Poster: Adapting Data from Physical Activity Sensors for Visualising Exertion in Virtual Reality Games

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Abstract
Head mounted display (HMD) virtual reality (VR) games have shown promise beyond entertainment. Work has shown that playing VR games even for 10 minutes can provide players with valuable levels of physical exertion that is much higher then their *perceived* exertion. Despite VR showing promise at providing engaging forms of exercise, there is a risk that players can become over-exerted because they are so immersed in VR games, potentially leading to injury. Activity trackers like smart watches and chest heart-rate monitors can help with keeping track of exertion. However, the player is inherently locked out of the real-world while they are in the game. This means that the data can only be viewed if the player takes off the HMD, interrupting their game session. At present, the design of suitable feedback about exertion has had little attention in HMD VR games. In this paper, we show how fully-immersive VR and data from activity trackers can be combined in real-time so players can track their level of exertion, to help prevent over-exertion during gameplay.

Author Keywords
Virtual Reality; Exergames; Exertion; Activity Trackers; Over-Exertion; Real-Time Heart-Rate

ACM Classification Keywords
H.5.1. [Multimedia Information Systems]: Artificial, augmented, and virtual realities - Miscellaneous

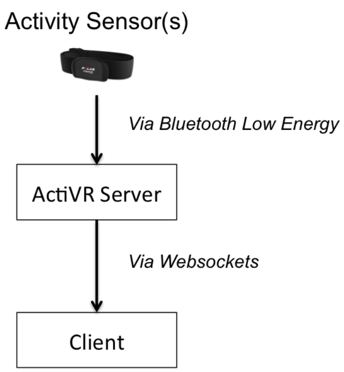

Figure 1: The ActiVR server enables activity sensor data from one or more BLE devices to be sent to a client (via websockets) that is running an ActiVR-enabled VR game.

Introduction

Virtual reality (VR) technology is becoming increasingly refined and accessible, with dropping costs for high performance head mounted displays (HMDs) such as the HTC Vive[1]. Due to the HTC Vive's room-scale tracking, players can move around a space naturally. Previous work testing VR games has shown that players may experience high levels of actual exertion with comparatively lower perceived exertion due to the level of immersion provided [10, 11]. There is also an emerging body of research on VR exergames and their diverse forms, such as exercycles [2, 7], balance board [3], and accelerometers to detect walking and running [12, 9].

Despite the potential of this emerging work on exercise and game experience in VR, there is a need to address the potential for over-exertion, especially as a player may be so engrossed in the game that they are unaware of this risk. This is a potentially important risk as overexertion has been reported as a problem in previous studies on exergames, particularly for older players [6, 1] and can potentially lead to coronary problems or injuries. Current VR games cannot address this because they have no access to data about the player's exertion level [10]. Previous work has shown the potential of integrating activity information within 2D games [4], but little work has explored using this information within 3D fully-immersive HMD VR games. Moreover, there is a need for work on in-game interfaces that alert the user but do not distract from the game experience.

Therefore to address this we present ActiVR, a physical activity tracking system for HMD VR games that is designed to enable players to monitor their real-time heart-rate data and alert them when they reach high levels of exertion. The key contributions of this work are:

[1]HTC Vive - https://www.vive.com

- Exploration of ways to overcome the risk of over-exertion in VR games by using heart-rate sensors.
- Exploration of in-game feedback approaches that do not intrude on the game but do give clear feedback.

VR System Prototype

The ActiVR system has two parts (Figure 1), the ActiVR server and the ActiVR-enabled VR game (client).

ActiVR Server

The ActiVR Server is based on open source code[2] by Microsoft. The application enumerates all Bluetooth Low Energy (BLE) devices and receives raw data sent from them. Therefore, the application can connect to and receive data from activity trackers like the Polar H7 and Fitbit heart-rate monitors that use BLE to connect with smartphones, as they are small and low-powered devices. Our ActiVR server application[3] uses Websockets so that it can send data to other applications, such as VR games made in Unity.

ActiVR-enabled VR game

We created a VR game, called Snowballz, in the Unity game engine to test the ActiVR system by receiving and visualising the data sent from the ActiVR server. The game was created for the HTC Vive VR HMD and involves the player picking up and throwing snowballs at waves of incoming enemies (Figure 2), which become progressively difficult each wave.

In Snowballz there are two different data visualisation modes: (1) situated within the virtual environment itself where the player's heart-rate intensity is represented as a 3D heart (Figure 3A); and (2) the head up display (Figure 3B), which

[2]Windows Bluetooth Low Energy Sample - https://github.com/Microsoft/Windows-universal-samples/tree/master/Samples/BluetoothLE

[3]ActiVR Server Source - https://github.com/callumparker/ActiVR

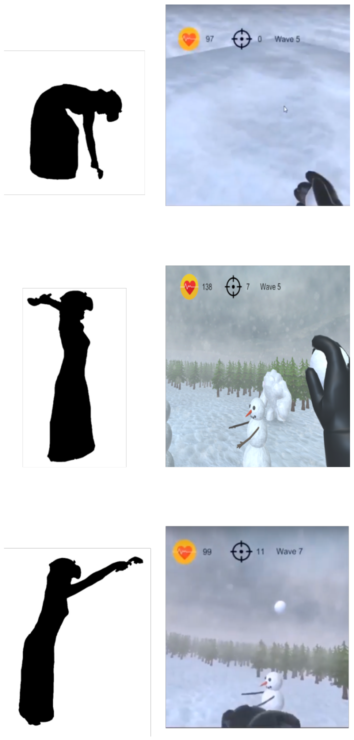

Figure 2: Snowballz VR is an ActiVR-enabled game. The images from the top shows the process of the player picking up a snowball and throwing it at incoming enemies.

is fixed in the upper part of the player's view and shows from the left the player's current received heart-rate from the sensor, number of enemies hit, and the current level.

Figure 3: Different data visualisation modes - **A**: The Snowballz VR game with the heart-rate information displayed in the environment. The 3D heart represents the heart-rate and its glow intensifies and pulsates as the player becomes exerted; **B**: Player's heart-rate coloured red due to the player becoming vigorously exerted.

Once the player's heart-rate reaches a vigorous level, determined by the player's heart-rate becoming 70% of their maximum heart-rate (220 - the player's age) [5], the displayed information in both modes will turn red along with a pulsating heart icon. This design, with the pulsing to catch attention, aims to only highlight the heart-rate when it is high.

Conclusions and Future Work

We have presented ActiVR, a system for sending exertion data to VR games. The system was demonstrated through our VR game called Snowballz, which visualised the heart-rate data received from the ActiVR server within the game, so that players can keep track of their levels of exertion while they play, to reduce the risk of overexertion.

Future work will test the different modes of displaying the exertion information in a user study to understand how the exertion information should be visualised and to gain insights into what type of information is most useful while playing VR games, such as heart-rate, breathing rate, and calories burned. Furthermore, we plan to explore the individual differences, such as exertion, gameplay, goals, and information preferences. This could be useful for enabling personalised games [13] that implicitly respond to the level of exertion. Such games could adjust the difficulty or elements within the game in real-time to prevent overexertion.

While the system we presented only utilised heart-rate, other forms of data can be used so the system can gain a more fine grain understanding of an individual's exertion level, such as their breathing or heat expenditure [8].

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