of design, especially compared to other, more technically driven frameworks. Designers should consider using SGAF for other serious games productions, too. Especially the frameworks central statement, to discuss all design decisions in terms of their support of the game`s purpose deliberately helps to focus even if the suggested categories are interpretable and may not apply in all cases. However, like other serious games productions, the combination of gameplay, pedagogic and domain content is difficult to establish. It required significant efforts of each team member to gain necessary multidisciplinary insights and skills. Already small design details may have major impact on the learning goals of the game or interfere with motivation to play, player experience and fun. A very close interchange of all involved disciplines it is crucial to stay focused on the purpose and to weave it closely into the design and conflict of the game.

Our next steps are the development of a further improved version of "Gedanken-suche" regarding the game design improvements, as well as the implementation of further content and hidden metrics about player’s performance in the game. Further-more, a formative study is currently planned to examine the questions found during focus group tests. At last, we continue close relationship to teachers and schools, to discuss the use of "Gedankensuche" as well as the creation of further material as first steps towards a preventive class unit.

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Evidence-based psycholinguistic principles to remediate reading problems applied in the playful app *Letterprins*: A perspective of quality of healthcare on learning to read.

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Abstract

The present study described a new reading game (Letterprins), designed to improve the reading development of children with reading problems. Letterprins contains a series of reading-related tasks, based on previous research, which have been shown to facilitate children's reading development. In order to ensure treatment fidelity integrity the game is played in collaboration with a parent or caregiver. The parent/caregiver needs to indicate the correctness of the child's responses. The app adjusts the exercises based on the child's performance, and thereby optimizes learning. The app addresses reading development at the sound, word, and sentence level, and thereby captures a large range of the stages in early reading development.

1 Introduction

For citizens in our knowledge economy reading is a fundamental skill. However, about 1.5 million Dutch citizens do not have a sufficient level of literacy and as a consequence are unable to participate fully within society. The annual costs of illiteracy in the Netherlands are more than 0.5 billion euros (Groot & Maassen van den Brink, 2006). These reading problems are not caused by socio-economic background and ethnic origin, but by the quality of the reading education (Dijksma, 2007; Inspectie van het Onderwijs, 2011). The app Letterprins [Letter Prince] aims to prevent and remediate reading problems from the start of first grade. It is initiated by parents and is intended to enhance children's reading skills by using the app in the home setting. Letterprins is a collaboration of the department of special education of the Radboud University Nijmegen with the gaming company Monkeybizniz, which is specialized in serious gaming, playful apps and in valorizing scientific knowledge. Letterprins

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is based on cutting edge research; evidence-based principles from educational and psycholinguistic disciplines translated into practice, which is applied into a promising gaming technology for children with reading disorders (Franceschini et al., 2013). Recently, Letterprins was nominated for the National Prize of Literacy 2013 [Nationale Alfabetiseringsprijs].

We will describe the purpose and content of the app Letterprins for children with reading disorders and dyslexia along the dimensions of quality of healthcare reported by the Committee on Quality of Health Care in America (2001). These dimensions encompass safety, effectiveness, patient-centeredness and efficiency1.

2 Reading disorders and dyslexia

In order to describe the content of the reading app Letterprins along the dimensions of quality of healthcare we will first offer a definition of reading disorders and more specifically of dyslexia, as it is formulated by the Stiching Dyslexie Nederland (2008):

> Dyslexia is a disorder characterized by persistent difficulties with learning and quickly applying processes in reading and spelling at the word level.

The major goals of Letterprins are linked to this definition and to the goals of treatment for dyslexia formulated by Stichting Dyslexie Nederland (2008). The content therefore focuses on the improvement of the technical aspects of reading, that is, recognizing words immediately (quickly) and accurately (correctly) when reading silently or out loud. Letterprins valorizes scientific knowledge of several intervention studies on the effectiveness of learning to read, and the analyses of effectiveness fit into the goals of the aforementioned treatment goals.

1 In the Netherlands, the dimension *Timely* usually is viewed as part of the other dimensions (Berg, Beersen, Groenewoud, & Ikkersheim, 2012). In this paper, the last dimension, *Equitability*, is not discussed separately.

3 Safety & Patient-centeredness: avoiding negative side effects and focus on the well-being of the child and its parents.

The first dimension of quality of healthcare concerns Safety, which involves that "harm due to a treatment or other healthcare activities is avoided". As for children with reading disorders and dyslexia, the major concerns in avoiding negative side effects of a treatment are to be placed within the social and emotional domain (Steenbeek-Planting & Kleijnen, 2011). Many children with dyslexia have an academic background with negative and stigmatizing experiences (Singer, 2008). They typically have a low self-esteem, and low expectations of their academic opportunities (Alexander-Passe, 2006). Children often experience pressure to improve their reading skills, at school or even in the home setting, and as a result they no longer enjoy reading. The situation in the home setting may in turn put pressure on the relationship between the child and its parents. Hence, although early reading interventions are crucial for the development of children with reading problems, these interventions should also provide children with positive associations with reading, fostering motivation for learning to read (see De Naeghel, Van Keer, Vansteenkiste, & Rosseel, 2012). The dimension Patient-centeredness concerns a focus on the well-being of the child and its parents (Kalsbeek & van Leeuwen, 2012). This dimension closely relates to the dimension Safety and, therefore, we will simultaneously describe how the principles of these dimensions are implemented into the app.

In Letterprins, first, positive associations are fostered by integrating interventions into a playful app where children are having fun learning to read. Second, Letterprins is designed to be implemented into the home setting, such that most of the time, the child is playing the app together with a parent/ guardian or sibling. In such a way, they are actively involved in the learning process of the child, while enjoying its reading achievements. Third, to avoid stigmatizing and negative 'labeling' experiences, the app is not intended for "dyslexics or reading-disabled only", but for all children learning to read. Fourth, the app is intended to be responsive to individual learning needs by automatically adjusting its content to the individual growth curve of the child. Also, it provides exercises that are appropriate to their stage in reading development (see 4.3). Moreover, the app is not based on a specific method for learning to read Dutch, but rather on general psycholinguistic principles in learning to read.

4 Effectiveness – applying evidence-based principles from educational and psycholinguistic research

In the app, the child performs various types of reading tasks that have proven to facilitate children's reading development (i.e. based on scientific publications). In order to ensure treatment fidelity integrity the game is played in collaboration with a parent or caregiver. During the tasks, the child has to pronounce e.g. letters or words, and the parent or caregiver has to press a button to indicate the correctness of the response. In this way, the app allows parents and caregivers to be involved in and facilitate the child's reading development process. Further, the importance of the parent-child relationship (e.g., Willemen, Koot, Ferdinand, Goossens, and Schuengel, 2008) has been integrated into the game in an interactive manner: The app allows parents to record messages to be played after the completion of each level. Throughout the game, the app keeps track of the child's reading development, and provides input as deemed suitable for the child's current stage of development (for a more elaborate description of the algorithms, see 4.3.1 and 4.3.2). The child then progresses through a series of gaming levels (as shown on a map screen, see Image 2), together with its animated companion Letterprins. As a team, they enjoy their successes in learning to read. With his friend, the child also beats the dragon which symbols their hard work and challenges in mastering the reading of tough words. In each level, principles from scientific research are applied. Hence, while the game Letterprins is very new, its effectiveness has already been proven. Further, a pilot experiment shows that the game is able to motivate children to practice their reading skills, as the children in our pilot sample played the game without prompting.

Image 1: Animated icon of Letterprins [Letter Prince]. © Letterprins

Image 2: **In-game screenshot of the map screen indicating the child's progress in Letterprins. © Letterprins**

Image 3: **In-game screenshot of one of the levels of Letterprins [Cow. Is this an animal?]. © Letterprins**

4.1 Structure in gaming levels

The structure in gaming levels closely follows the zones of proximal development (Vygotsky, 1978) as they are built up in regular methods for reading in education. Moreover, as Letterprins is aimed at remediating and preventing reading problems, it applies the principles from the Protocols for Reading Problems and Dyslexia (Wentink & Verhoeven, 2003; Wouters & Wentink, 2005).

The gaming levels start out by practicing the most commonly used, single letters in Dutch words (e.g., s, i, v), followed by less commonly used letters and letter combinations (Dutch graphemes, e.g., j, f, oe, au). The sequence of letters is moreover determined by the mean accuracy of receptive letter knowledge, measured in 5-6 year-olds at risk for dyslexia (Noordenbos, Segers, Serniclaes, Mitterer, & Verhoeven, 2012). In the subsequent levels, children practice short words that can be read by solely applying the letter-sound correspondence rules (Booy, 1995; e.g., bak, man). The game then challenges children in practicing words that are relatively difficult to learn, because some of the letters and sounds do not adhere to the correspondence rules that they have been taught before. These words need the application of complex spelling rules (e.g., boom + en → bomen [trees], bom + en → bommen [bombs]). The last gaming levels encompass longer words and compounds (that is, morphologically complex words, e.g., boekenkast, herenfiets).

4.2 Practicing reading: words, meaning and sentences

Reading is a complex multifaceted construct that needs to be acquired (Byrne, 2008). The recognition of single words is the foundation of reading and all other reading processes depend on it (Snowling & Hulme, 2008). In theoretical models of reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Perfetti & Hart, 2001; Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990), both assigning word meaning (semantics) and sounds (phonology) to the written word (orthography) are important skills that determine reading competence. Therefore, in each gaming level of Letterprins, children train these skills of assigning sounds and meaning to written words. In order to transfer their skills of reading single words to the comprehension of texts, each gaming level also encompasses the reading of sentences, focused on meaning, and assigning words to categories. Different studies show that vocabulary knowledge has a direct influence on reading skills in children in all grades of primary education (Ouelette & Beers, 2010; Ouelette, 2006; Ricketts, Nation & Bishop, 2007; Nation & Snowling, 2004). Children who know the meanings of more words have a better understanding of these words and also have better developed decoding skills.

4.3 Computer algorithms to differentiate among individual learning curves

No two children are alike, and all children follow their own learning curve. Practicing at a level of difficulty that is neither too high nor too low, is the level at which optimal learning takes place. In order to differentiate among children, the app incorporates two important computer algorithms. Applying the principles of these algorithms has been shown to be crucial to enhance the general reading skills of both poorly developing children and children with very severe reading disorders (Steenbeek-Planting, van Bon & Schreuder, 2012; 2013). The first computer algorithm concerns the words children practice within each gaming level: words they previously read correctly or incorrectly. The second algorithm concerns how long words are presented on the app screen.

4.3.1 Algorithm 1: Practice on words read successfully or erroneously

When children learn to read, (remedial) teachers typically focus on the words children read erroneously. After all, these are the words that need improvement. However, Steenbeek-Planting, van Bon and Schreuder (2012, 2013) showed that it depends upon the reading level of the child, which words are the most optimum for the child to practice with: For children with a reading level up to the end of first grade, practicing words they read successfully increases both their reading accuracy (that is, their precision or correctness of reading) and their general reading speed. In contrast, for children with a reading level beyond first grade, practicing their failures increases reading accuracy and general reading speed. This principle is applied in the game, firstly, by offering children words to practice that are typically read correctly (based on empirical research) versus words that are typically read incorrectly. Secondly, dependent upon the child's reading competence, the specific words a child reads successfully or erroneously are returned to the subsequent gaming levels for further practice.

4.3.2 Algorithm 2: Varying presentation time of words

The Dutch writing system has rather strong letter-sound correspondences at its basis (transparent orthography). A prime characteristic of reading disorders in languages with transparent orthographics such as Dutch, is the impairment in reading speed (de Jong & van der Leij, 2003; Landerl, 2001; Serrano & Defior, 2008). Therefore, although the initial gaming levels focus on reading accuracy, subsequent levels focus on improving reading speed (Steenbeek-Planting et al, 2012; 2013; van den Bosch, van Bon & Schreuder, 1995; Wentink, van Bon & Schreuder, 1997). In practice, the exposure duration of single words on the screen is varied to maintain an accuracy rate of approximately 80%. The optimum of presentation time is calculated for each child at the beginning of the gaming levels, and thereafter it fluctuates during each level. After reading each word, the reading accuracy of the last word and the previous three words are evaluated by the app. The exposure duration of the next word is increased by about 20 ms if two or more out of four words are read incorrectly, and is decreased by about 20 ms if three or more out of four words are read correctly. In the other cases, exposure duration remains unchanged.

5 Efficiency – an economic view, and concluding remarks

The dimension Efficiency concerns the economic view of avoiding waste. A playful app in the home setting is highly efficient and of economic advantage if it supports the educational system in teaching children learning to read[2]. However, in the Netherlands teachers do not have a ready and general set of evidence-based and practice-based reading materials to provide parents with. Moreover, timely interventions can diminish the severity of reading problems. This preventive aspect could, in the long-term, diminish the large amount of children currently in need of receiving training in treatment centers for dyslexia. Therefore, a reading app that valorizes scientific knowledge and evidence-based principles, well implemented in the home setting from the onset of reading acquisition, could have major economic impact on the chain of two of our society's key systems, education and healthcare. Technical innovations such as playful apps from the gaming industry can accelerate this implementation (see e.g., Britnell & de Boer, 2012) by bringing the important actors and stakeholders (child, parent, education and healthcare) together to realize the most efficient growth curve for children learning to read. Future research should verify to what extent parents can contribute to the quality and cost-reduction of these two systems if they would be involved as a full partner of the educational system for children learning to read, and as a full partner of the healthcare system for children with learning disabilities.

2 See for a first Dutch study on cost-effectiveness of a treatment for dyslexia Hakkaart-van Roijen, Goettsch, Ekkus, Gerretsen, and Stolk (2011).

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An Active Lifestyle for Youths through Ambient Persuasive Technology. Implementing Activating Concepts in a School Environment

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Abstract

The PlayFit project aims to design for a structural reduction in sedentary behavior throughout the day. The challenge is to engage teenagers by connecting to their mainly sedentary lifestyle by playful persuasion. Therefore we defined four design principles: (1) embedded in the context (2) trigger an intrinsic need to play, (3) adapt to a personal playing style and (4) facilitate open-ended and/or emergent play. In the past three years we have been exploring solutions through design research and applied these insights to three new concepts, each tying into a different aspect of a school day. In this paper we share the first insights in applying these design principles and implementing the concepts that help reducing sedentary behavior in schools for vocational education.

1 Introduction

Recent studies indicate that teenagers in most western countries are not physically active enough [1, 2]. Active mobility has been effectively designed out of our everyday life [3] and an increasingly sedentary lifestyle is the unhealthy result; teenagers sit during classes, in their lunch break, and often at home behind a computer or television [4] [5]. To be more specific, Dutch teenagers, especially in vocational education, do not adhere to the advised Dutch norm for the maximum amount of sedentary behaviour per day: "less than two hours computer-time and/or watching TV (both broadcasted and recorded)" [6]. Dutch teenagers(twelve to seventeen years old) sit or lie around 3.5 hours after school is over. This behaviour makes them the most sedentary group in the age group 4-17 year olds. In addition, during holidays they display even more sedentary behaviour than senior citizens (65+ and 75+) [6].

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The negative effects of a sedentary lifestyle have become more apparent in recent years. Intervention programs try to address this problem, mostly by propagating a physically active lifestyle [7], promoting sport participation [2] and addressing physical activity in gaming, such as exergames [8]. However, these programs seem to have a hard time to create a structural effect in the lifestyle of this particular group [7]. The general idea is that most initiatives rely on external motivators and could benefit from an integrated approach.

The PlayFit project aims to be effective in the long run by addressing intrinsic motivation and an integrated approach. The PlayFit project designs for playful interventions through ambient interaction to engage teenagers in moderate levels of activity throughout the day. Previous publications [9, 10] have shown strong indication that triggering intrinsic motivation results in affective means to generate higher activity levels. By starting from existing activities and by connecting with the world of experiences of teenagers we aim to establish a low threshold to engage in a playful interaction. Developing an integrated approach ties into many aspects of the educational system. The location in school, the moment of play for one thing, but also facilitating a period of transition in which a school can adopt activating concepts. This paper presents three new concepts, each concept is designed for a specific context and content during the day. With each concept we provide insights in ambient gaming techniques for a healthier lifestyle and we will share the preliminary findings on implementing each concept as part of an integrated intervention in a school-environment.

1.1 Regular, moderate activity through ambient gameplay

In the PlayFit project [9, 11], we reversed the problem of low levels of activity. Rather than aiming for an increase in activity levels, we decided to aim for reducing the time spend sedentary throughout the day. Secondly we do not aim to reach a certain activity level, but we aim to stay away from arriving at sedentary activity levels. The concepts aim to generate short spurs of moderate-intense physical activity ('casual activity', see figure 1) that connect to the teenagers' daily activities and interests. Sitting in itself for prolonged periods can compromise metabolic health, and breaking up sedentary time is beneficial [12].

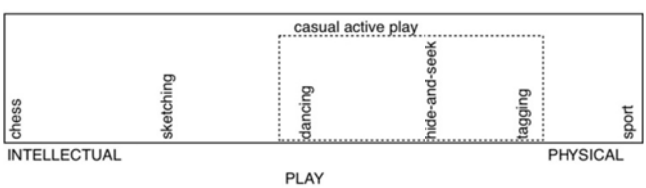

Fig. 1: Casual Activity

We offer these moments through 'ambient play': throughout the day we invite teenagers to engage in social and physical play. Concretely, we design and implement interactive installations that elicit playful and social interactions for during the breaks, for during regular lessons and to enhance physical education. We focus on long-term intrinsic motivation through social interaction, exploration, personalization and expression. The PlayFit project firmly believes that only through addressing intrinsic motivation, we can support the process of adopting a less sedentary and more playful lifestyle [13, 14].

Each experience revolves around comparing, discussing and playing together – on purpose, we do not include elements such as measuring the activity in the experience. Measuring activity levels would direct the game experience towards competition and rewarding physical fitness, thus stigmatizing the children who are less fit. By leaving it open-ended, players can find and exploit their preferred playing style in their own way – including competition .

1.2 A teenagers daily interests and activities

The goal of the PlayFit project is to elicit moments of casual active play, that connect to the teenagers' daily interests and activities. This poses two preliminary questions: what are the teenagers' daily interests and activities, and how can we connect to them?

In order to answer these questions, a literature review was conducted on youth, youth behaviour, lifespan development, and leisure activities, focused on Dutch secondary school youth. This review was complemented by seven focus groups at high schools, in which daily activities and interests were discussed [15].

From that study we identified four core interest and activity areas for the Dutch youth:

- Exploring: trying novel experiences; exploring and developing one's relations, preferences and boundaries.
- Communicating: social interaction; verbal, written, virtual and body communication; individual and group interaction.
- Personalising: adapting and personalising one's items, environment, activities and actions, both individually and in peer groups.
- Expressing: broadcasting one's individual and group identity and opinion, through actions and appearances.

Those four areas offer design opportunities to connect to the youth's daily interests and activities. Two well-known examples clarify this: the social network site Facebook and the video service YouTube both connect to the needs for exploration, communication, personalisation and expression, by allowing visitors to perform those activities through their network sites. We believe that, by using those interest and activity areas, we can trigger youngsters to participate in a moment of casual active play.

1.3 Development of design principles

So far, we have mainly focused on designing for play in first encounters: most of our prototypes [9] [10] [15] elicit emergent play that is inviting and enjoyable for the users on the first encounter. Through research with these prototypes we have built a basic understanding of how we can persuade teenagers to start playing in a social and physical way. Our focus for the remainder of the project is on eliciting play in recurring encounters: how can we design for playful interactions that occur time after time, in the setting of a high school? Students will encounter these interventions several times a day, five days a week: The PlayFit goal is to elicit a moment of play on most of these encounters.

We defined four design principles for ambient gameplay. The gameplay should be (1) embedded in the context (2) trigger an intrinsic need to play, (3) support personal playing styles and (4) facilitate open-ended and/or emergent play.

Embedded in the context: The moment of the day should have the main focus (a math lesson, leisurely walking from classroom to classroom) whereas the activating aspects should move to the periphery of attention. As a result a design becomes a small, "calmly activating" intervention [16].

Trigger an intrinsic need to play: triggering curiosity to attract the user's attention appears to work very well. Teenagers are familiar with an interactive environment; novel or ambiguous designs draws attention and some users will start exploring. Following this, social curiosity can draw others, starting a chain-reaction of users drawn to the design.

Support a personal playing style: To move beyond the initial trigger and create a structural engagement through return visits to the design, there should be some personalization possible. A preferred response, playing strategy or even activity should be easily available to explore and play with particular aspects of the concept. For example playing for the most beautiful results in feedback, or even playing for competetion.

Design for open-ended & emergent play: by allowing the users to come up with goals and playing styles themselves, we design for emergent play. Social interaction, the players and the environment all determine the way in which users play together – which makes sure that every encounter is different.

For each of the three concepts we will describe how these principles were applied and how successful they were in terms of playful persuasion with the target audience., thus sharing learning points from this project.

2 Ambient Gameplay

2.1 Activating math lessons

A typical educational setting in school involves mostly sedentary behavior: sitting in a classroom and minimalistic movement of the extrema (fingers). Increasing the activity levels in a lesson is therefore a quick win. To activate youth during class we created an activating mobile gaming platform, and started experimenting with math-exercises.

A mobile platform is a convenient choice, in 2012 at the age of twelve, nearly all youths in the Netherlands own a mobile phone, of which 58% is a smartphone [17]. A typical smartphone comes with a number of sensors, including location trackers like GPS, which allows for movement based gaming.

2.1.1 Design

The version tested for this paper is a single player game to train and develop skills around a specific mathematical operator. The activating element lies in controlling the game by walking. The gameplay area shows six key elements:

- An avatar representing the player;
- The playing field;
- Blocks with a number
- Active fields that can add a number to the equation
- A pod representing the current outcome
- A pod showing the target outcome

The aim is to place exactly those numbered blocks on the active fields that the numbers combine exactly into the target outcome. The avatar can relocate the numbered blocks. The avatar is controlled by two inputs. The touch-controls in the top right corner show four arrows that will rotate the avatar to face the desired direction. Figure 2 shows a screenshot of the game, training multiplication and adding up.

The key-interaction for the PlayFit project is the movement of the user, detected by the GPS-sensor in the mobile device. With current penetration rates of The difference in GPS-location over time (i.e. by walking) determines the movement and speed of the avatar.

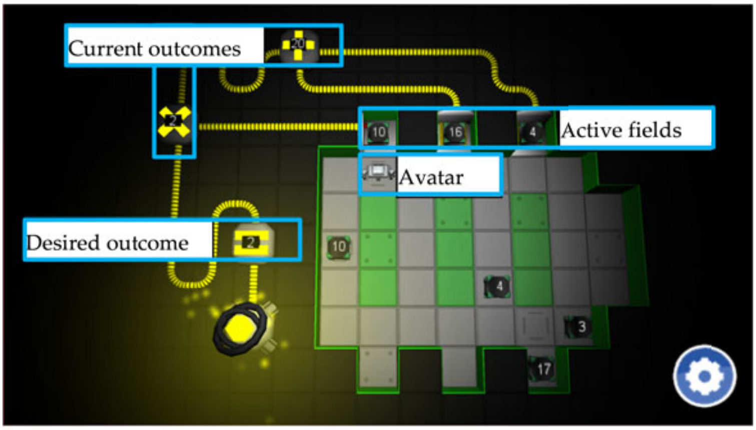

Fig. 2: The gameplay area of the mathematical game, showing the six game elements in the moment when an equation is successfully completed.

2.1.2 Application of design principles.

The tested version of this game is a working proof of concept, using essential functionality. The game is *embedded in the context* by focusing on completing levels of math exercises. The focus on walking moves to the periphery as the primary goal is to finish the math exercise. The game currently satisfies an *intrinsic need to explore*: the gaming environment and the novelty connect to the world of the gaming teenagers. The anticipated multi-player environment is expected to satisfy the need for *communication* and *expression*. The game can facilitate multiple factors that support a personal playing style, for example faster walking, or walking with obstacles or in figures. *Emergent play* is envisions to occur with the multi-player functionality. The teenagers will have to work together and find a collaborative strategy to solve the math – exercises. It's expected that by working together a game-layer will emerge on top of the gameplay offered that is open-ended. Playing strategies can vary from competition in math, competition in speed and in collaborative problem solving.

2.1.3 Evaluation of essential gameplay

The goal of the evaluation was to test a proof of concept with the essential gameplay. The game has been evaluated at two different schools in the Netherlands. In total seven teachers and twenty teenagers were observed while playing the game. Subsequently they were interviewed. The teenagers were enthusiastic and eager to play when the game was introduced. Strong points were

(1) the clear, self-explanatory gameplay, (2) training math in a gaming environment and (3) being outside, gaming during regular class hours. Main points for improvement were (1) the limited amount of complexity, (2) the weather dependency and (3) the layout of the interface. The tested version there were only levels around applying 1 operator. The dependency on dry weather as the game cannot be played indoors due to poor GPS reception. During sunny spells the dark colors in the interface made it hard to distinguish the game elements. Girls complained about the robotic-theme, they felt it was more appealing for boys than for girls.

The teachers saw much potential in this mobile gaming platform. First of all they expect it will spice up their lessons, which will increase engagement with the subject.. They it requires them to overcome some practicalities, like shared supervision between indoor- and outdoor math takers, and bad-weather conditions. Second, it will add a strong element of fun for their students while working with math. This is a big relief for teachers that have a hard time making an attractive curriculum for the more abstract topics in vocational education. Thirdly they see much potential in designing a customized training program for both challenged and advanced students through automatic tracking of game-results. The teachers suggested the a multi-player option spontaneously. Adding a multi-player option would help them in making students work together both groups of similar and of mixed levels.

2.2 Gamifying trampolines

Participation in a typical physical education (PE) lesson is often difficult for teenagers. The threshold to show their physical skills in front of the whole class is high; especially when the teenager is physically challenged by for example overweight. Bringing a gaming environment into physical education can point that attention to the performance in the game rather than their physical performance. As such, a game, for example using a trampoline, can positively influence the involvement of these teenagers in physical education.

2.2.1 Trampoline as a game console.

The open-ended game consists of three trampolines, each producing unique sound and light effects when jumping. The effects can be manipulated by jumping frequency and amplitude. The classic games in physical education are typically rule-based. Our design principles however require to create a form of open-endedness to the game. In contrast with other concepts, for the environment of a PE lesson the idea of an open-ended game immediately challenged. To learn more about the potential success of an open-ended game, we also designed a rule-based variant. The rule-based game consists of one trampoline that controls a video game on a screen. The video game is a classic horizontal scroller in which a character needs to run and jump over obstacles. Speed and jump-height are controlled with the trampoline through frequency and power of the jumping player. Figure 3 shows an example of both games.

Fig. 3: Two versions of a trampoline game. The left picture shows the open-ended version, the right version shows the rule-based version controlling the screen.

2.2.2 Application of design principles

The games are *embedded in the context* of PE education. The opend-ended version can *trigger a need to play* to explore the interactions, explore gameplay in which there is room for communication, personalization and self-expression. The rule-based version triggers a need to play by offering competition. The open-ended version allows much room for supporting a *personal playing style* where the rule-based version depends on personal skills in controlling the trampoline. The open-ended version allows open-ended play by definition, where the rule-based version does not.

2.2.3 Evaluation of open-ended vs. rule-based trampoline game.

The game was evaluated with 161 teenagers in the age of 12-17 in vocational education, at two different schools. A comparison between the open-ended trampoline game and a rule-based trampoline game [18] showed that the open-ended game was less engaging than the rule-based game in which goal and structure were immediately clear. The (rule-based) game was perceived as a fun and effective means to raise activity levels with a trampoline. From the interviews we learned that the target audience feels safe in an environment where there is a strong structure in gameplay and where goals and rules are immediately clear. Therefore, the requirement to explore first and then to be creative in establishing self-defined rules creates a strong threshold to use an open-ended platform with this target audience in Physical Education.

2.3 Eliciting Activity during free time

Even during free-time teenagers tend to reduce their activity levels to a minimum. In reducing sedentary moments there is much to win in activating them during their breaks. The PlayFit concept we would like to discuss here is the latest version of the "Walk of Fame" [9].

Fig. 4: The Walk of Fame. Walking on the carpet starts a recording. Partial playback results in funny combinations of heads, trunks and legs moving down the hall. The installation elicits repetitive walking to perfect the coordination of displayed body-parts.

The Walk of Fame is an interactive installation where teenagers play with - and by - walking through a corridor. The system records players, cuts the recording in three pieces, and projects a person's head with a body and legs from other recordings. Easy to learn, but hard to master: it is easy to create a funny composition, but a perfect combination of head-body-legs requires cooperation with other players - and much walking through the corridor. Figure 4 shows an example recording.

2.3.1 Application of design principles

The walk of Fame is *embedded in the context* of walking through a corridor: it does not require a special action, it unobtrusively detects when someone is walking down the corridor and starts recording. The installation *triggers an intrinsic need to play* by inviting to explore the type of interactions and to collaborate with others in manipulating the effects, increasing their activity levels at the same time. The installation supports a personal *playing style*, there are many aspects that can be played with, timing, syncronicity, mixing body parts over the layers and experimenting with different types of movement. The walk of fame also supports *open-ended play*: players decide on the go what they will create, and how they will combine it together.

2.3.2 Evaluation.

So far the Walk of Fame has been evaluated in 2 short pilot studies (1 day) with teenagers and children, and one longer pilot (10 days) at dancing center Dynamo (Eindhoven, Netherlands) during the E-Moves festival. Both studies consisted of observations during free play. The results have not yet been fully analyzed, but the results show that the installation is very well capable of triggering curiosity and exploration. Both the children and the dancers repeatedly started a recording to experiment with a wide variety of ways to walk down a corridor.

Future work will include an evaluation of six weeks at a high school in vocational education. The focus will then be on learning about what it requires to maintain a good level of interest in the installation and subsequent activity levels.

3 Discussion

3.1 Testing the concepts

3.1.1 Activating math lessons

The evaluation indicates that the current version has the primary intended effects. The game connects to teenagers as expected, persuading them to walk in a playful way, while being occupied with a math exercise. However, the learning experience is currently limited to plain math exercises. Learning math in an open space has the potential for a richer learning experience. Additionally, the engagement is expected to gradually wear off as it currently relies on the novelty of a gaming environment in education. To generate a structural effect, the game needs to be appealing to more needs, for example Communication (B) and Expression (D), which can be achieved through multi-player functionality.

Additionally the mobile platform and eventually using mobile internet can extend the gameplay further, but also a viable business model. By adding several types of logs, we can collect interesting data for both educational stakeholders as well as from the health industry. Logging game progress for example can help teachers to track the advance of their students. Logging health data can be of interest to health professionals to monitor measures in health-risk reduction. We currently explore viable business models with multiple stakeholders.

3.1.2 Trampoline as a game console.

The evaluation of the two trampoline game concepts clearly indicated that in the context of Physical Education an *open-ended game* aiming at *elicitation* of *emergent play* was not successful enough in addressing the target user group, compared to a rule based game. We have not compared the walk-of-fame with a rule-based version, it could be that the availability of a choice between the rule-based game and the open-ended game in itself determined the outcome of the study. Other explanations for findings in this study could be that the threshold to play an open-ended game in a class-room setting is higher than during free time (e.g. the walk-of-fame), that both games should have been screen-based trampoline games for a fair comparison, or that jumping on trampoline in itself induces an increased feeling of being exposed with this audience. Further research is definitely required to pinpoint what determines the success of an open-ended game with this audience.

Future versions of the rule-based trampoline game will focus on broadening the type of video games that can be played with a trampoline, for example an advanced horizontal scroller like in the Mario series [19] or Guitar Hero series [20], with five trampolines, each trampoline controlling a button of the guitar - thus making the trampoline a more versatile game console.

3.1.3 Walk of Fame

It is interesting to see that the Walk of Fame has an instant appeal to passers-by. This concept relies on triggering curiosity, and we can expect that that effect will wear off over some time. The main focus is now to study the period of time that an interaction stays interesting and to develop new, rich interactions, to structurally trigger a need to explore and to ensure prolonged social and physical play. Planned interactions involve changing the way recordings combine, for example by using two slices (instead of three), different orientations, silhouettes, video images and stop motion pictures. Furthermore we are looking into ways to include adaptation to a personal playing style.

The Walk of Fame is very simple to setup, it requires commonly available devices. To stay interesting though, it probably requires regular updates with new interactions. We currently explore business models for this concept based on a subscription model for new interactions.

3.2 Activating teenagers

The positive feedback for each of the three presented concepts indicate that in this environment teenagers can be successfully persuaded to raise their current activity level throughout the day. Each game was designed for a specific moment in the school day and each version (although not yet fully developed) was received with enthusiasm. In two concepts, the activity (walking) itself stayed out of focus as the teenagers were busy playing the game, solving math exercises or creating interesting recordings of body parts.

All studies conducted have been pilot studies or at its best exploratory studies. The studies resulted in positive indications for the success of the designs. A more thorough approach is required to find stronger evidence for the long-term success of the concepts. A long term study into each concept is planned. The research questions focus on maintaining a structural engagement of the target group and on validating the achieved reduction in time spend sedentary.

The designs for each concept focus on reducing sedentary time for a specific moment during a school day (physical education, math and during free time). Together they provide the basis for a strong, integrated approach to activate teenagers throughout the day. Our next studies will look into the aspects of combining the three moments together. Each concept is designed to raise the activity level as a side effect of the primary goal. We question for example whether compensation strategies in terms of activity will occur. Other aspects are addressing the entire audience and engaging them continuously throughout the day, and to what extent. Future research is required to find out how well and which part of a school population is activated with the PlayFit solutions.

3.3 Optimizing for activity and interest

To address a heterogeneous group requires a broad range of activities. The presented concepts are designed and studied to start with covering a broad range at once. We are aware that these concepts probably do not appeal to the entire audience, simply because not all activities and triggers are equally appealing to each individual. The project would be most successful if it could. Therefore the project started explorations for an overall concept, a monitoring platform for activating games.

By developing a monitoring platform we can monitor sedentary and active moments, and the type of activity. Youths have a personal profile that reflects their activities, weight, role in the game, interests, social network etc. The personal character will match he profile of the player. As such we can differentiate for the different playergroups and lifestyles (for example the importance of self-monitoring for girls and competition for boys). In addition an overall concept allows to support the transitions between the different phases in life (e.g. the interests of a 12 year old differ from the interests of a 16 year old). Currently studies with youth are conducted to explore what kind of means can be used to communicate activity levels and at the same time trigger more activation.

3.4 Implementing all three concepts in a school environment

For each concept the design principles were leading, in an attempt to seamlessly connect with the current teenage lifestyle and start activating them from their current activity level. The design principles itself seem to be a fruitful direction to implement activating concepts without a paternalistic focus on the topic of a healthy lifestyle. That is a big win for activating this target audience, nonetheless there are still some obstacles to overcome that have not yet been sufficiently studied.

An intervention during free play is less disruptive in a curriculum than a game for a math lesson or during PE education. Therefore we start with complementary material that can be used to train the weaker, or to challenge the more talented students.

When organizing the evaluations in the schools, we found that the teachers need to be clearly informed and convinced of the added value. Most personnel was very postive towards the evaluations, because each concept is highly appealing for its innovative aspects, new technology and focus on a healthy lifestyle. Nonetheless it also became clear that the concepts require good educational content to be integrated in math- and PE lessons. Training to work with these concepts is required, but that is not distinctive for PlayFit concepts. The current technological revolution that is taking place in schools (adoption of tablets, smartboards etc) requires educators to be involved and trained in the plethora of new methods and tools in education.

For each concept we also indicated directions for a viable business model, and that requires further attention. Schools work with limited budgets thus assuming the school to pay for a game platform or a large installation is a bold assumption. The presented concepts provide opportunities to involve a larger number of stakeholders. Not only the usual suspects in the educational field, like schools, parents and publishers, but also the health-, the sports- and game industry are interesting partners.

4 Conclusions

The preliminary evaluations presented indicate that reducing sedentary behavior through triggering intrinsic motivation lowers the threshold for engaging in activating games. We also conclude that further research is required to understand the success and limitations of open-ended play in an educational setting. Finally, we have laid the basis for an integrated approach that can reduce sedentary behavior throughout the day: all three concepts trigger more activity during complementary moments in school day. Further research is planned to measure and learn about the long term effects and how to structurally engagement youths in these novel concepts.

To implement these concepts in a school environment, we found a positive attitude towards the chosen directions, because they are innovative, engaging and aim at a healthy lifestyle. The next steps require to ensure high quality content, and to overcome practical obstacles in implementing all concepts in a school-environment with a sustainable business model.

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