Zombie Fit!: Using Virtual Reality Games to Promote Physical Exercise

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ABSTRACT

A major problem that currently prevails in many parts of the world is the lack of exercise and physical activity done among the general public. Countless campaigns exist that focus on motivating individuals to not only exercise, but also eat healthier. These campaigns, however, are not enough to solve the physical inactivity epidemic as more work still needs to be done. One possible solution is to design and implement a new innovating system that combines video games, virtual reality, and exercise in such a way that it promotes physical activity.

This paper describes in detail *Zombie Fit!*, a virtual reality, zombie-based video game that attempts to motivate individuals to exercise by mapping real-world movements to game interactions and storylines. Such system was implemented through a low-fidelity prototype and a high-fidelity, functional prototype. Each prototype was used in an independent user study to gather useful data on the practicality of the system and user opinions. While evaluating the implemented prototypes, users were instructed to do several body movements such as running in place, air boxing, and stretching. Through two user studies, it was found that a virtual reality exergame system is intriguing enough to motivate individuals to exercise. The effectiveness of *Zombie Fit!* in comparison to other more conventional exercise methods was, however, not tested since such research would require lab-controlled experiments that compare calories burned.

Author Keywords

exergaming; virtual reality; exercise; zombies; motivation; running in place; virtual reality side effects; Oculus Quest; Unity Game Engine

INTRODUCTION

Problem Statement

The United States, as well as other countries, is facing a problem with people not getting the recommended amount of exercise for a healthy lifestyle. Lack of exercise, among other factors, can contribute to overweight and obesity. An emphasis is placed on obesity since it can lead to illnesses such as chronic disease, disability, and sometimes even death [1]. Lack of exercise is a problem that affects individuals of all ages. For example, just one out of three children engage in physical activity every day while one in three adults get the recommended amount of physical activity each week [1]. Children are also spending more and more time behind electronic devices such as smartphones and tablets. In fact, it is estimated that children spend more than seven and a half hours in front of a screen each day [1].

Because exercise time seems to be decreasing and screen time increasing among the general public, it was only intuitive to design a system that combined more advanced technology and exercise. Consequently, video games and virtual reality were chosen as a basis for our system. This system would, in essence, aim to increase motivation for exercise, as well as promote physical activity, through a non-traditional space. Furthermore, our system would, ideally, increase the number of people who exercise and thus help more individuals live a healthier lifestyle through video games.

Virtual reality was chosen due to the increasing popularity of the technology and the existence of effective virtual reality exercise games. More specifically, our system would be able to expand on some of the previous virtual reality exercise games by being more interactive and adding elements of suspense. Increasing the interactive aspect of effective virtual reality games and adding elements of suspense would help immerse players more in the virtual environment. Our initial hypothesis is that potential users will be motivated to exercise more often if such a system exists. Because of this, our research will attempt to evaluate the practicality, feasibility, and effectiveness of a virtual reality exercise game (also known as an *exergame*) that incorporates zombies and suspense elements. The system should also meet specific conditions and needs, such as being convenient to use, safe, fun, and interesting.

Intellectual Merit and Broad Impact Significance

Developing such an immersive system would allow researchers to conduct experiments and user studies in order to answer prevalent questions such as “Does a virtual reality exercise game motivate individuals to exercise more,” “How effective is it to exercise using a virtual reality game,” and “What are the effects of using virtual reality headsets for long periods of time?” For this particular research, we will focus on the first question only. Systems that motivate individuals to exercise would

be revolutionary and would help combat overweight and obesity problems in a fun and interactive manner.

Design and Implications

Our system is a zombie-based video game that was designed in Unity and uploaded into an Oculus Quest. The system was designed and implemented with the following three specific user tasks in mind: running in place, stretching, and air boxing [Table 1]. Once the first functional prototype was complete, a user study was conducted to get feedback on the practicality and immersiveness of the system. Through this user study, it was learned that the main implication of our design is that a virtual reality exercise game should map real-world movements to game interactions and storylines.

User Goal: Complete an Effective Workout Routine		
User Intention	*System Responsibility*	*System Goal / Game Storyline*
Touch stretch to warmup for workout	Prompt the user to pick up a virtual object, such as a chair, from the floor	Allow players to grab virtual objects and use them as weapons
Run to burn calories	Prompt the user to run in place for a certain number of time	Simulate escaping from a zombie herd
Air box to exercise	Prompt the user to hit virtual zombies with a virtual object	Defeat zombies in order to survive

Table 1. Essential use cases used to develop the details of accomplishing the three user tasks.

BACKGROUND

There are multiple systems that have been developed that contain elements of virtual reality, exergames, or both. One of these systems, Astrojumper, integrates both virtual reality and exercise. Astrojumper has full-body motion tracking that allows it to capture user movements such as dodging, ducking, jumping, and grabbing [2]. The virtual reality environment is created via a stereoscopic projection display for users to see and interact with. This combination of the virtual reality environment and the tracking of full body movement allowed designers to implement a variety of exercise games that the user could engage with [2]. In one of these games, the user is instructed to dodge planets that are moving in his or her direction to earn points [Figure 1].

Figure 1. User dodging virtual planets in Astrojumper, a virtual reality exergame, in order to earn points.

The idea of tracking users' full body movements was considered for our system since we are also interested in maximizing physical activity and increasing interaction with the virtual environment. Furthermore, the way Astrojumper maps users' movements to tasks in the virtual environment was also considered for our system (e.g. physically jumping maps to virtually jumping). However, we could not implement many of the features afforded by Astrojumper since our system uses the Oculus Quest virtual reality headset hardware (instead of a projection) to display the virtual environment [Figure 2]. It is important to note that we will be using the headset to not only track head movement, but also to map users' height to the virtual environment. For example, a person who is squatting will be able to see the difference in height perception in comparison to when they are standing.

Figure 2. The Oculus Quest virtual reality headset hardware used to implement *Zombie Fit!*

Another aspect that was mentioned in a publication that specifically made suggestions for the design of exergames was implementing a system with an exercise configuration created by the American College of Sports Medicine (ACSM). This configuration, in essence, consists of a 5 to 10-minute warmup period, 20 minutes of exertion/extended physical activity, and a 5-minute cool down period with low intensity physical activity [4]. It is critical to note that this configuration was followed in all games implemented by Astrojumper [2]. This aspect was heavily considered by our group while we designed *Zombie Fit!* since it appeared to be successful in other systems.

The publication on designing exergames also made other relevant suggestions such as not making the game too hard or too easy, as well as including clear goals, unambiguous feedback, a sense of personal control for the players, and rewards [4]. The publication also suggests that designers should exclude anything that may impose feelings of self-doubt or self-concern within users [4]. These aspects were analyzed by the publication through various video game systems, including the Nintendo Wii, PlayStation EyeToy, PlayWare, and a physically interactive version of Tetris. Our team determined that these suggestions were good aspects to include in our system since they were shown to work well with users. Consequently, we planned on designing *Zombie Fit!* to be

moderately difficult and to prompt users on what they need to do at any particular point in time. Furthermore, it was decided that the game should also allow users to roam on their own from time to time in order to give them a sense of freedom.

To begin creating our exergame, we first needed to determine what game engine to use. Our team ultimately decided to use the Unity game engine to create our virtual environment. We used various Unity tutorials to help us complete several tedious and difficult tasks, such as designing the virtual environment, giving objects the ability to be grabbed, creating colliders, and allowing the user to move within the virtual environment using the left controller's joystick. These tutorials were found from the official Unity Learn page [6] and Tutorials Point [7]. Furthermore, we also had to integrate the headset with Unity through the official Oculus site since this is the only way of creating virtual environments that are compatible with the Oculus Quest headset. It is worth mentioning that this integration provided several packages and multiple APIs. These packages and APIs contained first-person control prefabs, haptics scripts, and many other resources that can be used to help implement a virtual environment through an Oculus Quest headset [5]. Several free assets provided by Unity were also used to implement *Zombie Fit!*, which reduced considerably the time and effort required from us during the implementation phase.

DESIGN / USER STUDIES

Our original design of the system began with the idea of implementing a zombie-based game that had exercise components integrated into its functionality. In addition, our team deliberated about implementing such a game using either augmented reality or virtual reality in order to make the system intriguing enough for individuals and thus motivate them to exercise. Nevertheless, we did know that we wanted the Science Hall building at New Mexico State University (NMSU) to be part of our design. After days of debate, we concluded that, if we chose the augmented reality route, then we would map out the current user environment into a mobile application and augment zombies on top of it. In contrast, if we chose the virtual reality route, then we would create a virtual environment based on the computer science labs and some of the surrounding areas, such as offices and hallways. Ultimately, after doing research on both technologies, our team decided to use virtual reality (more specifically, the Oculus Quest) as it would provide a more immersive experience for users.

After deciding on what medium and system to use, the implementation and design of the potential game was carefully thought out. We decided that the game would have a first-person storyline. The user would, in essence, be a student exiting the main computer science lab (located inside Science Hall) after a long night of doing homework. The user suddenly realizes that there is a herd of zombies outside the lab and that he (or she) must fight back and run away to survive. Since the purpose of our system is to integrate exercise, we wanted the user to engage with the game via physical activities while fighting zombies/escaping. The physical activities that were originally chosen included the following: squatting to avoid getting bitten by a zombie, punching the zombies, running in place to run away from (or towards) a zombie, and grabbing virtual objects from the floor.

A low-fidelity prototype was designed and implemented. This prototype was then used in a user study to get feedback from participants. The feedback collected allowed us to make proper adjustments to our design and thus make our system better meet users' needs. The prototype was created out of cardboard and construction paper, and was shaped to mimic the headset and controllers of the Oculus Quest [Figure 3]. In addition, we also created storyboards for the two designed exercise routines. One of the storyboards was based on the American College of Sports Medicine configuration with a warmup, stimulus, and cool down period [Figure 4]. In contrast, the second storyboard was based on a moderate exercise routine that would be done constantly by users during gameplay. These storyboards served as visual aids for participants since they simulated what users would see through the virtual reality headset (e.g. virtual environments, exercise prompts, storylines, etc.). It is worth noting that the exercise prompts were described to each participant using the "Wizard of Oz" method, which is used whenever the functionality of a system is simulated by the person who created the prototype.

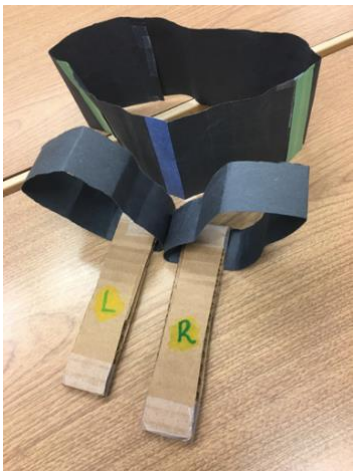

Figure 3. Low fidelity prototype of the Oculus Quest. This prototype was created with cardboard and construction paper.

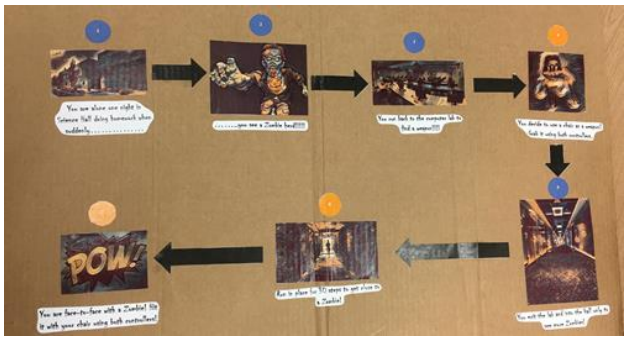

Figure 4. One of the storyboards used to guide our participants through the user tasks of our system. This storyboard was used to implement the ACSM Model low-fidelity prototype. We note that the orange circles are stages of the game in which the participant will have to accomplish a specific task.

Our team walked seven participants [Table 2] through the two storyboards and instructed them to perform tasks such as squatting and punching. And open-ended interview was then conducted with each participant. Responses were collected, analyzed, and compiled to see any similar themes or patterns in the participants' comments. A full overview of the questions asked and summaries of participants' comments can be found in Table 3.

Participant Number	*Special Attributes*
1	male; teacher; middle-aged adult; video game player
2	male; undergraduate student; early 20's; video game player
3	male; undergraduate student; early 20's; wants to exercise more
4	female; graduate student; middle-aged adult
5	graduate student; late 20's; video game player
6	female; high school student; 18-years of age; exercise enthusiast
7	female; undergraduate student; 28 years old; desires to get fit

Table 2. General descriptions of the seven participants recruited for user study one.

Interview Question	*Summary of Recorded Qualitative / Quantitative Data*	*Lesson(s) Learned from Participants*
Which design do you prefer, if any? Why?	2 out of the 7 participants preferred the Constant Exercise Model design. They both agreed that this design was more physically challenging. The remaining 5 participants preferred the ACSM Model design since it was more realistic and engaging.	The ACSM Model design is preferred more than the alternative since it is more realistic and engaging.
Is either design fun? Why?	All participants stated that both designs are fun. Furthermore, the majority of participants commented that the design's immersive aspect made the evaluation fun.	Both designs might be considered as fun by future potential users.
Do you feel like you are exercising?	5 out of the 7 participants felt like they were exercising while using either design.	Both designs might allow future potential users to exercise successfully while using the system.
Would you use a system like this to exercise? Why?	5 out of the 7 participants stated that they would use either design to exercise. All 5 participants agreed that both designs made exercising interesting and/or fun.	There exist individuals in the real-world that would use our system to exercise.
Any other suggestions or comments?	Many participants had additional suggestions. A few mentioned that there should be feedback on the number of steps taken by the user. Others commented that, instead of running for a set number of steps, the system should tell the user to run in place for a period of time. A few participants mentioned that the system should incorporate other physical objects such as dumbbells and exercise balls. Lastly, a couple of participants stated that the context of the squatting task did not correlate to the game's storyline. One participant, for example, suggested that it would make more sense to squat to simulate placing a barrier on a door.	We can incorporate other physical objects to our system in order to immerse users more. Furthermore, we have to map user tasks more accurately to the game's storyline.

Table 3. List of questions asked to participants for user study one and summaries of their responses.

From the consensus of the comments gathered, we were able to evaluate our low-fidelity prototype. These evaluations were made to see what improvements we would make in our next iteration of design to fit users'

needs better. During user study one, we also observed participants and looked for specific answers to questions such as "What went wrong when the users performed the tasks," "What went right when they performed the tasks," and "What design was more fun?" These observations would allow us to pinpoint what areas in the design to modify. Some of the most noted observations included the confusing and overcomplication of instructing users to do two or more tasks at the same time, the positive response to the ACSM model, the awkwardness of squatting, and the overall consensus that both designs simulated physical activity. The complete list of conclusions drawn from the observations can be found in Table 4.

Formulated Question	*Observed Data*	*Lesson(s) Learned from Participants*
What goes right when performing the tasks?	All participants know how to squat, run in place, and air box.	Our system can safely assume that most potential users will know what these simple exercise tasks are and their implications.
What goes wrong when performing the tasks?	A majority of participants had a hard time doing two or more tasks at the same time.	Instructing a user to do two or more tasks at the same time might overcomplicate the system.
Which design is more effective in motivating exercise?	All participants were intrigued by both designs.	Both designs are intriguing and interesting enough to motivate users to exercise.
Which design is more error-prone?	All participants delineated more from what they were told to do while using the Constant Exercise Model prototype.	The Constant Exercise Model design needs better written instructions that are less confusing and clearer.
Which design is more fun?	All participants appeared to have fun while using both designs.	Both designs might be considered as fun by future potential users.
Which design is more physically challenging?	Both designs made participants work up a sweat. More specifically, participants started to get somewhat physically tired when they started running in place.	Running in place for a long period of time is physically challenging.
Which design has clearer instructions?	All participants seemed to understand the instructions given to them while using the ACSM Model design. However, a small majority of participants were confused by the instructions provided to them while using the Constant Exercise Model design.	The Constant Exercise Model design needs better written instructions that are less confusing and clearer.
Which design is more realistic?	A majority of participants agreed that the squatting task found in the Constant Exercise Model design was out of place.	Squatting is awkward while using the system since it does not map well with the storyline.
Which design is more practical?	A majority of participants had an easier time using the ACSM Model design since only one task was assigned to them at a time.	It is not practical to do more than one major physical task at a time while also playing a game.
Are more modular tasks easier to instruct?	All participants had an easier time understanding modular tasks assigned to them.	It is much easier to instruct a user to do a modular task than multiple tasks at the same time.
Which combination of tasks are awkward or out of place?	A majority of participants agreed that squatting was awkward and out of place.	Squatting does not map well to the game's storyline.

Table 4. Summary of observed data that was collected from the seven participants during user study one.

We shortly began working on our first functional prototype after summarizing our observations and participants' suggestions/feedback. The overall design that we ended up picking was the ACSM model. This was due to the fact that all participants in user study one indicated that this model was easier to use since it had more modular tasks. Thus, our first functional prototype would only have users conducting one task at a time. There are three tasks in total that the user would be doing while using our game: picking up a virtual chair from the floor, running in place for a given amount of time, and hitting zombies with the virtual chair. Following the ACSM model, our first functional prototype was going to base the warmup period, stimulus period, and cool down period on these three tasks. The warmup period would consist of the user grabbing the virtual chair from the floor. This would make the user physically stretch, which would aid as a warmup for the upcoming exercise. The stimulus period would be mapped to the task of running in place since running elevates the heart rate and burns calories [3]. This provides a source of moderate physical activity. The user hitting zombies with the virtual chair will be loosely mapped to a cool down period since the user will stop running and just use their arms to swing.

Using the Unity game engine, our team began creating the virtual environment that the users would be navigating through using the Oculus Quest. The design of this environment was loosely based on the first floor of the Science Hall building where the computer science offices and computer labs are located [Figure 5]. This design was chosen since our initial target audience was going to be college students. We assumed that many of our participants would be familiar with the area and would be

able to relate to the design of the game given the fact that only NMSU students and faculty were recruited. Figure 6 illustrates one of the rooms designed for the first functional prototype. This particular room tries to simulate a specific Science Hall computer lab.

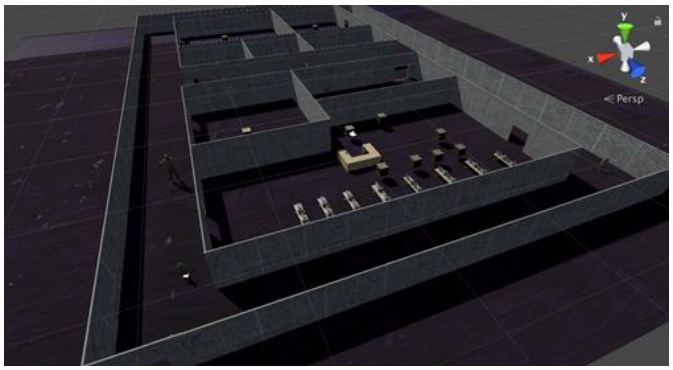

Figure 5. A birds-eye view of the entire virtual environment. Ideally, each virtual room would map to a specific physical room in the Science Hall building.

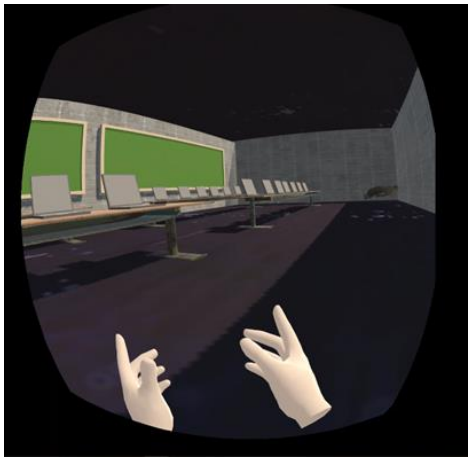

Figure 6. One of the designed rooms in the virtual environment.

The zombies and virtual objects (e.g. chairs) were implemented to allow users to perform the three previously mentioned tasks and to immerse them more into the virtual environment. The zombies also had animations that allowed them to appear as if they were walking and attacking. However, they were not walking upright due to an error in the *RigidBody* attribute (i.e. an element needed so that the zombie could be hit by the virtual chair). This was not fixed by the time we had our second user study, but we noted that it would get fixed by the next iteration. We had two different types of objects that could be grabbed: virtual cubes and virtual chairs. Both virtual objects could be grabbed using the trigger button located on the right Oculus Quest controller. Figure 7 illustrates what it looks like when a user grabs a virtual chair and hits a zombie. Navigating through the virtual environment was also mapped to the controllers. More specifically, the joystick on the left controller would allow the user to walk forward in the virtual environment while the joystick on the right controller would allow him or her to rotate in place as if they were changing direction. It is critical to note that users could also change in direction by moving their head around. Our team, however, was not able to implement the running in place functionality, meaning that users can only use the joystick to move forward in the virtual environment. The "Wizard of Oz" method would, therefore, be needed to simulate this functionality when instructing a participant to run in place. Lastly, ominous music was added to the game in order to enhance the suspension among users.

Figure 7. Screenshot illustrating what the user will see when grabbing a virtual chair and hitting a zombie.

Our second user study was done with six participants of various ages, genders, and interest in video games/exercise [Table 5]. In addition, this user study was conducted with observational questions similar to those used during the first user study. Again, we were looking for any improvements that could be made to the system and the overall user experience. Because the first functional prototype used a real virtual reality headset, an emphasis was made to check whether participants experienced any discomfort such as dizziness or disorientation. Table 6 summarizes all observational questions and collected data.

Participant Number	*Gender / Age*	*Frequent Video Game Player?*	*Favorability Towards Exercise (1 – 5)*
1	Female / 20	Yes	1; Extremely unfavorable
2	Male / 30	Sometimes	3; Neutral
3	Male / 26	Yes	2; Somewhat unfavorable
4	Female / 28	No	4; Favorable
5	Male / 22	Yes	4; Favorable
6	Male / 24	No	3; Neutral

Table 5. Demographic data collected on the six participants that took part in our second user study.

Formulated Question	*Observed Data*	*Lesson(s) Learned from Participants*
What goes right when performing the tasks?	All participants know how to run in place and air box. Furthermore, there is an effective mapping between the physical tasks and the virtual environment. For example, all participants felt like they were actually running in the virtual environment and that they were physically punching a zombie.	The virtual environment does not affect running in place and air boxing.
What goes wrong when performing the tasks?	It was quite difficult for all participants to grab the virtual chair since it was hard for them to calculate how much stretching is needed to actually get close to the object. Furthermore, grabbing virtual objects using the Oculus Quest's controllers was not really intuitive.	Instructing users to touch stretch in order to grab a virtual object may cause some disorientation since all users have different physical heights that map differently to the virtual environment. A small tutorial on how to grab a virtual object is also needed.
What elements of the design are fun in nature?	All participants were intrigued by the functional prototype. They all expressed enjoyment at how the zombies and virtual environment were designed. Three of the six participants still continued to use the functional prototype even after the evaluation was over.	The functional prototype is intriguing and interesting enough to motivate users to exercise. The functional prototype might also be considered as fun by future potential users.
Is the design error-prone?	All participants had a hard time grabbing a virtual chair, as well as hitting a zombie.	The colliders in each game object should be more accurate and precise. Allowing participants to grab virtual chairs from different angles might also make the design less error-prone.
Is the design physically challenging?	All participants appeared to get physically tired at times, especially when running in place.	Running in place for a long period of time is physically challenging for some individuals. Physically challenging movements does not, however, equate to exercising in most cases.
Is the design realistic and immersive?	All participants unanimously agreed that the functional prototype is realistic and immersive. In fact, all participants commented that they felt like they were physically "inside" the virtual world.	It is possible to create a realistic and immersive video game using VR technology.
Is the design practical and does it map well with the real world?	Five of the six participants commented that the design is practical and that all tasks map well to the physical world. One participant stated that the design is practical but that grabbing a virtual object does not map well with the physical world since a button needs to be pressed to successfully grab the object. All participants commented that the functional prototype should only be used in an open space in order to avoid hitting physical objects.	Some users might not like grabbing virtual objects using buttons. Furthermore, a warning must be given to users stating that the system must only be used in large and open areas.
Does the design cause any discomfort (e.g. dizziness, disorientation, etc.)?	Three participants physically showed signs of discomfort. One participant commented that she felt disoriented while two stated that they felt a little nauseous while using the system.	A portion of all users will experience some physical discomfort while using the system.
Are any of the assigned tasks awkward or out of place?	None of the participants stated that a task felt awkward or out of place.	The three assigned tasks map well between the physical world and the virtual environment.

Table 6. Summary of observed data that was collected from the six participants during user study two.

Some of the main takeaways from our observations included the following: the virtual environment was immersive and realistic, there was enjoyment in the design of the zombies, there was difficulty in grabbing the virtual chair and hitting the zombies, and that some users experienced discomfort (such as nausea or dizziness) while using the system. The conclusions formulated from our observations were supported by the data that was gathered from an exit interview. This exit interview was conducted with all participants after they finished using our functional prototype. The questions asked to participants during this exit interview and a summary of their responses can be found in Table 7.

Post-Evaluation Interview Question	*Summary of Recorded Qualitative / Quantitative Data*	*Lesson(s) Learned from Participants*
Did you experience any discomfort during or after gameplay, such as nausea, dizziness or disorientation?	Three out of the six participants felt discomfort during gameplay. More specifically, one participant commented that she felt disoriented and had to physically remove the VR headset numerous times. She did say, however, that running in place helped her get less disoriented. The other two participants that experienced discomfort commented that they felt	We can expect a large portion of users to experience some sort of discomfort. Purposely mapping more physical movements to the virtual world might help reduce some of these discomforts.

	dizzy and a little nauseous during gameplay.	
Were any of the tasks (grabbing a virtual chair, running in place, or hitting a zombie) difficult to accomplish? Why?	All participants stated that grabbing the virtual chair was somewhat difficult to accomplish. Five of the six participants cited that they had to be extra precise and accurate with the controller when trying to grab the virtual chair. One participant stated that the controllers have awkward buttons, but that she got used to them quickly. Furthermore, she also stated that we need to be more specific since users might have the false impression that they need both hands to grab the virtual chair.	Colliders around the chairs must be modified and reprogrammed so that they are easier to grab with the controllers. A tutorial level might also make it easier for a user to learn how to grab a virtual chair.
Did the game establish an immersive experience? Why?	All participants unanimously agreed that the game did established an immersive experience. More specifically, all participants commented that the game was very well designed and that its realistic design choices made them feel like they were actually "inside" the virtual world. Furthermore, all participants that frequently play video games commented that the functional prototype was very immersive and enjoyable.	Designing the virtual environment in a realistic manner makes the gaming experience immersive. In addition, most users that are frequent video game players might agree that our system is, in fact, a video game (i.e. having validation from actual video game players is important).
Did you feel like you were exercising? Why?	Four of the six participants stated that they felt like they were exercising. More specifically, they mentioned that running in place made them feel physically tired. In contrast, the other two participants did not feel like they were exercising since they were, according to them, not moving enough.	Running in place for a long period of time is physically challenging for only some users. Because of this, the final system should have levels that vary in exercise difficulty. More specifically, levels that increase in difficulty should prompt the user to move for longer periods of time.
Would you use a system like this to exercise? Why?	Five of the six participants stated that they would use our system to exercise. Furthermore, all five participants stated that they would use such system since it is immersive and makes exercising fun. One of the participants would not use our system to exercise since he is not interested in exergames. It is important to mention that the two participants who had an unfavorable view of exercise would consider using out system to exercise, which means that there was a change in opinion after they evaluated our functional prototype.	Most users would use our system to exercise. However, users who are not interested in exergames in general would rather go to a gym or outside to workout. Nevertheless, we can safely assume that our system does change the opinions on those individuals who have an unfavorable view on exercise.
Any other suggestions or comments?	All six participants suggested that we fix our zombies (i.e. our zombies sometimes fall over) and that we should make them chase after the game character. In addition, all six participants suggested to add the "running in place" functionality instead of allowing users to use the joystick to move around the virtual environment. Three participants suggested that we display instructions in order to make the objective of the game clearer. Five participants suggested to add more grabbable objects such as a laptop or desk. Lastly, two participants commented that it would be beneficial to have more "modular" objectives since, as of now, the functional prototype is a sandbox game, which means that there are minimal restrictions placed on the game player.	Our final system should have the "running in place" functionality, as well as clearer objectives. In addition, more grabbable objects should be introduced and virtual zombies should be programmed to chase after the game character.

Table 7. List of questions asked to participants for user study two and summaries of their responses.

The main takeaways from participants' responses in this exit interview include the following:

- Five out of the six participants would use our system to exercise
- The environment is immersive and fun
- More virtual objects that can be grabbed should be implemented
- The zombies should get fixed so that they walk upright (adding more realism to the game)
- Moving forward in the environment should be implemented via motion tracking instead of the controller's joystick
- Objectives, feedback, and goals should be added to the game
- The virtual environment might be too realistic since some participants experienced discomfort during gameplay

For our final functional prototype, modifications to the design were made so that they implemented as many of the suggestions made by our recruited participants. More specifically, in our last functional prototype, the zombies were able to walk upright and chase after the game character, thus adding another layer of suspense. Some of the virtual rooms were redesigned to lack both detail and

decorative objects so that they could be more "abstract." It is critical to mention that this was done to help alleviate user discomfort since participants noted that they would get dizzier and more disoriented when they would navigate in rooms that contained more detail (i.e. rooms that contained non-functional decorations such as chalk boards, desks, and laptops). We also made a room full of cubes that could be grabbed in order to provide a complete abstract environment that a user could go into to "recalibrate." Lastly, the virtual environment's colors were made darker and duller to attempt to alleviate discomfort among users.

Since many participants requested more grabbable objects, we added a few more chairs and a classroom globe. A "bite count" was also added to provide users with feedback when they get attacked by a zombie. That is, the bite counter increases whenever a zombie collides with the game character. A health bar was implemented as well, but is not functional. Along with the bite count, the health bar would also serve as feedback if it was functional. Together, the health bar and bite count would ideally motivate the user to avoid getting attacked by the zombies. Nevertheless, we were unable to implement some aspects suggested by our participants in our final functional prototype due to time constraints. For example, we were unable to implement the running in place functionality, prompts, and the countdown timer. These are discussed in greater detail in the *Future Work* section of the document.

As this section illustrates, our design evolved greatly from its initial conception to its implementation. During each design iteration, prototypes were implemented and used in user studies. These user studies resulted in valuable and practical suggestions from participants. Consequently, user suggestions were a core motivation moving forward as we redesigned our system. These user studies also resulted in options that we had not considered before, such as making the virtual environment more abstract in order to reduce discomfort among users. Our group, however, only selected those available design choices and options that would help aid our research premise of evaluating the practicality, feasibility, and effectiveness of *Zombie Fit!*

EVALUATION

Because of the nature of this project, we will focus more on the second user study since participants evaluated a much more mature prototype with functionality that would be included in the final implemented system. As mentioned in the previous section, our first functional prototype was implemented using Unity and downloaded into an Oculus Quest. This designed apparatus was then used in a second user study in which a single team member from our group instructed participants on what to do. Because of this process, our second user study incorporated the "Wizard of Oz" method since some of the functionality and storytelling of our first functional prototype was simulated through instructions and commands. Table 8 summarizes the instructions and commands that were given to each participant during this evaluation.

Instruction / Command	*Reasoning*
"To walk or run in the virtual environment, you must use the left controller's joystick. However, you must also walk or run in place. Moving around in the virtual environment only using the joystick, and without moving in place, constitutes as cheating."	The functional prototype allows participants to walk or run in the virtual environment using the left controller's joystick, which defeats the purpose of our system's goal of providing a means of exercising. Instructing users to run or walk in place simulates a functionality that does not exist (i.e. using the controllers' sensors instead of the single joystick to move the game character around the virtual environment).
"There is a zombie apocalypse! You need to find a weapon! Grab the chair next to you using the right controller's side trigger."	There should be some sort of context as to what is going on in the game and why the participant needs to grab the chair.
"Run towards the zombie next to you. Remember, you must run in place while using the joystick."	We should remind participants constantly that they must walk or run in place in order to move in the virtual environment.
"Hit the zombie as hard as you can a couple of times."	Participants should know that they can defeat a virtual zombie by hitting it with the virtual chair.

Table 8. List of instructions and commands that were given to participants before or during the evaluation in order to simulate storytelling and some functionality.

Before meeting with our participants, we created an open-ended, unstructured interview script containing the following list of questions:

Pre-Evaluation Interview Questions

1. What is your gender?
2. What is your age?
3. Are you a frequent video game player?
4. On a scale of 1 to 5, with 5 being favorable and 1 being unfavorable, how do you feel about exercise?

Post-Evaluation Interview Questions

5. Did you experience any discomfort during or after gameplay, such as nausea, dizziness or disorientation?

6. Were any of the tasks (grabbing a virtual chair, running in place, or hitting a zombie) difficult to accomplish? Why?

7. Did the game establish an immersive experience? Why?

8. Did you feel like you were exercising? Why?

9. Would you use a system like this to exercise? Why?

10. Any other suggestions or comments?

It is critical to note that questions one through four were asked to participants before the evaluation began, while questions five through ten were asked shortly after they finished playing *Zombie Fit!*. Tables 5, 6, and 7 summarize the data gathered before, during, and after each participant evaluated our system. As mentioned in the *Introduction* section of this document, our initial hypothesis is that potential users will be motivated to exercise more often if a virtual reality exergame exists. Furthermore, our research attempted to evaluate the practicality, feasibility, and effectiveness of a virtual reality exercise game that incorporates zombies and suspense elements. Table 9 presents data clearly to provide evidence for our argument and establish the validity of our hypothesis. We note that we accomplish this by summarizing relevant results that were gathered in user study two. In addition, an emphasis will be placed on qualitative data rather than quantitative data.

Research Component	*Result / Evaluation*	*Evidence*
Hypothesis: Potential users will be motivated to exercise more often if a virtual reality exergame exists.	We accept our hypothesis as true. If potential users were to buy such a system, they would be, more than likely, intrigued by its nature and thus use it more often than not. This would directly result in doing more exercise since users would be motivated to use the system.	In user study two, we concluded that five out of the six participants would use our system to exercise. More importantly, two of these five participants had an extremely unfavorable view on exercise. This means that there was a change in opinion after they played *Zombie Fit!* Relevant quotes recorded during user study two include the following: - "I really hate exercising, but I would definitely use your system. It's fun and cool." - "The game is really cool! I'm intrigued, not gonna lie." - "If I had this system to exercise, I would use it daily."
Practicality	A system like this is, for the most part, practical and convenient to use. However, a portion of all users might experience some discomfort while playing the virtual reality game if it is designed too realistic. In addition, a warning must be given to users that the game should be played only in a large, open area.	Three out of the six participants in user study two felt discomfort (e.g. dizziness and disorientation) during gameplay.
Feasibility	It is feasible to design and implement a virtual reality exergame. That is, there are countless resources on the internet that make such process easy and reasonable. In addition, Oculus Quest (and other brand name) headsets are no were near as expensive as physical exercise equipment.	We were able to implement a somewhat fully functional system in a span of only three months. The Oculus and Unity websites provide scripts, assets, APIs, packages, and other pre-made resources that are readily available to anyone with supporting hardware.
Effectiveness	The system immerses users into the virtual environment and is designed well. The system is also intriguing, fun, and interesting.	Five out of the six participants in user study two stated that they would use our system to exercise. In addition, all six participants unanimously agreed that the system was designed well and that it immersed them into the virtual environment.

Table 9. Summary of results for each research component. We note that we use user study two as evidence to support our claims.

It is critical to note that our system and research only provides an intellectual basis on whether or not such system is intriguing enough to motivate users to use it and thus (indirectly) exercise. In other words, our research and data cannot answer other more specific questions such as "How effective is it to exercise using a virtual reality game (e.g. calorie burnout comparison)," and "What are the effects of using virtual reality headsets for long periods of time?" In addition, we cannot conclude if a fully implemented version of our system could substitute "real" exercise in its entirely. More prototyping, research, and experimenting needs to be done in order to answer such questions. Nevertheless, we can safely and confidently conclude that virtual reality exergames should be taken seriously as they might be the next big thing in exercise and video game development.

DISCUSSION / IMPLICATIONS FOR DESIGN

While creating our virtual reality exergame, it was very important to design and implement prototypes, as well as evaluate them through user studies. This enabled us to build the system step by step and allowed us to slowly add in changes as needed. In addition, testing our exergame prototypes on participants of varying genders, sexes, age ranges, and levels of interest in video games/exercise allowed us to gather a more inclusive sample, which led to more meaningful and applicable results. Avoiding collecting sensitive data, such as weight, helped our participants feel more at ease when testing our system. It is also important to get user feedback from these tests to see what modifications need to be made on any system component. While evaluating our prototypes, our participants made very helpful comments and suggestions on features to add in the future, as well as anything that made the system less immersive and interactive. For example, if our participants had not told us that grabbing a virtual chair was difficult in our first functional prototype, we would have never known about it. Therefore, it would have remained difficult to grab virtual objects and possibly create feelings of discomfort and stress within users. Having open communication with participants while and after they use your prototype is also important. Open-ended interviews aided greatly in getting honest feedback from our participants. More specifically, our participants did not feel restricted in what they could say, which is a problem that occurs with questionnaires since they tend to have limited options. Consequently, user suggestions should be a core motivation moving forward whenever you are redesigning your system since participants will, more than likely, suggest options that you have never thought about before.

Because there is the added element of virtual reality in these types of exergames, it is highly recommended to advise participants to stop playing the game if the discomfort levels get too high. It is also recommended to check-in with the participant during the use of the system to see if any discomfort arises. If so, attempt to find out what triggered the discomfort. Was it the use of specific colors? What about specific areas that have more items concentrated? Did the discomfort started when the participant began exercising? Modifications will need to be made based on what aspects caused the discomfort. For example, many of our participants stated that they had discomfort whenever they would navigate in the virtual rooms that were full of realistic items and objects. One of these rooms contained several tables, laptops, chalkboards, and chairs. As a result, we ended up redesigning some of the rooms in the virtual environment to have a minimal appearance. One room, for instance, only had cubes that could be grabbed while another only had a chair and a zombie in it. This created a more abstract space and, thus, was less likely to cause discomfort among users. It is recommended to design and implement a virtual environment with an abstract approach if one wishes to minimize discomfort and disorientation. However, designers should be aware that making the virtual environment too abstract might make the game boring and not immersive enough. Therefore, a good balance between abstract and realism needs to be found by designers.

Lastly, throughout this research, it was learned that the main implication of our design is that virtual reality exergames must map real-world movements to game interactions and storylines. Most importantly, having users' body movements be mapped to navigation in the virtual environment can help with discomfort. This is because when the physical body is not moving, but the user is moving forward in the virtual environment, the brain gets disoriented. This can cause uncomfortable sensations such as dizziness, queasiness, and nausea. While we were not able to implement the tracking of body movement, users did notice that the discomfort decreased when they ran in place while navigating in the virtual environment with the controller's joystick. Mapping real-world movements to game interactions and storylines also makes the system more immersive, which is a crucial component that must be met in order to motivate users to use the system to exercise.

We have, in essence, designed and implemented a system that can help motivate users to exercise more. This is because our system provides an alternative way of exercising that is more enjoyable and immersive. Though we have not completely solved the overweight and obesity problems in the United States (or the entire world for that matter), our system and research does provide relevant design principles and examples that can be used by future development teams that have more resources.

CONCLUSIONS AND FUTURE WORK

Virtual reality games are becoming increasingly popular, and virtual reality headsets and systems are starting to be commonly found in homes. The goal of our system, *Zombie Fit!*, was to increase exercise motivation for individuals in a non-traditional way. As indicated by our user studies, there are individuals in the general public who are interested in using a virtual reality exergame. More specifically, five out of the six participants in user study two stated that they would use our system to engage in physical activity. Two of these participants had previously indicated that their favorability of exercise was low. Therefore, our system and research provide evidence that it is possible to increase exercise motivation in individuals that previously did not enjoy exercising. In addition, and as summarized in Table 9, our research proved that it is practical, feasible, and effective to design, implement, and use a virtual reality game to exercise.

Since screen time appears to be increasing and physical activity decreasing among children [1], it would

be excellent for the health field to attempt running some experimental trials with our system. In our initial questionnaire, we noticed that many individuals preferred to exercise in the comfort of their own home. Our system can be used at home with ease, so this may help increase exercise motivation for these individuals. It would also be interesting to see if the addition of a system like ours at gyms help people exercise when they start to grow tired of traditional physical activity. We would also need to study the long term effects of using *Zombie Fit!*. Since we are not experts in the health field, we would need assistance from people who can study the psychological, physiological, and emotional effects of using our system for weeks (or even months) in comparison to more traditional exercise methods. This way, it can be determined whether our system can be a recommended substitute for traditional exercise, a supplement to it, or not be recommended at all.

In the field of computer science, our project would help add another piece to the growing area of virtual reality exergames. While conducting our research, we did not find any virtual reality exergames that had zombies or elements of suspense and terror. We believe that these elements help a user's heart rate go up due to the feeling of suspense. This would aid in stimulation of the cardiovascular system and also possibly aid the user to start exercising because of the already elevated heart rate. These, of course, are hypothesis that would need to be proven or disproven through experiments, research, and studies.

For future iterations, *Zombie Fit!* would ideally be able to track body movement. This is the biggest aspect that we would like to have functioning because we believe that it is a significant part of users' experience (i.e. more specifically, tracking body movements and using such measurements to change the state of the game would make the system more immersive). In addition, tracking body movement would allow the user to navigate by exercising instead of having to use the controller's joystick and the "Wizard of Oz" methodology. This would help us achieve our original goal of allowing users to engage in physical activity without needing external directions or commands. Another aspect that we would like to have implemented would be a functional health bar that would decrease in health percentage whenever a zombie collides with the virtual game character. A timer being displayed when the user needs to run in place would also be implemented in a future iteration. Both the health bar and timer would give the user appropriate feedback. For example, if there is no timer being displayed on the screen, how would the user know that a minute has passed? It would be extremely inconvenient and a nuisance for users if they had to mentally keep track of time.

In addition to displaying feedback on the screen, we would also like to implement feedback that occurs when a user hits a zombie with a virtual object. This feedback may take form in the zombie reacting in a specific way, such as falling backwards to the ground. We could also have a health bar on every zombie. This health bar would decrease in percentage every time its associated zombie would get hit by a virtual object. Once the health bar is completely depleted, the zombie would fall to the ground and stay immobile for the rest of the game.

To build on the feeling of the system being a game, we plan to add objectives, goals, prompts, tutorials, and various levels of difficulty. Objectives and goals will give the user direction in what tasks need to be done. Following the storyboard we had for the ACSM model in user study one, we would start the player with a cut-scene of them being in the Science Hall computer lab. Then, they would be instructed to exit the lab, enter a room to grab a specific virtual object, run in place for a certain amount of time, and hit the zombie with the grabbed object. These objectives and instructions will be displayed as small prompts onto the virtual environment. The tutorials are also important since they allow users to get familiar with the virtual environment and learn all the different controls (e.g. using the trigger button to grab virtual objects). Different levels of difficulty can also be implemented to add novelty to the game. For example, the hardest level might have more zombies or zombies that are harder to defeat. Each increase in difficulty would also increase the amount of exercise needed to pass the level. Lastly, perhaps more tasks can be implemented (e.g. punching, jumping, etc.) in order to add some variety to the exercise routines being done by users.

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APPENDIX A

Supplemental documents created during this research project can be accessed by clicking on the following links:

- *Original System Concept:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/ETbU0FtMq-dMiVW12my8LgsBlUwjoNOgKb9jtRTKl85YiA?*e=myEcka*
- *Data Gathering Preparation:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/EfEuTJQuvHdKm-1qwXp0x20BmJuvBvgZYK_p1E8k_OtqHg?e=Bjhgxf
- *Needs & Requirements:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/EYsMQnGWExVPlu4yl_OuevcBNjpicZWp4_eHDGIDMXlfsg?e=nn2wkG
- *Literature Review:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/EcHHqgZHN2BHlvmDocab0uYB3OZ40h2kDd3bugSj_dm8tw?e=yWLayv
- *System Proposition:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/EX0XJEsPLeNEka2zZQo2-ZEBnGtAh9H0R5CK-E2afF6Y6Q?e=Hj2Wpi
- *Low-Fidelity Report:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/ETrAAmNyltJIhDRT_OYMY_sBVhzl-aKTkUG1q29c_JARgw?e=AW1IIw
- *User Study One Report:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/EcDBD1Erh3JCrqV-iWeJLHUBbQcm90ehlA_w4-Yw_3YrQQ?e=elrexP
- *User Study Two Report:* https://eltnmsu-my.sharepoint.com/:b:/g/personal/jose5913_nmsu_edu/EWuuDrjcYdVLr2oTjswbm2UB-5nwaYavUIlfHAauODAQXg?e=Sq4Vej