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The use of sensors in virtual worlds for obesity control

A case study about virtual/real motivation to encourage self-determination against obesity through the Internet of Things

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Abstract.
Obesity is currently one of the most relevant public health concerns worldwide and may cause several diseases (heart diseases, diabetes, increased cholesterol levels, among others). The successful treatment of chronic diseases, particularly obesity, depends strongly on the participation and engagement of the individual as an active subject of his/her own treatment. The use of the Internet of Things in 3D virtual worlds was studied in the current research as a support strategy aiming at offering to the user the feeling of "being present" in a context specially designed to promote motivation and allow interaction with 3D objects. This article reports part of a qualitative case study that surveyed the impact of the combination of 3D virtual worlds with the Internet of Things and mobile devices as elements capable of boosting motivation in subjects enrolled in an obesity control program. The work was based on the theory of self-determination using extrinsic motivation strategies, with a view to achieving a behavioral change capable of promoting improvements in health and life quality. The analysis of preliminary data confirms that the project has the potential to motivate and encourage survey participants in their weight loss process.

Keywords: Internet of Things, obesity, 3D virtual world and self-determination

1 Introduction

Obesity represents one of the major challenges for public health in the 21st century, with alarming trends in many parts of the world [1], this is an ever-growing problem, according to the World Health Organization [2], overweight can already be considered as one of the major public health issues in the world. The last forecast made by that institution brought alarming data: if the projections are maintained, it is expected that, by 2025, around 2.3 billion adults are overweight and more than 700 million suffer from obesity. With this scenario in mind, the present research was developed with the purpose of investigating strategies to encourage mild and health physical activities with the purpose of losing weight and improving life quality.

This article reports results of the research that used devices currently available within the context of the Internet of Things and the 3D virtual world, based on the theory of

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self-determination in order to boost motivation in the weight loss process, in obese participants. The research project was developed in an environment supported by 3D virtual worlds, with the help of motion sensors. Additionally, conversational agent technologies were also combined, aiming at achieving better results in terms of self-determination among people suffering from obesity problems, who need to improve and/or acquire healthy habits [3]. This study investigated possible technological strategies and their impact on the motivation of obese individuals who participated in the research.

The use of the Internet of Things has been emerging as an accessory in the weight loss process in the current society [4]. Internet of Things is an expression used to define a technological revolution that seeks to connect electronic devices used in the day-by-day (such as household appliances, portable appliances, industrial machines, means of transportation, etc.) to the Internet, which development depends on the dynamic technical innovation in fields as important as wireless sensors, artificial intelligence and nanotechnology [5]. The use of sensors, advanced analysis and intelligent decision-making has been deeply transforming people's everyday lives and many solutions have been arising to help in the weight loss process. Several researches address the use of this technology in helping to lose weight, according to Burke [4], who investigated the use of mobile devices in dealing with overweight or obesity, he believes that a daily feedback message, delivered remotely every day, enhances the weight loss process for participants.

The survey reported herein used the Internet of Things to encourage self-monitoring motivated by a feedback based on Ryan and Deci's theory of self-determination [6], with the purpose of allowing for the weight loss and self-care. Through the communication of a motion sensor with a 3D virtual world (specially designed to boost motivation), which was associated to conversational agents (chatterbots) who use a knowledge base built on AIML (Artificial Intelligence Markup Language) [7]. The knowledge base was set up for the purpose of supporting the sending of motivational messages based on the theory of self-determination and on data produced by motion sensors used by the users, which allowed to customize the extrinsic motivation degree, as well as the approach method [8].

2 Example of the use of 3D in health

Several investigations have shown that the use of 3D virtual environments has the potential to promote good results in terms of enhancements of health-related aspects [9]. In the last decade, immersive environments based on simulators have become a platform capable of recreating the clinic experience in health education. They have a relatively low cost, they allow for a flexible learning process and have a patient-centered approach that promotes engagement in the learning process [10]. According to Brenda et al. [11] the Virtual World has proven, in the last two decades, to be a complementary tool in the assessment of patients with food disorders and obesity, and it is also used for body consciousness purposes in behavioral change situations.

Otte et al. [12] presents a case study on the use of the metaverse to increase motivation for elderly people to become more physical active, connecting devices of the real

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world with virtual worlds, and allowing for the interchange of information through tele transportation of virtual objects in the Second Life software.

Fig. 1. Overview of the study settings. (Left, front view of the system. Right view, back of the system with small and big screens).

The group of participants was made up by four senior citizens, two man and two women with an average age of 63.2 years. They were taken to a room adjacent to the laboratory, and they were not able to see the setting of the experiment. They received a general introduction into the Metaverse Project, which did not tell them about the purpose of the experiment. Participants also filled a small questionnaire to assess their familiarity and experience with sports, then they could ride a stationary bike, which was designed towards a big screen within the researcher's metaverse and a small screen that provided information, as seen in Figure 1. It could be seen that the principle of exchange of information between real and virtual worlds is simple, but the solution is not trivial and requires some programming effort, as well as the definition of a data exchange protocol. From the results of a focus group study, it has been shown that a virtual environment could increase motivation to being more physically active and that users are responsive to a virtual coach.

There is a lot of research on this subject. This article is just an example of another alternate Internet approach to Things with metaverses based on the theory of self-determination.

3 System methodology developed to validate the research

The system was designed to provide support to research activities proposed herein and entails a 3D metaverse environment populated by scenarios built to look like gyms and fitness studios. This virtual environment is peopled by avatars (users) and conversational agents (similar to the user's avatars). These agents were built to interact with the user, both inside and outside the virtual world, supported by a chatterbot system. The system was structured as follows:

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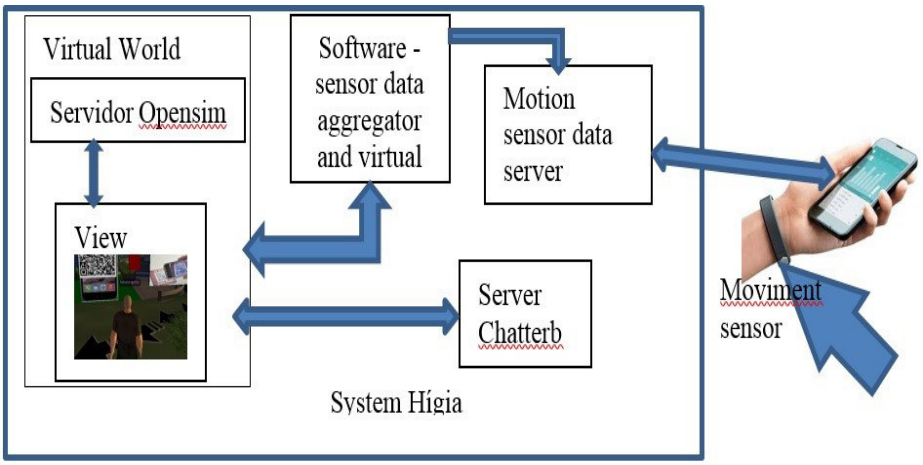

Fig. 2. Flowchart of the HIGIA System

In order to have a functionality between the programmable modules and the agent, it was necessary to define an interaction model, as show in Figure 2 below. The OpenSim [13] server is the 7.6.1 version in standalone mode. That allows the creation of a 3D virtual world to which pre-existing objects created externally may be imported or in which other objects and 3D scenarios may be built or adapted. It allows the registration of users and it may also stablish interconnections with other external systems, such as the SMS system – Short Message Service. The SMS system is used to send motivational messages available in the chatterbot basis and the messages are sent based on the data collected by the motion sensor (this sensor is a type of pedometer, which was used to measure the movement of the participant and after analyzing this data interact through the metaverse and / or the smartphone, in order to motivate).

The access to the 3D virtual world is established by using a client program named viewer. V**iewer** [14] is a software used to access a virtual world to which there are many kinds and manufacturers. This project employed Singularity, which offers better performance and reliability in the rendering of mesh objects, as well as in the animations programmed for the avatars. 3D objects built in environments other than OpenSim, typical of the 3D designing, end up being more complex structures (mesh) that are not appropriately renderized in all the existing viewers.

The sensor data aggregator and the data collector of the virtual environment was implemented using PHP and MySQL. This system may be contacted directly from the virtual world using the functions of the LSL programming language (Linden Scripting Language) [15] and OSSL (OpenSim Scripting Language) [16] used to define the action and reaction scripts included in the 3D objects. There are also features that allow to establish communication with remote systems through the use of Web services, as it was done in the case of the Pandorabots server [17] and with the SMS server (Short Message Service). This server offers a chatterbot service, used to host the knowledge base with the recommendations and answers that the conversational agent used to interact with the participant. These answers and questions are transmitted using a chat

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window in the virtual world, through which the user's avatar interact with the NPC/conversational agent. The agent was implemented using the Non-Player Character (NPC) feature of the OpenSim. NPCs are entities similar to the users' avatars, however they are computer-controlled.

The above methodology summarizes and explains the methodological steps, it is important to point out that it was necessary to build a functional structure to meet the basic principles of the research, in order to analyze the data received and sent to the mobile devices.

4 Development of the research

The participants engaged in the research were chosen by means of a set of criteria (men, average age of 40 years, self-declared obese and willing to participate in the experiment). The participants firstly came to know, individually, the objectives of the research and how they would participate in the validation of the HIGIA System.

The exploratory research is in development, until the present moment the participation of two subjects was concluded, only the small number of participants, a more daily investigation was carried out during three months of research, combining interviews, self-regulation questionnaire, data collected from the sensor of movement, analysis of all the dialogues occurred in the virtual world, analysis of all messages sent via SMS and the four body measurements (weight and waist circumference).

The research established a spectrum of the variation for a set of factors inherent to the research. The weight of the participants should fall within the same category as proposed by ABESO – Brazilian Association for the Study of Obesity and Metabolic Syndrome, which classification define ranks on the basis of the BMI – Body Mass Index (underweight, normal, overweight, obesity class I, II and III). Additionally, the limitation of devices to be used for monitoring physical activity also influenced the size of the sample (two motion sensors were used). As highlighted by Riva et al. [19], it is important to include in the sampling participants with similar genders and ages, which was also a criterion used in this investigation.

A system was implemented in a 3D Virtual World (OpenSim) with the goal of encouraging the learning of health-oriented behaviors. The system developed was named HIGIA, as an acronym to Individual Habitat and Attitude Interactive Guide (in Portuguese). Pace counters were used as a motivational strategy to engage the research subjects in their obesity control programs. The device records the subjects' activity and their data is then transferred to the 3D metaverse through a connection with a smartphone that initially receives data in each synchronization and then transfer it to the manufacturer's server. Later raw data is retrieved and aggregated, using an API provided by the manufacturer. This data is then treated in the environment directly connected to the virtual world. Information arising from this data feed the messaging routing, giving feedback and suggestions to the user. This information is also presented to the participants as part of the outlined persuasion strategy. A conversational agent was also implemented into the environment. The implementation of the agent uses the NPC (Non-Player Character) feature available in the OpenSim environment. The agent

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(NPC) has the task of guiding the participants through the virtual world using several motivational strategies.

At the beginning of the participation, each person received a motion sensor that was used 24 hours a day and were told to synchronize at least once a day through an application installed on their smartphone. They also had their weights and the measurement of abdominal circumference recorded.

In the first phase, everyone was left with the motion sensor (pedometer) for 1 month, they were instructed to visit and interact with HIGIA at least 2 times a week and perform a task list they received. At the end of one month the participants answered the self-regulation questionnaire and were measured and weighed.

In the second phase of the research, the participants did not have access to the HIGIA System metaverse and continued to use the pedometer and received stimuli via SMS, this phase lasted 1 month, they continued receiving messages from the System and receiving the stimulus from the pedometer (the device Stipulates a goal, that when the user hits and issued a sensory warning). At the end of this month the participants answered the questionnaires and delivered the pedometers.

In the third phase, the participants did not receive direct motivational stimuli, it was a phase to analyze if there was an internalization of motivation, after one month the participants answered for the fourth and last time the questionnaires, where they are measured and weighed (totaling 4 self-regulation questionnaires and 4 measurements)

When starting the participation, each person received a motion sensor which should be used 24 hours a day and should be synchronized at least once a day, through a mobile application. They also had their weights and abdominal circumference recorded. They also visited the virtual world, followed by the researcher who provided guidance concerning the navigation and the use of features available in the HIGIA System.

Fig. 3. – Aerobics class

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In figure 3 we have the avatar of the participant, exercising in an aerobics class, according to Fox et al. [20] this causes a transference of expectations or understanding of behavior from his avatar to his own behavior in the real world.

During the first stage of intervention (which lasted one month), the users could visit the virtual world as many times as they wanted. Thus, they could experience a fitness virtual environment. One of the participants mentioned that "it was the first time that he had ever stepped in a gym". They could also watch videos about methods and ways of losing weight, received tips from HIGIA's System conversational agent and, during the day, they also received SMS messages. Such messages were generated upon the analysis of the sensor's data, aiming at reinforcing behaviors or advising.

Fig. 4. – Season facts and photos

The Figure 4 shows the "facts and photos" season of visual motivation, made up of images and facts of people who managed to lose weight changing habits and leading a healthier life. Here you can find panels, posters, videos and QRCode (pointing to motivational video messages), these materials also contain tips, motivational phrases, small videos, etc. All material was carefully chosen according to the Self-Determination Theory

Another example of motivation, one can cite the avatar figure 5 of the participant, could question the NPC, on matters related to the system.

In the Figure 5 we can see a NPC talking to a participant of the research, in front of a gym, where there are NPCs being active and show examples of physical activities in which the user can engage. The proposal of this investigation is to assess if this kind of virtual example would affect real users, fostering disposition for physical activities

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The conversation between the user's avatar and the agent involves answers emerged from the knowledge database built using the AIML language. The patterns of derived answers and questions were prepared in line with Ryan and Deci's [18] Theory of Self-Determination and with the support of physical education experts and a doctor. All manifestations of the conversational agent/NPC were designed in order to motivate the user to become physically active. Suggestions, tips, recommendations for health improvement in regard of obesity are presented in the dialogues established between the user and the agent (chatterbot). The table below shows a few examples of messages presented to the users.

Fig. 5. Interaction of the practitioner with the HIGIA System

The interaction between the avatar and the agent may take the form of questions made by the users (texts typed to the chat window) when they are in the metaverse. The answers are generated by the chatterbox software based on the content of the knowledge base. For the same question, there is a wide range of possible answers, which are selected randomly to avoid a repetitive reaction pattern.

In Table 1 we have some examples of messages sent to the participant through the SMS of his smartphone and making use of the data received by the sensor the movement.

Table 1. Examples of messages

Objective	Message or media
To show follow-up and monitoring	You have not accessed / synchronized your data for XX days

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Insufficient level of activity	You haven't reached your goal today, but don't give up, little daily efforts will make you reach your goal and lose weight.
To congratulate good results	Congratulations, it is the second day this week that you manage to reach your goal. You deserve an improvement in your life quality.
To encourage self-care	You are responsible for your body
To offer help, guidance and examples	Let's pursue your goals. Together we can do it. Example of people jogging in the park or exercising in a gym. Motivational videos Short voiceovers with voice synthesizing associated to a character. Animation of NPCs being physically active.

In Table 2 we have examples of dialogues occurring within the metaverse, in the first phase of the research. All the dialogues that occurred in the metaverse of the research, were analyzed, according to the theory of self-determination.

Table 2. Examples of questions and answers

Question	**Answer**
Which drugs can I take to lose weight	There is no secret or magic formula. Get physical Don't give up, reduce your carb intake You should try to eat less calories than you spend in order to lose weight.
How to burn calories	Jogging for one hour will burn 400 calories on average, which equals to a medium slice of lasagna or a medium coke

According to Breckon [21], in order to lose weight, a combination of real and virtual motivation could work better, which was proven in the present investigation that showed a higher amount of body motion and weight loss in this first stage than in the others, where the presence of the virtual world was no longer made available.

The chatterbot's knowledge base is also accessed by the routine in PHP responsible for sending motivational or warning messages through the use of a Gateway with an SMS service. In the present investigation, there is a SMS gateway associated to the Pandora service.

In the second stage (which lasted one month), the participants kept using the motion sensor and receiving the motivational messages via SMS, but they could not interact with the virtual world. At this stage, it was possible to notice a reduction in the amount of motion, but the participants still kept losing weight, although with less intensity than in the previous stage.

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Table 3. Examples of messages sent via SMS

Tips	Answer
Related to tiredness (when the person does not reach the goal)	Excessive intake of alcohol may cause fatigue Inactivity and sedentarism usually cause fatigue
Congratulations for having reached the goal.	Congratulations! You've reached your goal!

In the third and last stage, participants kept using the motion sensor, which provided them information about how they were moving, their body measurements were taken at the end of the stage, but they were no longer connected to the HIGIA system. Measured by a self-regulation questionnaire answered monthly by the participants, motivation was seen to have decreased at this stage. There has also been a reduction in the amount of motion and weight loss was not relevant at this stage.

5 Conclusions

The main contribution of this investigation was to verify the possible contribution arising from the performance of a conversation agent in an immersive world, with external data generated by sensors. It was possible to observe the motivational potential of this kind of resource among obese individuals.

By collating motion data acquired by the motion sensor, we could notice that there was a sharp increase in their daily body motion. An example of the impact of this combination of elements could be perceived through the statement of one of the users, saying that "when I received the message about having achieved my goal, it was an inexplicable joy". That shows an effect arising from the implementation of strategies based on the theory of self-determination. As highlighted in [7], a relevant aspect about practices not intrinsically motivated is how the individuals become motivated to carry them out and how this motivation affects persistence, behavioral quality and well-being. This investigation showed that the elements used, that is, the 3D virtual world, agents and sensors were capable of leveraging extrinsic motivation. The participants went from a state in which they were not motivated to get physically active to a state of personal commitment, although not yet characterized as intrinsic motivation, as once the triggers stopped, there was a reduction in the commitment with the maintenance of the effort to perform physical exercises. According to the theory of self-determination, they would have achieved a stage of controlled motivation, with enforced regulation.

In figure 6, we have a graph that illustrates the data of the two participants of the research.

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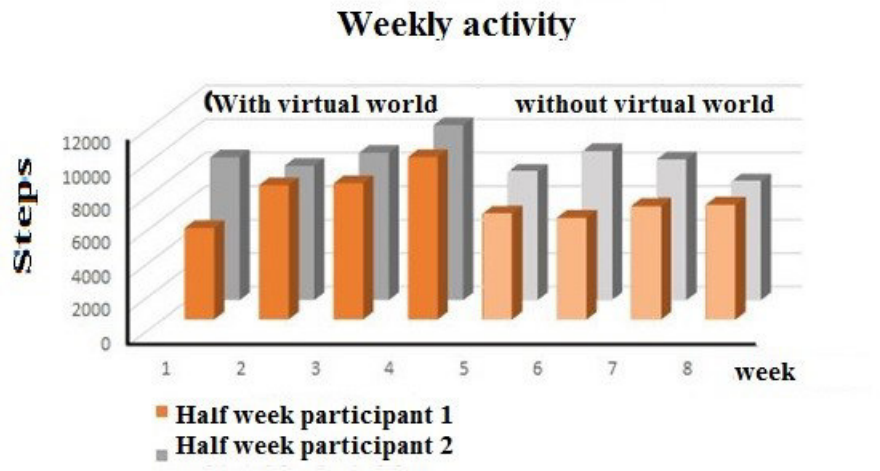

Fig. 6. Graph of number of steps X weeks of two participants

During the time of intervention with the "HIGIA system", there was a great involvement, which resulted in large losses of weight (average of 5 kg in the first phase and 2.5 kg in the second phase) and as we can see in figure 06 an increase of 70% of movement in relation to the usual amount of informed movement (from 1 to 1,5 km per day) by the participants in the initial interview. In this way, the research can prove that given the virtual stimulation, with the non-intrusive monitoring of a sensor and the constant and diversified presentation of motivation, could promote a modification in the search for quality of life.

Thus, the research could establish that given a virtual encouragement, with the non-intrusive follow-up of a sensor and the constant and diversified presentation of motivation, they could promote a change in their search for life quality.

It is important to highlight that, in the second stage of research, there was a motivational decrease that could be ascertained from the data collected from the motion sensor. In the third stage, when the triggers stopped, motivation was not yet internalized [22], which started to reduce the intensity of body motion. That allows us to assume that if there was a virtual gym for individuals aiming at changing their life quality, they would obtain advantages and a significant support if they could use a metaverse with enabling conditions, in addition to associated sensors that could continuously assess those data related to the desired behavior. Each person could, in addition to acquiring their own sensor, which is already a market trend, obtain motivation support from a 3D virtual world, participate regularly in the virtual gym, informing their weight and synchronizing the sensor so they could keep experiencing a positive motivational environment that would enhance their life quality.

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