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THE DEVELOPMENT OF A REAL-TIME MOVEMENT SONIFICATION EXERGAME FOR BODY-WEIGHT SQUAT TRAINING

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ABSTRACT

Participating in physical activities is often difficult for individuals living with blindness or other visual impairments. The use of exergames has shown promise in affording these individuals engaging and novel methods for participation in physical activity. Specifically, movement sonification is one method shown to be reliable in providing guidance and helping users orient their bodies in space. Through this research we aim to develop an auditory-only exergame that provides augmented feedback, using a combination of verbal instruction and real-time movement sonification, for low to no vision users to learn to perform body-weight squat movements correctly and safely. We anticipate that this research will assist in further establishing the importance of movement sonification feedback for better exercise training and comprehension in physical activity when no visual input is present.

1. INTRODUCTION

Individuals living with blindness or visual impairments often report having difficulty participating in physical activity due to fear of injury and inexperience. [1] They have limited options for exercise instruction, many of which are resource-intensive and costly. [2] As a result, these individuals often report being significantly less active than sighted individuals, which can lead to an increase in obesity and an overall deterioration in health. [1] Recent advancements in exergame development have begun to address these concerns, creating applications that are accessible to the visually impaired via auditory interfaces. [3]

2. BACKGROUND & RELATED WORK

2.1 Exergames & Visual Impairment

Exergames are virtual games designed to encourage physical activity and fitness through entertainment. [4] These games have also become a valuable tool in motor skill development. [2] Not only have they been shown to be entertaining, but they also lower the barrier for learning and engagement in new activities. [2, 4] This is especially important in developing accessible exergames, as it allows users to feel comfort and confidence as they use an application. [3] However, there is still a lack of exergames designed for individuals with visual impairments. [4] This is likely due to the difficulty in overcoming the challenges of designing an interactive application without the use of a visual interface. [3] A 2017 study by Rector et. al., introduced Eyes-Free Yoga, a yoga exergame designed for blind users, that provided step-by-step verbal guidance on the performance of yoga poses. [2] In their paper, Rector reported difficulty in determining what verbal descriptors would be most informative for body positioning and instruction. Considering that some users were not previously familiar with the selected yoga poses, they experienced difficulty in translating the verbal instructions into body orientations and movements in space. The addition of non-verbal auditory feedback information, specifically movement sonification, can address this gap as it has been show to enhance a user's understanding of movement descriptors [5] and temporal and spatial information [6], which can result in improved movement techniques and overall performance. [7]

2.2 Movement Sonification

Movement sonification refers to the transformation of motion signals into sound. [8] Users can listen to generated sounds mapped to bodily motions, allowing for a greater understanding of how and where their body is moving in space, and providing an effective technique for improvement of physical performance. [9] This approach has proven especially beneficial for rehabilitation, dance and sports technique improvement. [10] Still, there is limited research on how movement sonification can be used to provide instruction for accessible exercise learning and not solely improvement. Integrating real-time movement sonification, in addition to standard verbal instruction, into an exergame can create an alternative method of exercise learning and training for individuals with visual impairments, offering them richer feedback for skill acquisition. [10] Therefore, we aim to develop a system that provides real-time movement sonification feedback for exercise instruction that ensures the user is performing the exercise safely and correctly.

3. DESIGN METHODS

3.1 Exercise Selection & Safety

For the purposes of this study, we chose to develop our system around the body-weight squat exercise. We chose this movement as it is fundamental in many activities of daily living such as, sitting and lifting and because it serves as a basis for more dynamic tasks involved in other physical activities. [7] This application is designed for no to low vision users with normal hearing. We conferred with a physiotherapist and personal trainer to ensure the appropriate feedback is being presented. To provide better instruction, we have compartmentalized the squat movement according to four main criteria gathered from our expert interviews: foot placement, knee alignment, knee flexion, and weight shifting. The system provides real-time movement sonification feedback on the performance of the aforementioned criteria.

3.2 Technical Development

The application's auditory interface is being developed in Unity3D Game Engine and the desired sounds are generated using Faust programming language. Navigation of the application occurs via voice commands to allow for interaction without a visual interface. The necessary body tracking information, for bodily motion mapping, is extracted using the Azure Kinect's Body Tracking SDK.

Within the application, verbal instruction and movement sonification provide a step-by-step guide on how to properly execute a body-weight squat. Once the user understands the fundamentals of the movement, the system monitors their performance of the squat and returns sonic feedback for real-time adjustment of the performance, if needed. The system will then assist the user to focus on each area of improvement individually and sonify each of these areas independently to avoid overly dense feedback. For the squat exercise, the areas of improvement revolved around the ankles, knees, hips, and back, as well as the shifting of weight throughout the movement.The angular changes and weight shifting are mapped to sonic renderings using the Faust Unity plugin.

4. EXPECTED CONTRIBUTIONS

We anticipate the main contribution of this work will be the creation of an auditory-only exergame that emphasizes real-time movement sonification feedback for body-weight squat learning and performance that can be operated without the need for in-person training. The system will be designed to ensure the safety of its users. We believe this system can improve the user's motivation and confidence in their ability to pursue physical exercise and better health. Lastly, in future work, we plan conduct a user study to evaluate the system. We also plan to expand this workflow to additional exercises, in order to create a full, thorough workout regimen.

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