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Effects of Virtual Reality during Exercise in Children

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Abstract: Virtual Reality (VR) could be an interesting tool to combat obesity and sedentariness in children. During the last years a multidisciplinary research team comprised of engineers, psychologists, physiotherapists and paediatricians have been testing these technologies. Throughout the tests, physiological (cardiovascular and metabolic response with biomedical sensors (smart fabrics TIAS) and psychological responses have been collected. The results presented in this paper reflect two main aspects: 1) the feasibility of the monitoring techniques employed and 2) the validity of virtual reality and exergaming technologies as promoters of physical activity and their potential as tools in clinical intervention programs. In the first study (n=90) children, a commercial platform was tested as support tool to aerobic exercise in a treadmill. Results showed a more physiological effort by obese group and limitations to measure effort perception with Borg scale especially in obese group. In second study (n=126) a new VR platform was developed (VREP) and tested as support of aerobic activities, a difference of first study, all the boys completed both conditions (same Aerobic exercise with/without support VR). 59.5% felt that they had to exert more effort in the traditional condition. Regarding to acceptability in both studies the vast majority of the participants liked the idea of combining physical activity with the VR platform as a form of treatment to increase physical activity. The capacity of VR technology to create controllable, multisensory, interactive 3D stimulus environments within which children's performance can be motivated, recorded, and measured, has been tested in these studies, offering clinical assessment and intervention options which are not possible using traditional methods.

Keywords: Virtual Reality, Children Obesity, Smart Fabrics, Physical Activity, Physiological Response, Active Gaming
Categories: J.3, J.4, J.6, J.7

1 Introduction

1.1 Physical Activity as Obesity treatment

Physical inactivity has been identified as the fourth leading risk factor for global mortality (6% of deaths globally). This follows high blood pressure (13%), tobacco use (9%) and high blood glucose (6%). Overweight and obesity are responsible for 5% of global mortality (World Health Organization 2009).

The prevalence of overweight/obesity (OW/OB) among children and adolescents, which has significantly increased by 30% in recent decades, has become a serious public health concern in all industrialized countries (Janssen et al. 2005; Ogden et al. 2012; Wang & Lobstein 2006). This increase has immediate and long-term health implications. This is because the increased prevalence of childhood obesity has resulted in an increased prevalence of the comorbidity associated with obesity (Jackson-Leach & Lobstein 2006; Dietz & Robinson 2005). Moreover, obesity during adolescence increases the risk of disease and premature death during adulthood, regardless of obesity during adulthood (Van Dam et al. 2006; Must et al. 2012). Although prevention is recognized as the most efficient way to avoid obesity, many children and adolescents who are currently obese require treatment (Dietz & Robinson 2005). Essentially, the major objectives of a weight-reduction programme are to change eating and behavioural habits and to enhance physical activity (PA).

PA in addition to dietary changes has proven to be beneficial to improving body composition, blood pressure levels, lipid profile, insulin sensitivity, self esteem, neurocognitive function and cardio-respiratory fitness (CRF) (Ian Janssen 2007; Physical Activity Guidelines Advisory Committee 2008; Ian Janssen & LeBlanc 2010). There are emerging data to suggest that CRF attenuates some of the factors contributing to metabolic syndrome in adolescence, often independently of adiposity (McMurray & Bo Andersen 2009). The benefits of PA in obesity treatment seems to be clear, but the research results show us that the optimal exercise modality to be recommended for its treatment remains unclear. The impossibility to perform the kind of PA usually recommended (type, duration, frequency and intensity), the lack of a clear statement about its specific goal and the fact that the prescribed physical activity is not enjoyable, are some of the reasons described in the literature to explain the low compliance and efficacy of paediatric obesity treatment programmes (Pavey et al. 2011).

It is necessary to explore new ways to prescribe PA as part of the treatment of obesity in children and adolescents which takes into account the orthopaedic, fitness and behavioural particularities of these populations. It is believed that technology could present new possibilities in this area.

1.2 Virtual Reality

Virtual reality (VR) is a new form of human–computer interface that allows the user to interact naturalistically with, and become immersed in, a computer generated environment (A. Rizzo et al. 2004; Rey & Mariano Alcañiz 1989). Virtual reality technology allows the creation of three-dimensional environments, within which people can interact and be motivated, recorded, and measured, thereby offering possibilities for clinical assessment and intervention that are not possible with traditional methods (“Skip” Rizzo et al. 2011; R. M. Baños et al. 2002; Rose et al. 2005; Maureen K Holden 2005).

Virtual reality is a technology which has no dependence on any specific technological approach or hardware setup that limits its range of application. The creation of a VR user experience can be accomplished by using a wide variety of interaction devices and sensory display systems designing digital content presented in a computer-generated graphic world. There are two kinds of VR implementations. Immersive VR combines computers, head-mounted displays (HMDs), body-tracking sensors, specialized interface devices, and real-time graphics to immerse a participant in a computer-generated world that changes in a natural way as the participant moves inside it. This modality has much more limited potential for our purposes due to the fact that its clinical application to the child population requires that the users visit special laboratories or have access to expensive equipment. The cumbersome nature of the equipment also complicates the performance of physical exercise. By contrast, it is possible to experience non–immersive VR by using modern computers and/or games consoles. This format presents a three-dimensional (3D) graphical environment on a commercial digital graphics system (television, monitor, projector), within which the user can navigate and interact.

1.2.1 **VR & Health**

VR systems applied to healthcare contexts have been successfully used with adults with simple phobias (P. Anderson et al. 2003; Parsons & A. A. Rizzo 2008; R. M. Baños et al. 2002), posttraumatic stress disorder (A. S. Rizzo et al. 2010; Mariano Alcañiz et al. 2003), addictive behaviours (José A Lozano et al. 2002), acute pain reduction (Gold et al. 2007; Hoffman et al. 2003; C. Botella 2008), and cognitive and motor impairments following stroke, brain injury, and other neurological disorders (Rose et al. 2005; Kizony et al. 2004; Ma et al. 2007).

1.2.2 **VR & Children**

As regards children and adolescents, the use of VR technology in these populations is less common. It has been employed in children with disabilities (autism, brain damage, motor impairment) (Strickland 1996; J McComas et al. 1998), psychological phobias and behavioural disorders (Bouchard 2011; Talbot 2011; C Perpiñá et al. 1999; “Skip” Rizzo et al. 2011), and teaching (Joan McComas et al. 2002), but it has been mainly used for entertainment purposes. In this last case, researchers have investigated the value and usability of commercially available interaction devices and methods that can be used widely and allow users to interact with digital content using more naturalistic body actions, beyond what is possible with traditional game interfaces (e.g., Konami Dance Dance Revolution (DDR), Sony EyeToy, Nintendo Wii, Microsoft Kinect) (Yang 2010; Finkelstein et al. 2010a; A. J. Daley & C. A. J. Daley 2009; Huiginn et al. 2009). One the most important ideas around the benefits of virtual reality is the manner in which a person becomes more engaged in a test, treatment, or training activity if he/she is motivated to participate by some form of digital gameplay embedded in a VE. This perspective has encouraged research into how these technologies could be usefully applied to paediatric health care issues and disorders (K. Harris & Reid 2005).

1.2.3 VR & Physical Activity

More recently, work has been done on the use of VR in rehabilitation and as a motivator of physical activity (Plante et al. 2003) (Finkelstein et al. 2010b; Mestre & Dagonneau 2011; Meyer 2009a). Its effectiveness in these areas is based on the assumption that the user becomes immersed in an environment that simulates beneficial, familiar or novel audio/visual stimuli (Der-Karabetian et al. 1998). The additional psychological benefits related with its use increase the chances of long-term adhesion to an exercise program. It also provides a sense of challenge and regulated competition, which generally results in a more enjoyable exercise experience (Lotan et al. 2009).

This article focuses on the comparison of traditional aerobic exercise with and without the support of virtual reality with the aim of testing two main aspects:

1) The reliability of the participant monitoring techniques employed and the physiological response to and possible influence of virtual reality during aerobic exercise.

2) The patients' acceptance of the virtual technology employed in each study.

These two aspects were tested with obese and normal weight children in order to compare the two samples.

2 Study 1

2.1 Methods

2.1.1 Objective

Research suggests that children and adolescents enjoy interacting with screen based media (A. Taylor et al. 2005; Murdey et al. 2005). However, physical inactivity is one of the main causes of obesity in this population group.

Our hypothesis is that the use of a commercial VR exergaming platform supporting "traditional exercise" could improve the experience of this type of physical activity (PA) in children, and transform it into an enjoyable activity.

The objective of this study is to analyse the impact of the use of a commercial VR exergaming platform (WII Fit, walking Mode) to support the practice of traditional exercise, such as brisk walking, on physiological (cardiopulmonary & metabolic) and psychological variables in two different populations of children and adolescents (normal weight (NWG) and obese or overweight (OWOG)).

2.1.2 Participants

A total of 90 children with ages ranging from 9 to 13 years participated in this study. The sample was divided into NWG and OWOG. Obesity was diagnosed when body mass index (BMI) exceeded the 97th percentile for age and sex and overweight was diagnosed when BMI exceeded the 85th percentile for age and sex. The extent of obesity was quantified using Cole's LMS method which normalizes BMI, and its skewed distribution, by expressing BMI as a standard deviation score . Obese children were recruited from the Paediatric Obesity and Cardiovascular Risk Unit, CHGUV Valencia, Spain, for children being teated for obesity. Patients with secondary obesity syndromes and/or with acute illnesses were excluded from the study. Non-obese patients were recruited from a summer school in the Polytechnic University of Valencia. The criterion for recruitment was that normalized BMI was under the 85th percentile for age and sex. None of the subjects were taking any medication nor had any clinically manifest illness. In all cases, an informed consent was obtained from parents and participants prior to testing. The ethical committee of the hospital approved the study and their parents signed the consent form.

2.1.3 **Design**

After anthropometric measurements, the children were fitted with a physiological smart shirt (TIAS) and an indirect calorimeter (FitMate PRO). The child got used to wearing the devices while a biomedical engineer explained the protocol. The design of the study is displayed in Table 1. Participants in both groups were randomized into two condition groups, those using a treadmill for traditional PA (n=48; NG, n=12; OWOG, n=36) and those using a treadmill with the support of the exergaming platform (n=39; NG, n=14; OWOG, n=25) (Wii Fit walking exercise). The treadmill program was four minutes long at 4.2 Km/h (2.6 miles/h), with four additional minutes at 5.7Km/h (3.5 miles/h) (normal walking speed), which corresponds to light to moderate activity (Ainsworth et al. 2011). This was the same for both condition groups. Children in the traditional condition group did not receive any additional support. Before and after the treadmill walk, participants filled out the questionnaires. Body weight was recorded to the nearest 0.1 kg using a standard beam balance scales. Height was recorded to the nearest 0.5 cm using a standardized wall-mounted height board.

STAGE	DESCRIPTION
Initial Stage (15 min)	Initial measurements, initial psychological interview and colocation of TIAS and calorimeter
Traditional Exercise or Traditional Exercise with VR Support (15 min)	Brisk Walking on a treadmill at two different speeds (4.2 km/h & 5.7 km/h) (one group with VR support and one group without VR support)
Recovery Stage(5 min)	Final questionnaires answered while seated.

Table 1: Study One Protocol

2.1.4 **Instruments**

2.1.4.1 **Physiological Measurement**

- A smart shirt developed by our group was integrated into the VR platform to monitor the physiological response and offer new ways of human interaction with the VEs. Therapy Interface Activity Sensor (TIAS) (figure 1) is a multi-parameter wireless electronic shirt that records the physiological response and movement of the patient. It has been developed by I3BH and NUUBO (Guixeres et al. 2009). In this study it was employed to detect continuous ECG, HR and the amount of movement with its internal accelerometer. Mean HR for each participant in each period of the study was also calculated.

- The FitMate PRO (Cosmed, Rome, Italy) (Nieman et al. 2007) is a small metabolic analyser designed to measure oxygen consumption and energy expenditure during rest and exercise on a breath-by-breath basis (31). Metabolic equivalents (METs) for each participant for each activity were derived by dividing the average VO2 of the activity by the participant's average resting VO2 (real MET) or by a standard resting value of 3.5ml/k/min (1 MET) (Byrne et al. 2005).

2.1.4.2 Questionnaires

- Physical Activity Enjoyment Scale (PACES) (Kendzierski & DeCarlo 1991; Fernández García et al. 2008) adapted for children and adolescents: This measures the enjoyment of playing sports and doing physical activity. It includes 6 items scored from 1 to 7. The total score can range from 5 (enjoyable) to 35 (unenjoyable).

- Sports Habits: This is a three-item questionnaire used to assess the participants' sport-playing habits and PA self-concept. Its items were taken from the Physical Activity Questionnaire for Older Children (Kowalski et al. 1997). The questions were: "Do you think you are an athletic child?", to be rated from 1 (not at all) to 7 (totally), "How many days you do more than half an hour of a sport or physical activity?", to be rated from 1 (every day) to 6 (never), and "Which one of the following best describes you over the last 7 days?", to be rated from 1 (most of the time not doing physical activities) to 5 (very often doing physical activities).

- Computer Game Habits: This is a four-item questionnaire that inventories the playing devices that children have at home (computers, active or sedentary game consoles) and the children's habits regarding playing computer games.

- Acceptability questions: There were two questions about the acceptability of a VR exergaming support platform. The first question was, "If your physician recommended you to do this exercise as part of your treatment, would you approve of it?" and, "Would you be willing to repeat this experience if your physician requested you to?". The answers range from 1 (Not at all) to 7 (Completely).

- Borg's Perceived Exertion Scale (Borg 1982). This measures the perceived exertion of an activity. The scale lists numbers in ascending order from 6 (very easy) to 20 (very hard).

2.2 Results

2.2.1 Descriptive data

Eighty-seven participants were included in the data analysis. From the whole sample, 45 were males and 43 females. The mean BMIz was -0.03 (SD=.86) for the NWG and 2.44 (SD=.71). There were no significant differences in BMI regarding conditions

(F=.700) or gender (F=.277). The results regarding sport-playing habits indicate that most participants spend more than half an hour playing sports or doing physical activity two days per week (37.8%; no significant differences between groups X2=.173).

Regarding video game habits, almost all participants had a video-game console or computer at home (95.5%; no significant differences between groups X2=.586), and liked to play computer games (90.9%; no significant differences between groups X2=.09). The majority of them (64.4%) had an active video game console (WII or Kinect), and played it at least one day a week (no significant differences between groups X2=.967). Regarding the PACES scale, the average score was 17.5 (SD=1.5). A one-way ANOVA analysis was used in order to test significant differences between groups. Results did not show significant differences between groups or conditions.

2.2.2 **Acceptability**

The acceptability questionnaire shows that 85.7% of the participants agreed with the idea to use a VR exergaming platform as a clinical tool prescribed by a clinician (M=5.4 (max: 7); SD=1.6). 82.2% agreed with the idea of coming back and repeating the exercise (M=5.6; SD=1.6). There were no significant differences in the responses between NWG and OWOG.

2.2.3 **Physiological Measures**

In order to analyse the effect of a VR exergaming platform on physiological measures, an ANCOVA analysis with two between-group levels 2 (group: NWG vs. OWOG.) x 2 (condition: Traditional vs. VR Exergaming) was applied. PACES scores, PA habits, video gaming habits and age were used as covariables.

The descriptive data is shown in table 2. The results of the ANCOVA over HR show a significant effect between groups [F(1.83)=11.939; p<.001; η2=.12], with OWOG scoring than NWG. But there are no differences between condition (Traditional vs VR) or interaction. Regarding VO2 and METS, the results are similar, showing a significant effect between groups [VO2. F(1.75)=5.187; p<.05; η2=.06; METS. F(1.76)= 2.147; p<.05; η2=.05], with OWOG scoring more than NWG. There is no significant effect over condition (Traditional vs VR) or interaction. There are no significant effects according to BR and ACC, neither condition, group nor interaction. Regarding Borg's perceived Exertion, results shows that there is a significant effect of interaction between both groups [F(1.76)= 27.367; p<.05; η2=.05].

2.3 Discussion

The point of this first study was to explore the possibilities that virtual reality could offer as a therapeutic and motivational tool when used with populations of normal weight children and obese children from the "Hospital General Universitario". For this, a commercial non–immersive VR platform was used.

In this first study, our hypothesis was that when faced with the same physical activity of moderate intensity (MET 3–6), the level of effort of the obese participants would be greater than that of the normal weight participants, but that the use of a commercial VR platform could attenuate the subjective sense of effort and therefore increase adherence (Meyer 2009b).

		NWG	OWOG
		M (SD)	M (SD)
HR	Traditional	120.7 (9.2)	136.4 (14.4)
	VR	126.3 (13.8)	134.4 (17)
VO^2	Traditional	16.4 (2.4)	15.3 (4.4)
	VR	17.8 (2.6)	14.4 (4.6)
MET	Traditional	4.5 (.78)	3.8 (1.4)
	VR	4.9 (.71)	4.2 (1.3)
BR	Traditional	32.2 (4.1)	31.8 (7.3)
	VR	34.6 (6.7)	33.7 (6.1)
ACC	Traditional	.37 (.06)	.37 (.04)
	VR	.41 (.06)	.39 (.08)
RPE	Traditional	13.3 (3.2)	13.1 (3.1)
	VR	11.4 (1.4)	13.7 (2.4)

NWG= Normal weight group; OWOG= Overweight and obese group; HR= Heart rate; VO2= Oxygen volume consumed; MET: metabolic equivalent of task; BR: breath rate; CC=accelerometry; RPE= Rated perceived exertion.

Table 2: Mean and Standard Deviations (SD) for physiological measures and self-report exertion in Study One

We were able to confirm that the proposed activity represented a medium intensity effort in both groups and that it entailed a greater cardiovascular response (increase in HR) in the obese group. These participants in general had a worse physical condition than the normal weight children (the VO2 consumed was lower in the obese group). Despite the constant speed and similar physiological response, there was a reduction of RPE in the NWG which was not seen in the OWOG.

One possible explanation of why the significant differences in RPE was only seen in the NWG is that the instrument used to measure the subjective fatigue was not adapted for children (Eston, 2009). Another reason could be that the commercial VR platform used was designed as a recreational platform and not with the intention of reinforcing the motivation, a key point in people unfit. For that reason it could be thought that in OWOG it doesn´t achieve a reduction in RPE.

On the other hand we demonstrate that the majority of children and adolescents studied were familiar with and enjoyed using games consoles, video games, and active video games.

What is more, the vast majority of the participants liked the idea of combining physical activity with the VR platform as a form of treatment to increase physical activity. They were also willing to return a second time to do the same activity again.

One of the possible limitations of the study when analysing the positive effects of the VR was that the children only performed one of the two activities due to the limitations of duration time (children must accomplish more activities during the sessions) and they could not compare the aerobic exercise with and without the VR. This limitation was addressed in the second study presented below.

Because of this we decided to continue exploring the issue and to carry out a second study in which we tried to address the limitations identified in the first study as well as developing our own VR platform, VREP.

3 Virtual Reality Exercise Platform (VREP)

Following the results of the first study based on a non–immersive commercial VR platform, a new platform to overcome the limitations identified by the results was developed. The Virtual Reality Exercise Platform (VREP) is a new platform which attempts to leverage virtual environments during aerobic exercise with children. VREP has been developed to lead children through aerobic activities by introducing a virtual space that encourages the child to continue with the planned activity and is parameterized by a clinical professional. The platform model is composed by a three-dimensional (3D) graphical environment controlled and designed on a computer, an aerobic apparatus (in this case a treadmill) and a monitoring Smart Shirt (TIAS) which monitors the physiological response and movement of the patient during the PA.

VREP was designed for research and clinical applications. It features a set of special characteristics that differ from commercial platforms:

- Programmable messages showed on screen which allow a psychologist to stimulate children by sending messages in real time or as part of a pre-programmed session (figure 1).
- The ability to configure aspects of the VREP sessions including; the number of virtual opponents during the race, first or third person viewpoints and the speed and timing intervals during the race.
- Real time measurement and display of effort and emotional perception as graphical scales in the VE.
- The ability to add cognitive tasks which involve the recognition of hidden random objects to the aerobic exercise during the VE session.
- Integrate and synchronize the experimental data (physiological response and movement) wirelessly from a Smart Shirt (TIAS) (figure 1).

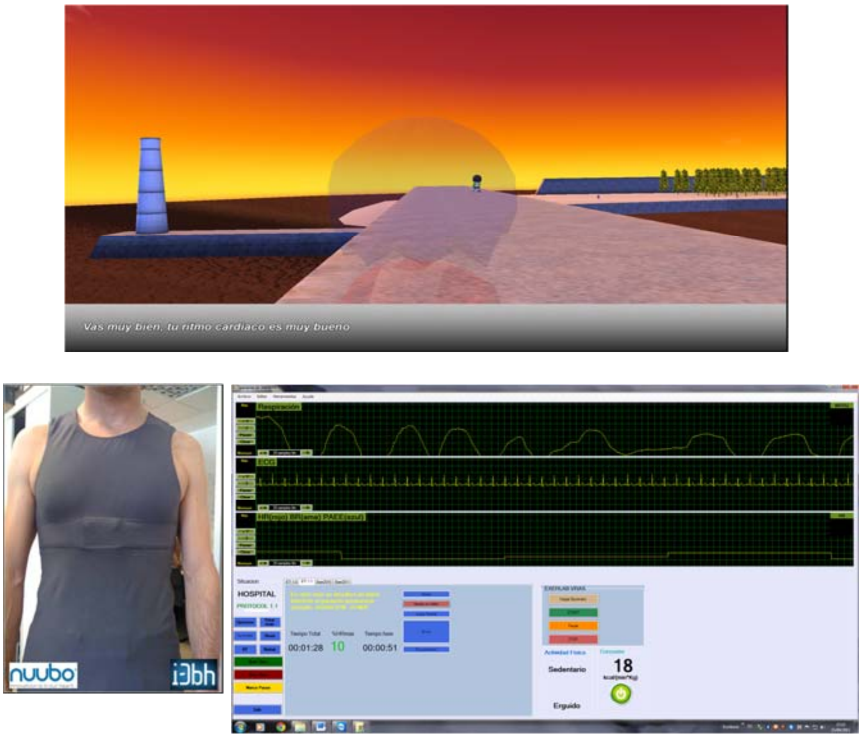

Figure 1: Screenshot of a VREP virtual environment (the grey bar is displaying a message) and TIAS with software receiving its signal

4 Study 2

4.1 Methods

4.1.1 **Objectives**

The main objective of study 2 was to evaluate VREP as a tool to promote and study physical activity in children. The specific objectives were: to study the energy expenditure during the use of VREP compared with traditional exercise in a sample of normal weight (NWG) and overweight or obese children (OWOG), and to evaluate the effect of VREP joined to aerobic exercise.

4.1.2 **Participants**

This study involved a new set of 126 child participants whose age ranged from 10 to 14 years, divided between NWG (n=91) and OWOG (n= 35). The obese participants were selected from the Cardiovascular Risk Unit, Consortium Hospital General, Valencia, Spain,. The non-obese participants were recruited from staff members' children at the Polytechnic University of Valencia and the University of Valencia during their participation in the universities' summer schools. The method used to select obese participants was the same as that used in study 1.

4.1.3 **Design**

After initial measurements (anthropometrics, body composition,) participants were fitted with a physiological smart shirt (TIAS). A calorimeter was not used as in study one. HR was a good enough indicator of physiological outcome and the use of a calorimeter would have been uncomfortable for the participants. The design of the study is displayed in table 3.

STAGE	DESCRIPTION
Initial Stage (15 min)	Initial measurements, initial psychological interview and fitting of TIAS
Traditional Exercise (15 min)	Brisk Walking on a treadmill at two different speeds (4.2 km/h & 5.7 km/h)
Traditional Exercise with VR (15 min)	Brisk Walking on a treadmill at two different speeds (4.2 km/h & 5.7 km/h) with virtual environment exposition scene 1 of VREP

Table 3: Study Two Protocol

Participants were randomized into two condition groups in a counterbalanced study, those who started using a traditional treadmill (n=64; NWG, n=43; OWOG, n=21) and those who started using a VR supported treadmill (n=51; NG, n=18; OG, n=33) (VREP). Both condition groups performed both exercises with 20 min to rest in between. The treadmill program was four minutes at 4.2 Km/h (2.6 miles/h), followed by four minutes at 5.7Km/h (3.5 miles/h) (normal walking speed). This was the same for both conditions. Children were informed as to how long they would spend on the treadmill and how fast it would go in both stages. Children in the traditional physical exercise condition did not receive any additional support. Participants filled out questionnaires both before and after participating. Anthropometric measurements were taken according to the protocol described in study 1.

4.1.4 **Instruments**

4.1.4.1 ***Questionnaires***

- Physical Activity Enjoyment Scale (PACES) (previously described in study1)
- Sport Habits (previously described in study 1)
- Computer Game Habits (previously described in study 1)

- Acceptability scale: 9 questions where developed to measure the acceptability of VREP compared to a traditional system. Several characteristics were inquired about, including suitability, emotional experience and willingness to use the VREP again.

4.1.4.2 *Physiological Measurement.*

- TIAS: Cardiac signal and movement (previously described in study 1).

4.2 Results

One-hundred and fifteen participants were included in the study. Descriptive data shows that the BMIz of the NWG was 0.14 (.71) and the OWOG was 1.74 (.36). From the total sample, 63 participants were female and 52 male. The sport habits variable indicated that most participants spent more than half an hour playing sports or doing PA five days per week (37.8%; no significant differences between groups, X2=.173).

Regarding computer game habits, almost all participants had a video-game console or computer at home (97.8%; no significant differences between groups X2=,586), and liked to play computer games (93.2%; no significant differences between groups X2=.09). The majority of them (78.8%) had an active video game console (Wii or Kinect) (but there were significant differences between groups, X2=.11, showing that the normal weight group contained more children with these technologies at home (n=57) than the overweight group (n= 40)), and played with them at least two days a week (no significant differences between groups, X2=.967).

Regarding the PACES scale, a one-way ANOVA analysis showed significant differences between the NWG (X=17.5; SD=1.5) and OWOG (X=18.2; SD=2.1) (F(1.122)=12.258; p<.05; η2=.03). Obese participants showed lower scores on enjoyment related to physical activity and sports.

4.2.1 Physiological results

In order to analyse the effect of the VREP support platform on physiological measures, a repeated measures ANCOVA analysis with two between-group levels 2 (group: NWG vs. OWOG.) x 2 (condition: Traditional vs. VREP) was applied. PACES scores, PA habits, video gaming habits and age were introduced as co-variables.

The descriptive data can be seen in table 1. The results of the ANCOVA over HR and percentage of HR reserve, a measurement correlated with oxygen consumption (Swain & Leutholtz 1997) (heart rate reserve is defined as the difference between the maximum heart rate minus the resting heart rate) did not show any significant differences between groups (NWG and OWOG) or conditions (TRAD and VREP), with no interaction effect present.

	NWG	**OWOG**	**F**
HR TRAD	120.9 (15)	127.6 (19.9)	.272
HR VR	128 (13.1)	124.5 (11.5)	
%HR TRAD	29.6 (12.3)	37.3 (14.7)	.278
% of HR VR	32 (9.6)	37.8 (11.9)	

NWG= Normal weight; OWOG= Overweight and Obese group;

Table 4: Mean and Standard deviations (SD) for physiolocal response in Study Two

4.2.2 **Acceptability analysis**

58% reported that if the clinician were to recommend some additional exercise, they would prefer the VR exercise over traditional exercise. 59.5% felt that they had to exert more effort in the traditional condition, compared to 40.5% who reported that they had to exert more effort in the VR exergaming condition. 66% felt more tired in the traditional exercise, compared to the VR exercise. 74% thought that VR was a better method to encourage people to do physical activity compared to traditional methods. Regarding emotions, children reported being happier (60.7%), less sad (65%), having more fun (80.6%) and being less bored (74.3%) in the VR condition compared to traditional methods. 63.5% of participants also stated that they would be more interested in repeating the VR condition over the traditional condition. There were no significant differences between NWG and OWOG in any of these questions.

4.3 Discussion

The objective of this study was to test the feasibility of VREP, while collecting data on the physiological performance and the acceptability of the VREP in a sample of normal weight and overweight/obese children. The children used both systems in this study, thus making it possible to compare groups more effectively then in the original study.

The analysis of physiological measures shows that there were no significant differences between the children's HR between groups or when using either system. The lack of significant differences can be explained by the low level of effort involved in the exercise.

Furthermore the VREP system, in contrast to commercial systems, allows the adaptation of the exercise to the special needs of obese children and also allows clinicians to introduce questions during the VR scenario. This helps to measure the children's mood states and thoughts as they occur.

In this second study each participant carried out both of the proposed exercises (traditional and VREP assisted). This allowed a comparison of the virtual environment designed specifically for the study. It also allowed the real time monitoring of the sensations felt by the subjects

A calorimeter was not used because the intensity of the exercise was already known (the same as in study 1) and because we believed that it could have interfered with the monitored subjective variables given the lack of comfortableness of the apparatus.

We could see that in one sample from study 1, the obese children group demonstrated an increased haemodynamic load (higher HR) while undergoing moderate activity.

5 General Discussion

In the first study, our hypothesis was that when faced with the same physical activity of moderate intensity (MET 3–6), the level of effort of the obese participants would be greater than that of the normal weight participants, but that the use of a commercial VR platform could attenuate the subjective sense of effort and therefore increase adherence (Meyer et al. 2009)

Despite the constant speed and similar physiological response, there was a reduction of RPE in the NWG that was not seen in the OWOG. One possible explanation of why the significant differences in RPE was only seen in the NWG is that the instrument used to measure the subjective fatigue was not adapted for children. Another reason could be that the commercial VR platform used was designed as a recreational platform and not with the intention of promoting physical activity.

One of the possible limitations of the study when analysing the positive effects of the VR was that the children only performed one of the two activities and they could not compare the aerobic exercise with and without the VR. This limitation was addressed in the second study presented below.

Because of this we decided to continue exploring the issue and to carry out a second study in which we tried to address the limitations identified in the first study as well as developing our own VR platform, VREP.

The hypotheses at the second study were VREP will improve adherence and TIAS would be enough to monitor physiological response given the uncomfortableness of the calorimeter.

The analysis of physiological measures showed that the activity supposed a similar effort in all conditions studied and only TIAS provide similar information as calorimeter in study one.

Furthermore the VREP system, in contrast to commercial systems, allows the adaptation of the exercise to the special needs of obese children and also allows clinicians to introduce questions during the VR scenario. This helps to measure the children’s mood states and thoughts as they occur.

In regard to physiological responses, the use of VR does not produce relevant changes in cardiac and metabolic response during aerobic exercise, however future studies should test different kinds of exercises and different levels of exertion to support this hypothesis.

The use of TIAS on this platform has been proven as an ideal physiological monitoring system for biofeedback during clinical VR sessions. E-textiles can be worn during physical activity in VR sessions where currently available electronic devices or other biomedical monitoring systems, such as calorimeters, would hinder or perhaps embarrass the user. This will allow for the VEs to be targeted and altered dynamically by a physician or psychologist according to the real-time physiological measurements.

Regarding to the acceptability, the vast majority of the participants liked the idea of combining physical activity with the VR platform as a form of treatment to increase physical activity. They were also willing to return a second time to do the same activity again

After these studies, VREP is going to be included in two clinical aspects:

Adding VREP to an intervention program: The VR approach can simultaneously deliver an intervention and collect data on how it is utilized, particularly with regard to the cognitive and emotional processes involved. VREP can be designed to address specific hypotheses, and it is possible to collect detailed data on the participant's response to the intervention without additional intrusion. Also, the capability to distribute identical virtual environments across multiple locations and platforms gives a new meaning to the concept of multisite data collection & intervention.

Adding VREP as a effort testing tool at the Hospital: The accurate measurement of maximal effort in children is known for its difficulty (Bar-Or & Rowland, 2004) . VREP will reinforce and motivate the child to achieve these maximal effort levels and assure that clinical tests obtain the results intended.

6 Conclusion

In these studies we have demonstrated that virtual reality may serve to enhance the psychological benefits of exercise, while improving adherence and motivation for children to engage in aerobic exercise. These two studies have measured more than 200 children and the benefit of virtual reality as a support for aerobic exercise has been demonstrated.

The capacity of VR technology to create controllable, multisensory, interactive 3D stimulus environments within which children's performance can be motivated, recorded, and measured, has been tested in these studies, offering clinical assessment and intervention options which are not possible using traditional methods (M K Holden 2005; Rose et al. 2005; Rosenthal et al. 2011; Finkelstein et al. 2010a). Such VR simulations can offer many assets unavailable with traditional approaches to both clinical and research methods (Kizony et al. 2004; Galvin et al. 2011).

Progress in the field will be enhanced by multidisciplinary collaborations between the technology industry, academia, and researchers with diverse expertise in behavioural sciences, pedagogical disciplines, computer sciences, and biomedical sciences (such as endocrinology, nutrition, and exercise physiology).

In these studies the acceptability and reliability of VR as a research tool during the promotion of physical activity in clinical scenarios has been addressed. A new platform has been developed to improve upon the limitations of commercial platforms. New studies must address the effect of this platform on clinical procedures and interventions programs aimed at treating obesity and sedentary behaviour.

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