Exertainment: Designing Active Video Games to Get Youth Moving

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***Abstract*— The advancement of ICT innovations provides us with a comfortable and convenient modern lifestyle. However, this modern easy lifestyle is proving to have some serious health consequences. Such technological advancements that have dramatically increased ones time in front of screens have been a contributing factor to increasing rates of obesity. In particular the youth obesity issue has gained more and more attention from researchers and health institutions around the world. Although technology innovations may lead to a sedate modern life, they also have a potential to solve the obesity issue in children. This paper provides a review of the issues in child obesity and the potential of active video games to mitigate these issues. Additionally, the paper also discusses the key requirements to develop an active video game that hopes to help combat child obesity through motivating youth to exergame. A framework is introduced to meet the requirements, from which a prototype was implemented. Discussion of the simulation and testing that were performed to verify the attainment of objectives is also detailed.**

***Index Terms*— Active Video Games, Exergaming, Health Informatics, Human Computer Interaction.**

I. Introduction

In modern society, sedentary lifestyle is objectively encouraged in exchange of physical activity [51]. Sedentary lifestyle happens to be defined to include hours spent sitting and watching TV or videos, using a computer, or playing computer games [3]. Various forms of screen time are become more common for many different reasons. Education at all levels is moving to a digitally connected and computer based interaction environment, with children in Kindergarten already receiving homework tasks to be completed online. Further, as parents are working harder and longer hours, and the office borders encroach on the home, the television, computer, or console is a short term 'baby sitter' for the children while the parents answer an email, finishing typing a report or other ubiquitous office tasks.

With increased screen time there is usually a matching decrease in physical activity, especially in children and adolescents. The days where afternoons are spent outside playing in the street or down at the park are dwindling. Further, as neighborhoods become less safe, more and more children are staying indoors and looking for digital entertainment and using digital means to satisfy peer communication and interaction. Coupled with other factors beyond the scope of this paper (such as poor diets due to increasing consumption of fast food) children and adolescents are getting overweight with the more screen time they consume.

It should be noted right from the start that a controversy stands for the correlation between television viewing and obesity. A randomized trial revealed that the BMI of a group with interventions to reduce the time spent on television views decreased greater than the one without [8]. In contrast, playing video games contributes to children`s weight, but not watching television [33]. From a logical perspective, watching television occupies the time which could be spent on physical activities, however, the lack of association between television and activity is evident from the collected data [33]. An argument, meanwhile, was trying in terms of age, to elucidate the result that television use could only be related to weight status among children and adolescents with age older than twelve [33].

As for playing video games, a strong association exists between it and obesity [33]. One randomized controlled trial offered evidence which could prove the attribution of less time spent playing video games helps manage BMI [8]. A bivariate effect is that obese and overweight children confront a serious dilemma in that body image dissatisfaction has been identified as a major barrier [61], especially for girls with a perceived lack of confidence, in being active [69]. As a result of these recent findings our research has been focused on the Video Gaming domain and the increasing amount of time children, adolescents and youth in general are spending submersed in digital virtual environments. Indications are that it is very difficult to get children to NOT play video games. At some level they will always be exposed to them, and with the influence of edutainment increasing 'gaming' is here to stay.

Our approach therefore is to use the very same information and communication technologies that are contributing to an unhealthy lifestyle to turn the tide again and use it for promoting a healthy one. As digital devices continue to get more complicated and host a growing number of features, we have found many modern devices include health related elements such as pedometers. Further, over the last 18 months there has been a huge market boom on fitness bracelets, lifestyle tracking devices and a host of software applications to support them. Our research aims to use such evolving technologies to track and monitor an individual's daily, weekly, monthly physical exertion and integrate it back into the prized digital virtual games they spend so much time using. The key is to ensure that the virtual rewards for physical world activity and exercise far

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surpass those they would simply get from playing a video game for hours on end.

The remainder of the paper is structured as follows. Section 2 provides a brief summary of background and related material. The conceptual design details follow in Section 3, with Prototype Testing and Analysis covered in Section 4. The Results, Conclusion and Future Work are provided in Section 5, with the paper concluded with a list of references.

II. Background and Related Material

Childhood obesity and children being overweight leads to several serious physiological diseases. A connection between it and the increasing rate of morbidity has shown to exist. Further, compounding the issue and making it more severe is its short duration of effects being one or two decades, and it being a factor that can increase the impact of a number of risk factors on other adult diseases [1]. The characteristic of predicting overweight later in life logically associates another negative consequence that parental obesity can be a determinant and potential for influencing their children towards higher BMI [1] [5].

Childhood obesity could elevate cholesterol level as a significant risk factor, as well as be predictive of premature death [2]. It is also an early metabolic derangement from which most of the other risk factors emerge later. The list of adverse health factors from childhood obesity can be extended further, including physical inactivity, excessive caloric intake, and specific nutrient preferences [2].

As a major means related to the reduction in obesity, physical activities have been recommended or considered with a high priority by many articles, some of which graded them as the primary environmental influences on childhood obesity according to a direct association [1] [3]. Intertwined with the circumstances of school-based programs [7] [10] [22], the result could be produced due to the well-trained school staff`s ability to deliver programs consistently [7], and the potential of exergames (a means for childhood obesity intervention) for lowing the degree of obesity [22].

In terms of reduction in obesity rates by physical activities, time spent on the activities plays a crucial role. One article mentioned that fat mass and BMI was inversely associated with the time spent in moderate-to-vigorous physical activity [19]. Another one said that is school-age youth should participate daily in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities [31]. A decrease on sedentary behaviors with an increase on physical activities tends to have an inverse relationship, and both contribute to controlling childhood obesity [34]. Two approaches were introduced by [10] and [13] respectively:

1) *Family practices also affect the behavior patterns associated with physical activity. Physical activity is likely to be increased among children with siblings and playmates or among children who live in neighborhoods where opportunities exist for safe outdoor play [10].*

2) Physical Activity can be encouraged by interactive computer games [13].

Active video games, also named exergames, happened to be an enhanced version of video games, which are able to track body action or reaction by employing active body movements as mode of interaction [28]. Thus they require players' physical interaction, and provide leisure and exercising simultaneously [14]. As they are hardly restricted by objective environments, for example, bad weather or limited available options, the process of additional physical exercise can be facilitated from their natural characteristics [14].

In terms of engagement, the mode of active video games has been established as an activity enjoyed by children [14]. Also, the promotion of building social fabric is another beneficial fruit of them [28]. Due to its used technologies, the children with visually impaired could gain assistance from the use in order to get around over some of the obstacles to physical activity, thus, to merit social significance by increasing a sense of equity [14]. Another feather of the possibility to be an agent for physical activity has been mention by article [14].

As far as this literature review investigated, authentic sports were irreplaceable due to aerobic exercise and the engrossing features of each. Nevertheless, active video games, as new generation of video games, appear to provide for such a positive outcome [28]. Compared to authentic sports, exergames got the edge of playing environment [14]. And they were able to act as mediums for exercise and physical activity [14] [20]. As demonstrated as following, comparison was operated in terms of energy expenditure and psychological outcomes.

As expected, Exergaming levels up physiological signs, such as heart rate, as well as aerobic activity for physical fitness can be earned from them [20][52]. However, what is needed to be noticed is that they are only capable of yielding light to moderate energy expenditure, similar to walking, skipping, and jogging, depended on the types of exergames. For some of them, predicted energy expenditure could even go up by at least 51%, which was, though, still lower than the authentic peers [53]. Frequency of playing exergames defines the contribution to fitness and weight loss over time [20]. Different game gives different result amongst different groups of participant. For example, the physiological cost of Exergaming on Wii Fit was lower than treadmill exercise and jogging [52], and more related information on Windows Kinect will be provided after. The comparison with trampoline and leisure walk was drawn, producing a comparable energy cost among young and old adults [54]. Anywise, active video games appear to be a safe, fun, and valuable means of promoting energy expenditure for children [52].

Besides being a complement to physical sports, teenagers could also benefit a lot from exergames, due to the friendly competition with peers, the opportunities for social interaction, and improved self-esteem [20]. Active games as a source of social interaction allow players to check out how they stack up against their friends' and other players' performances in various ways [28] [46]. One article holds a firm stance on players` attitudes towards active gaming, saying that the adolescents agree the type of games, particularly in the aspect of social interactive play a significant part of their success. [29]. As for the vital role of school for children and adolescents, active gaming has been modeled into an approach to prevent obesity, which yielded

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an encouraging result -- positive modeling behaviors can lead to positive behaviors at home. However, concerns still exist as they have the potential to displace time that deserves to be spent on a more gainful sports and physical activities [18]. But used wisely the opportunities provided by exergames give children a wide range of diverse activities to participate in, some of which they may not otherwise have been exposed to during the course of their lives, such as Boxing, Abseiling, Kayaking, and Kung Fu [18].

III. Conceptual Design

In order to envisage a suitable conceptual design all facets of Active Video Games needed to be explored, in combination with review of currently available technologies. It was found that although active video games are capable of expending more energy than traditional video games it was somewhat platform dependent. That is, different sets of data assessed by the recent research are derived from studies of different types of products. As such, games are now loosely categorized according to the physiological factors. Current active video games are capable of enabling light to moderate physical activity [16]. However, we have hypothesized from the literature and our evaluation that energy expenditure has a high correlation with relevant products. This significant factor has influenced our choice of platform for our conceptual design and final prototype.

Further, the assertion that active video games are able to complement instead of replace authentic sports is inclined to be correct; with walking the only reference activity according to which no significant differences in energy expenditure were found under the platform of the Nintendo® Wii [52]. None of the games investigated during the process of review fell into the group of vigorous-intensity activities, except for two (LightSpace, Sportwall), which were seemingly highly intensive. The majority of them tended to be lightly or moderately intensive [15] [17][45][54][58], and Xbox Kinect elicited greater energy expenditure than playing on the Wii [45]. Therefore, our design needed to include an activity that can be classified of high intensity in the physical world and transcribe that to the virtual.

Amongst the games under the platform of Wii, Wii Fit Free Jogging happened to be the most intensive activity, accounting for about 71% of Mean percentage of HR max and 5.9 for METs [15]. Meanwhile, the other ones (Wii Sports Boxing, Tennis, Baseball, Bowling, Boxing, and Wii Fit Skiing and Step) were not intense enough to contribute for children in order to gain an 60 min of daily moderate-to-high physical activity [15] [17] [52]. As for the topic of: 'if gaming experience impacted on energy expenditure', different results were found. Participants with gaming experience tended to have a lower heart rate when playing Wii Sports Tennis compared ones without [15]. Another article pointed out that no evidence exists to suggest that gaming experience or aerobic fitness influenced EE when playing AVGs [52]. Though, mode of operation did influence energy expenditure, in which multiplayer mode led to greater exertion than playing in single mode [45]. These research findings indicated that the included activity should also be simple to do and learn, can be done with groups of people, and is consistent in form and sensor detection.

Another important element for conceptual design consideration is the sustainability of the game and users willingness to replay it. Frequencies of playing exergames by school-children and adolescents were not solid. A dramatically decreasing with home usage was mentioned in a descriptive study when selecting Dance Dance Revolution as an intervention [21]. Meanwhile, the same game and Just Dance as an intervention had an increase in the proportion of students before and after the intervention. As for Just Dance, the percentage went more than double from 11.6% to 25.6%. In terms of usage, Dance Dance Revolution was reported to be 10.5% before implementation, and rose up to 19.8% after [22]. Therefore, we concluded the game and its integrated physical activity should be easy, fun, and if possible engaging to ensure players keep returning.

Another important feature of our overall solution was to utilize and integrate some of the more modern exercise devices that may be attractive to the youth market. These include the recent inclusion of pedometers and accelerometers in many mobile devices. However, due to the barriers of hardware, the designs of portable devices are inclined to fulfill definite requirements. Normally, they are able to detect simple physical behavior, such as jogging steps and rate, heart rate, by embedded monitors [23]. For the analysis software could be installed as being native, some functions were provided in a pragmatic way. For instance, a mobile personal trainer (MOPET) system motivates the user, by exploiting graphics as well as audio, to suggest how much amount of exercise is needed [23]. This type of benefit can be raised by combining with other advanced ICT technologies, such as cloud computing, and artificial intelligence [26].

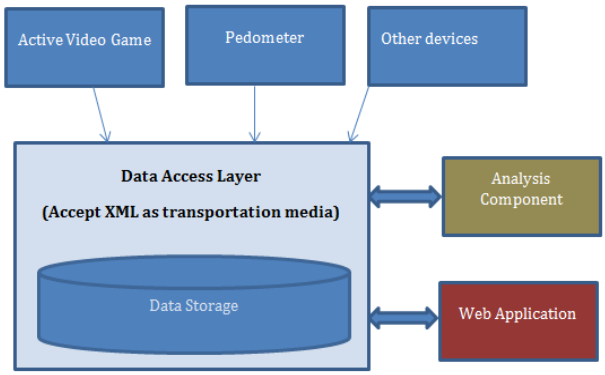

Figure 1. Components relationship for designing active video games

Therefore, in terms of conceptual framework, the design is intent on data-oriented infrastructure which fulfills the current requirements and opens the scope for future analysis and research. Thus, any devices which are capable of recording human body movements, such as jumping, jogging, even swimming, are, in theory, data sources. As for how to explore within the collected data pool, it is one of the main elements of our research and scoped as part of this paper. That is, we utilize it to develop an initial prototype to motivate users to do more physical exercise in an entertaining way. However, before the exergame could be produced a number of preconditions had to be met for the development to take place. They include:

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- Integrated Development Environment (IDE): the reason why this type of software is significantly important is that they are able to improve the efficiency dramatically.
- Software Development Kit (SDK): this is literally a set of application program interfaces (API) through which the related hardware can be manipulated by peripheral systems or programs. Most of the time, a bundle of tools is delivered within, such as ones of simulation, debug, and compilation.
- Motion Sensor: this type of hardware is normally coupled with a set of SDK including driving program. This is essential for the proposed prototype because the component of active video games is developed based on it.
- Devices with pedometers: this types of devices are widely embedded in smart phones, or body monitors in the form of lifestyle bracelets (Nike+ FuelBand, Jawbone UP, Fitbit, etc).

In figure 1 the relationships between the components are clearly illustrated.

IV. Prototype System, Testing and Analysis

The main contribution of our research is to replace sedentary activities, specifically video game play, with more physical exercise. Our prototype is oriented to offer a framework which is able to connect two separated fields. That is, daily activities and entertainment combined together to produce active video using available information and communication technologies. Therefore, functional testing and verification of the developed prototype play a dominant role during development and validation. Our system consists of two main components. One is a Kinect-based exergame we have developed, named Star-Jump. The second is a web based youth game application (B.E.T.T.E.R.: Battling Elemental Titans Through Exercise Routines) that also serves as a platform to receive exercise data from the Star-Jump game and daily recorded physical activity. The object of the system is not only to demonstrate how the infrastructure supports the implementation of the framework, but also exhibit the feature of this system`s extension. An evaluation is given to support claims in terms of to what extent the proposed system is a solution that can alleviate one of the causes of childhood obesitv.

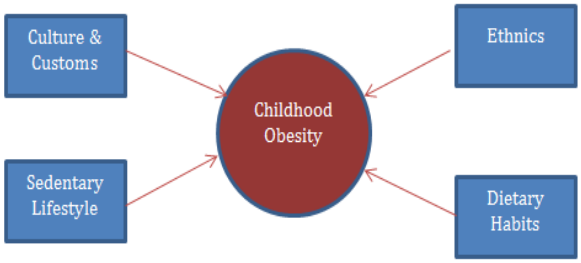

Figure 2. Factors contributing to child obesity

A. Objective of the Prototype

As discussed previously, childhood obesity has become an increasingly important issue. Figure 2 shows four main factors that contribute to this problem and also the focus of our greater research projects. This paper's findings focus on one of them, being sedentary lifestyle. The underlying assumption that the more sedentary activities are replaced by physical exercise, the lower BMI will be, shapes proposals into the verifiable hypotheses. However, as the fact of childhood obesity has at least four dimensions, it is reasonable to say that this system should not be used in isolation and considered to be the only way to manage youth obesity.

As for the process of forming the schema of the proposed framework a main design intention was not to in so much invent new technologies or tools. Rather, we attempt to build upon and use the current available technologies to provide a readily available and potentially affordable solution. As such different ICT components were responsible for the various functionalities of the framework. They include:

- The algorithm in the web application BETTER provides the management and utilization of exercise data.
- Active video game elements are provided under the technology of motion sensing using such a device as Microsoft Kinect.
- Daily activities tracking is provided by using devices that integrate pedometers and other exercise tracking technologies.

Furthermore, it is an important design objective that those functions or devices are separated and therefore can evolve individually. However, a key research innovation of our project and part of this framework is to investigate how they can be linked together. Hence, the core design guidance is following data-driven principles. Thus, as long as devices provide interfaces between themselves and a mechanism for transferring data, they are able to make contributions towards the study and alleviation of childhood obesity.

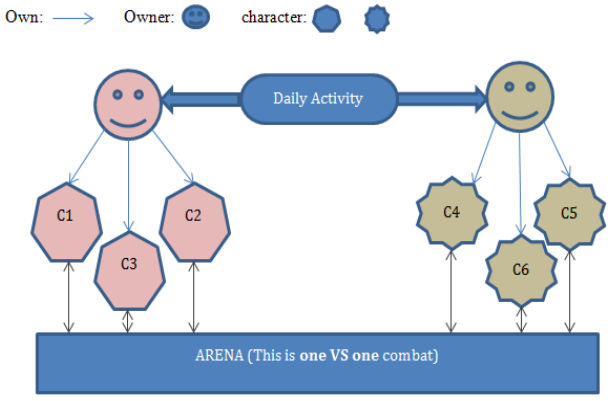

Figure 3. Overview of System Implementation

B. Overview of Prototype Implementation

As mentioned before, pedometers are considered a function provided from an external device and are therefore excluded from the development cycle. However, the interpretation of the results by the corresponding components of the web application, including import of the data file, extraction of the exercise data, and so on, are integral to the final solution. Figure 3 describes how the system works and is explained as follows.

- Real world daily activity tracked by an external pedometer type device is one source of achieving points for the web app virtual in game 'rewards'.

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- The Star Jump Kinect Active Video Game is another source of achieving points for the web app virtual in game 'rewards'.
- Virtual battles between Titans inside of the BETTER virtual world are another way of earning in game reward points. However these reward points are not generated through exercise and/or physical exertion.

C. Characteristics of the Web Applications

The interface for importing exercise data partly drives the operation of the web application. In order to open the application to support multiple devices, the design and implementation used layer of abstraction. The benefit is the separation between business functions (business layer) and data layer, plus ease in the functional implementation. Furthermore, due to the different formats of data results, each of them needs to be interpreted independently. The above approach adopts the strategic design pattern to overcome the interference of them according to the Single Responsibility Principle.

To keep the AVG web application engaging the "titan combat" algorithm is balanced to ensure the progression of Titans through an increase in its "level and steps within each level". Moreover, a random function producing the determinative points brings more suspense into final results of combats. However, to ensure players are more motivated to exercise Titans can be progressed more easily by transferring exercise points to a respective Titan to move it up Levels and Steps. This game architectural rule aims at ensuring players balance virtual play time with physical real world exercise. Other business rules of the BETTER web based AVG are meant to ensure an engaging and fun playing experience. They include the following key features:

- A TITAN can only challenge another one within 2 steps up of its own Level/Step and 1 step down of its own Level/Step.
- Reward Points from the Kinect-based video Star Jump game and the ones from portable exercise tracking devices are limited to 500 per 24 hours.
- Additionally, in order to keep children engaged, a TITAN can progress into the 'Hall of Fame', achieved through exercise and game play. The Hall of Fame is a peer mechanism for displaying success.

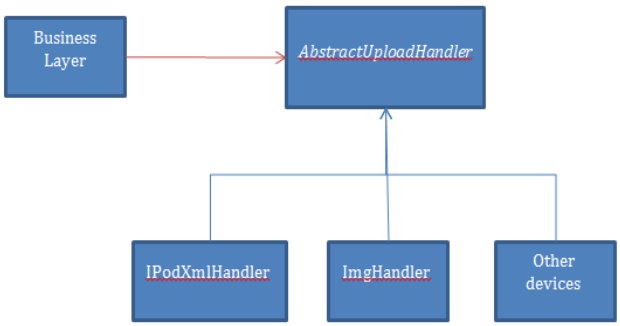

Figure 4. Web Applications

D. Characteristics of the Jumping Jack AVG

The 'jumping jack' program is another way the users of BETTER can create game points for their characters. It is also a way of allowing real time digitally monitored exercise to be incorporated into the game. So we include in thesis as having both options for children. This Jumping Jack AVG is a modified version based that integrates the Windows Kinect motion sensor, and is built using C# programing language, Kinect SDK version 1.7.

The purpose is to motivate children into physical exercise through a basic active video game. As mentioned, the program has been modified to detect star jumps (called jumping jacks for the children version) being performed by the interacting user. A diagrammatic representation of the initial and final state of a Star Jump are shown in Figure 5.As for the intention of this game, it is a type of physical jumping exercise performed by jumping to a position with the legs spread wide and the hands forming a straight line.

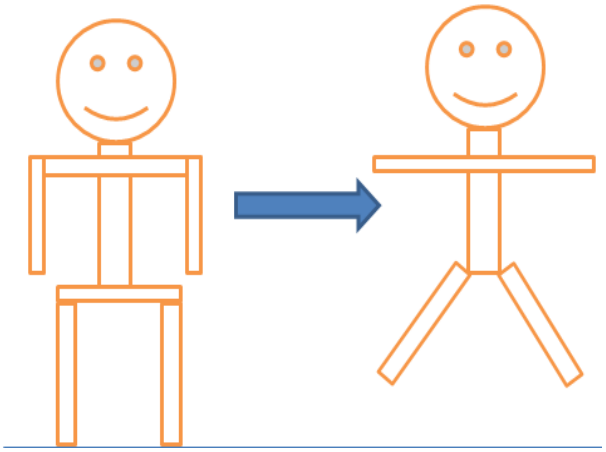

Figure 5. Jumping Pack

Also, in order to earn in game rewards to allocate to TITANS in the BETTER web application, the exercise data from the Kinect game needs to be recorded into a compatible file. Hence, the game functionality has three steps:

- Track the movements of both right and left hand joints, elbow joints, and knee joints.
- Inspect and verify if the movement fits the criteria of star-jumping/Jumping Jack.
- If it does, the record of the number of Jumping Jack's performed will be saved into an xml file located by a preconfigured virtual path.

E. Test Cases for the Prototype

The artifact produced as part of our unique research contribution is composed of two distinguishable elements, the BETTER web based AVG and Star Jump the Kinect Based Windows AVG. System testing was performed on each element individually in addition to the complete system. Thus are testing methodology focuses on the implementation of function by explaining the code and testing the applications through simulation. The choice of methodologies for development and testing (Evolutionary Prototyping and simulation) are deemed appropriate for this domain of research. This is due to the proposed solution being a set of active video applications and information and communication technologies integrated into an exergaming system.

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Real world testing with the target demographic of children and adolescents between the ages of 7-15 is beyond the scope of this paper. It should be noted however that this analysis is currently being carried out over an extended period as the solution continues to evolve. Therefore, the testing and simulation phases are focused on functional and integration testing and evaluation.

As a quality assurance (QA) process, functional testing is a type of black box testing methodology, which is based on the specifications of the software components. During the process, functions are tested by feeding them input and examining if the value of output is the same as expected. In the case of the web application, BETTER, three sets of test cases are built, including the maintenance of TITANS, rewarding the TITANS with exercise data files, and testing the combat algorithm. For the Kinect-based active video game, Jumping Jack, the main testing goals are: if it is able to record star jumps correctly; and if the xml document recording the exercise result can be generated in a well-formatted, correct and accessible fashion.

Before any testing and simulation actions could be performed, the system needs to be initialized and global pre-conditions need to be assured. This involves:

- The database service must be started properly.
- The initial simulation data has been inserted into database properly through a pre-defined SQL script.
- This web application has been deployed under an MS IIS web server with directory permissions set for both apps to read and write files to a directory location.

In order to ensure accessibility of the playing results into it is important to keep the relevant data persistence until the end of a playing session. To achieve this the adopted strategy was separated into a number of manageable object stages:

1) Generate an xml file: Creation of an xml is part of the game`s initialization. In this phase, a physical drive location is opened as a space for saving the record produced later.

2) Display the record of proper jumping jumps completed real time as feedback to the user.

3) Save the number of jumping jacks into the dynamically generated xml file continuously (The created xml needs to be loaded into memory in order to manipulate the meta-data contained within it).

4) Once users finishes their jumping jack session, save final result into the xml file and close its access.

V. Results, Conclusion and Future Work

Our research is about how active video games can be adopted as an effective approach to address the issue of childhood obesity. AVG's have been shown to encourage more physical activities than traditional video games ones, however only one or two current AVG's fulfill the criteria of energy expenditure in terms of lost-weight or control of BMI. Therefore, the research problem shifts into examination of fundamental technologies and devices, to see if active video games can be designed to fulfill the health requirements. Then the research problem broadens itself into finding an approach to motivate children into more physical activities in a persistent way. Daily activities happen to conform to our requirements of physical activity and in order to utilize them, another devices, such as pedometers, need to become part of the solution. Therefore a key problem is finding how to bind them together. With the combination of web and motion sensing applications a solution is possible.

Our solution, including the web based BETTER AVG and windows based Kinect Jumping Jack AVG, tested correctly. Further, when the two systems were completely integrated there was seamless communication between the two elements with complete success in capturing Jumping Jacks and successfully uploading the resulting exercise points into BETTER. These point were also successfully allocated to the respective TITAN chosen by the app user. Further, both the upload of exercise points from an external devices (in this case an iPod Nano 7th generation) and the combat between two titans was extremely successful. So in summary the objectives of this research phase colluded with success. That is, the designed application and selected information and communication technologies were successfully integrated into a working and testing prototype. Thus, producing an Active Video Game system that can be used to help motivate youth to exercise and combat growing child hood obesity issues.

In conclusion, ICT has the potential to be contributors in addressing and managing childhood obesity issues. Our key research findings and contributions are:

- Sedentary lifestyle as a significant contributor to childhood obesity can be alleviated to some extent by the use of information and communication technologies.
- The motion sensor, Kinect, has a natural aptitude for detecting body movements, and records the result.
- Portable devices can be utilized to encourage more physical activities so that exact analysis is possible.

This research redefines what active video games are by introducing them into integrated real world and virtual platforms. Our framework extends active video games into daily lives, which are represented by Kinect-based motion sensing programs and fitness/lifestyle tracking technologies. We provide the tested prototype implementation of the framework and several simulation test cases to verify the achievements of framework's objectives. Several future works currently in progress include real world testing.

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