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

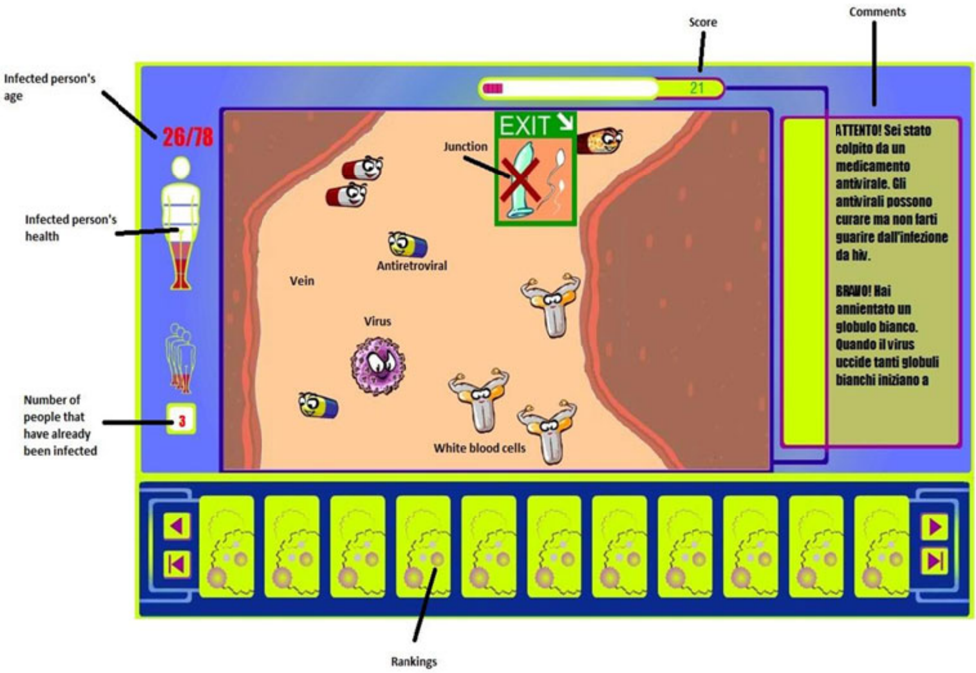

Fig 1: HinVanders game interface

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.

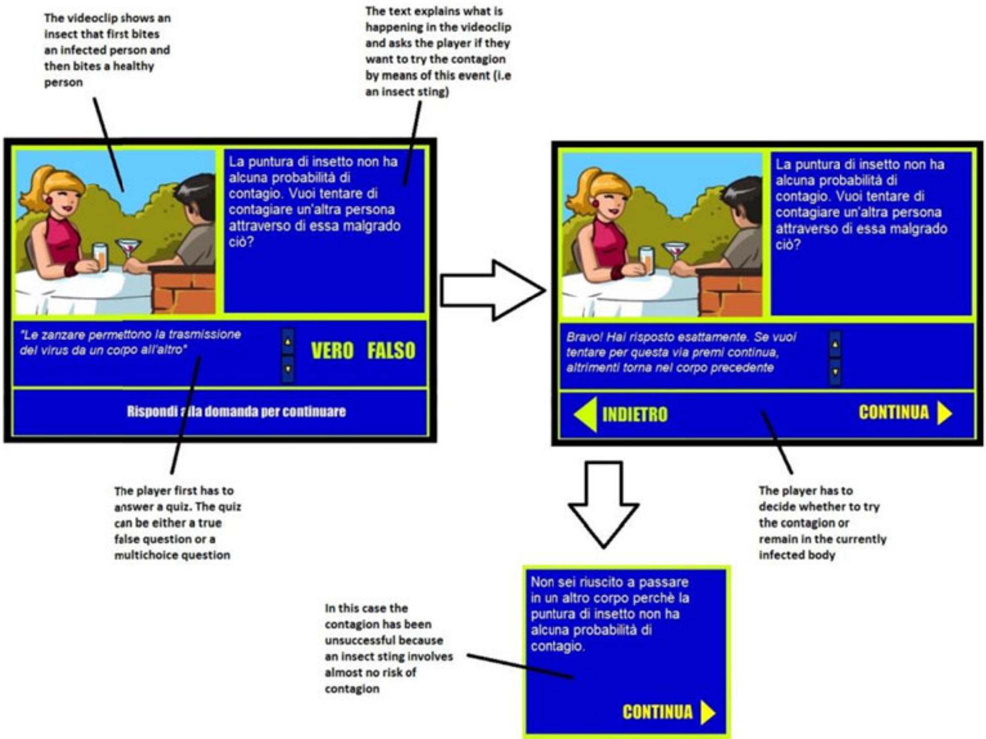

Figure 2: When the player hits a channel, the games explain what happens

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.

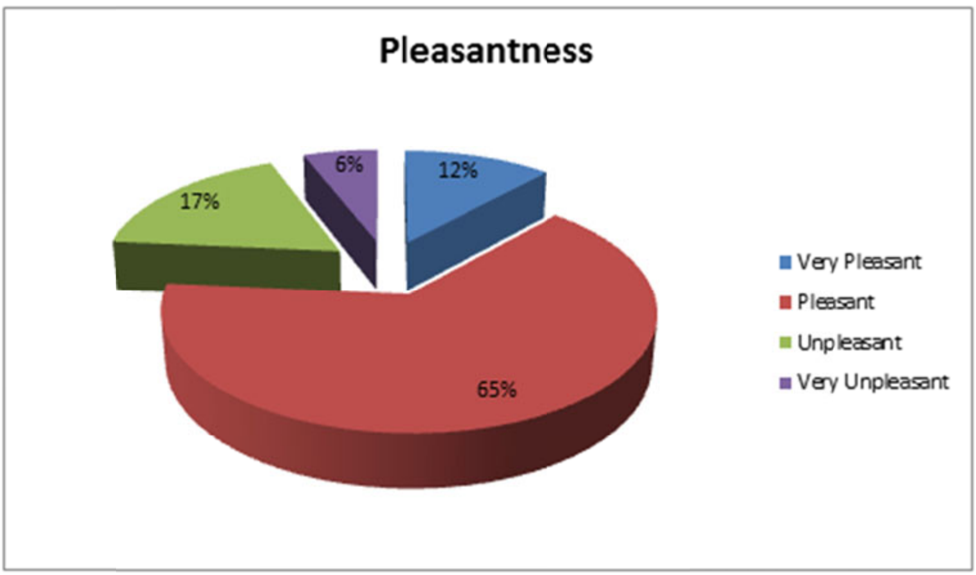

Figure 3: Perceives pleasantness of the game

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.

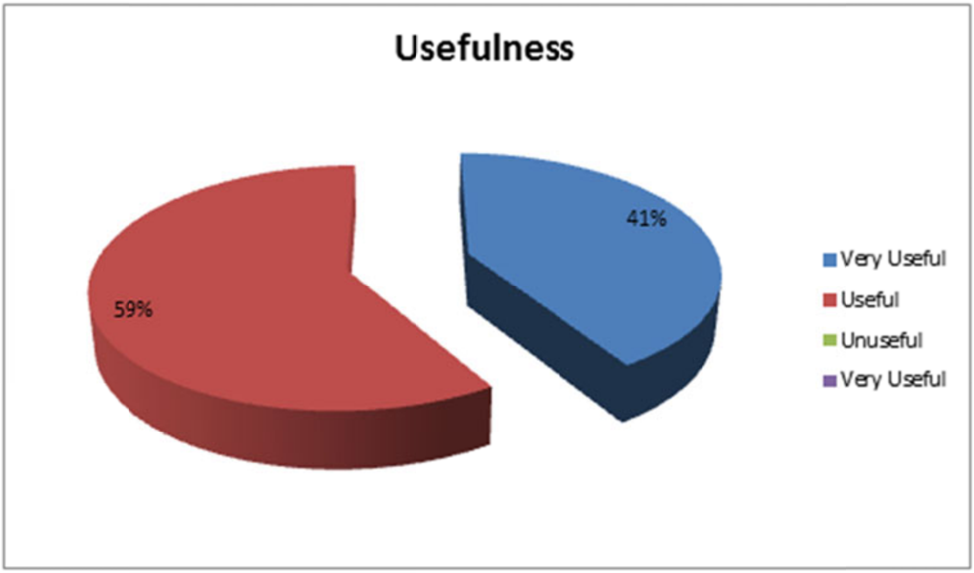

Figure 4: Perceived usefulness of the game

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.

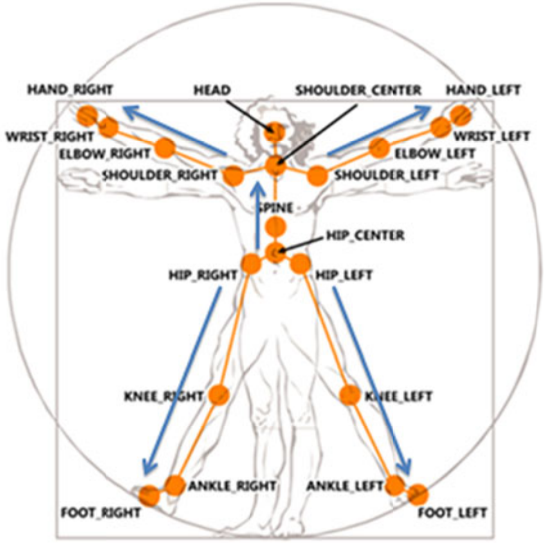

Figure 1: Stick model skeleton obtained with Kinect™ sensors and Kinect for Windows SDK (Source: **http://msdn.microsoft.com/en-us/library /jj131025.aspx)**

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.

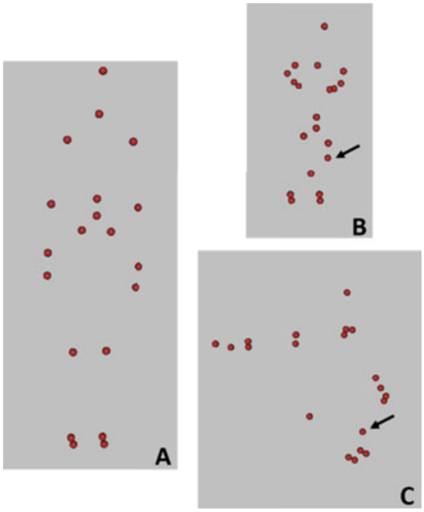

Figure 2: Example of miss tracking with Kinect™ sensor (before optimization). ***A*** Stick model diagram in upright position indicates that joint centres are well recognized (anterior view). ***B*** and ***C***. The subject is performing a deep squat movement (knee flexion), the arrow indicates that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

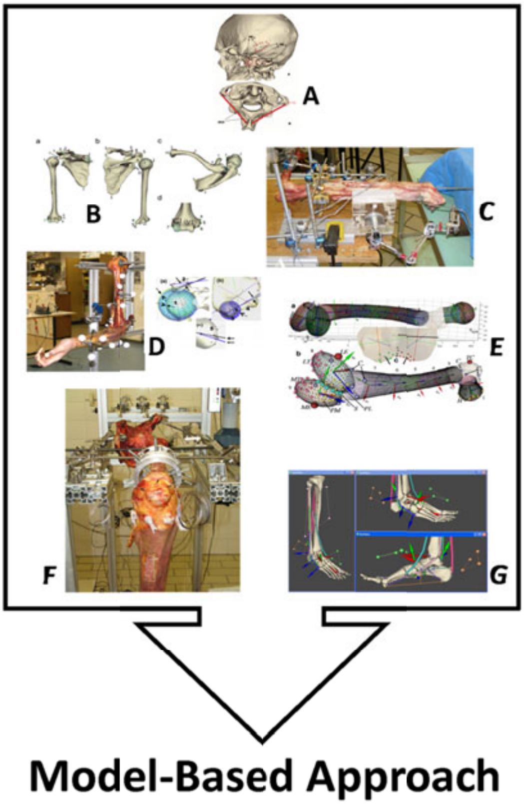

Figure 3: A few examples of biomechanical studies performed in the laboratory and implemented into MBA. ***A*** Musculoskeletal modelling and cervical spine kinematics [26,29]. ***B*** Shoulder rhythm (shoulder joint behaviour) [30-31]. ***C*** Hand, wrist and fingers biomechanics [32-34]. ***D***. Elbow (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).

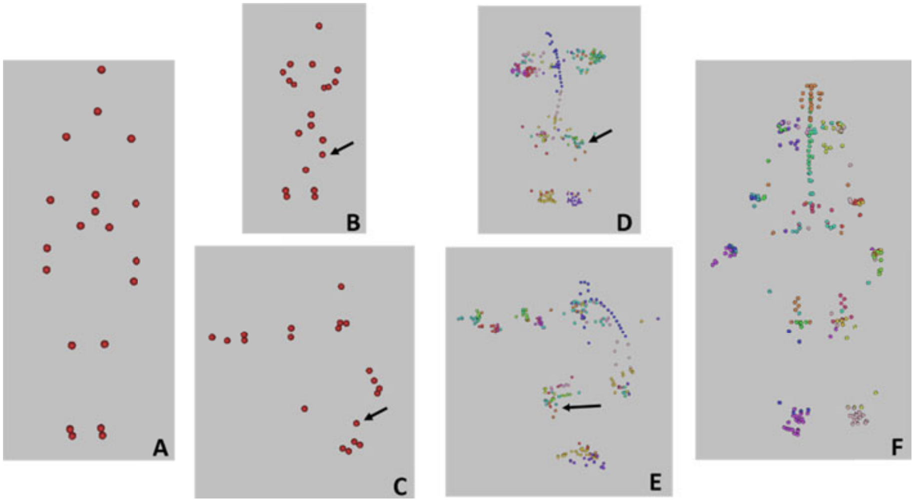

Figure 4: *A, B, C* Raw results (similar to Figure 2). Figures *D* and *E* show the same squat motion after MBA optimization process, arrows indicates that the left knee is in a more natural position. Figure *F* show the optimized skeleton in upright position. Note the supplementary anatomical data has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

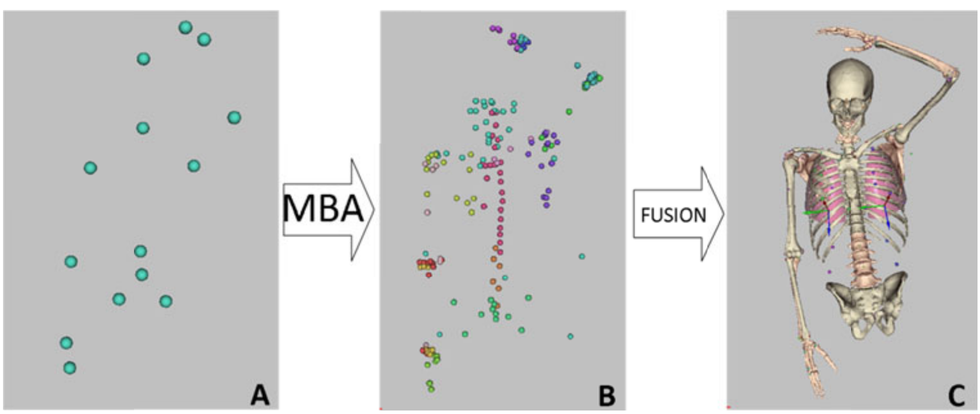

Figure 5: Example of complex 3D motion recorded with the Kinect™ and enriched with the presented MBA algorithm: conventional Hand-to-Head clinical assessment (called the Mallet Score [41]). ***A*:** raw results of the Kinect™ = input signal for MBA. ***B*:** optimized results = MBA output. ***C*:** MBA 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,