Strategies to Design a Mixed-Reality Immersive Environment and Influence Teen Health Behaviors

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Abstract. The influence of combined experiential learning through face-to-face instruction and immersive environment (IE) on health behavior change has not been examined extensively. The goal of the WAVE ~ Ripples for Change Childhood Obesity Prevention project was to determine the effectiveness of teaching nutrition and physical activity knowledge with an IE designed to reinforce these healthy behaviors (i.e. Rippleville), and if it could improve overall diet and physical activity. Participant engagement was crucial for the participant's exposure to the decision-making process and data collection. This paper describes the strategies implemented in Rippleville to maximize participation and to engage a remote and scattered teenage population into an IE, including our mixed-reality models, as well as learning, engagement, and programming strategies.

1 Introduction

As young adults transition from high school to college or the work environment, they demonstrate negative health behavior [14]. The Oregon State University WAVE ~ Ripples for Change Childhood Obesity Prevention project was an interdisciplinary project examining whether health behaviors can be influenced using face-to-face instruction in the physical world paired with an immersive environment (IE) called Rippleville. The project aimed to alleviate the negative transition behavior in adolescents by the introduction of PAN-FCS knowledge (Physical Activity, Nutrition, and Family and Consumer Sciences). Moreover, the WAVE project hypothesized that applying knowledge through an IE, such as Rippleville, could improve the learning outcomes and further influence behavioral change. This hypothesis is grounded in research showing that IE may cause change in a person's subjective experiences, body states, and physical space behaviors. Interaction within IEs has been shown to induce subjective experiences such as nicotine and alcohol cravings [1, 3, 5] and fears such as aerophobia [9] and acrophobia [12]. It has demonstrated effects on body states such as blood pressure [13] and body mass index [6]. Simulated exercise activity in IEs correlates to increased physical activity in the physical space [2]. Individuals who exercised

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Fig. 1. Aerial view of Rippleville

super powers in an IE exhibited greater altruistic behavior in the physical space [8]. In this work, we present Rippleville, an island (Fig. 1) implemented on the OpenSimulator (OS) which is an open source version of Second Life. For this study, the participants had their own avatar living on the island, which they controlled from a third person perspective. The WAVE project's participants were healthy adolescent soccer players, geographically scattered among nine high schools in two non-neighboring school districts. The ability to answer our research questions lied into the engagement of these adolescents in Rippleville. This paper presents our work on strategies to engage a remote and scattered teenage population into an IE. Section 2 presents Rippleville's learning objectives. Section 3 describes our mixed-reality strategy, then Sects. 4, 5, and 6 present our learning, engagement, and programming strategies respectively.

2 Learning Objectives

2.1 The WAVE Study

The goal of the WAVE ~ Ripples for Change Childhood Obesity Prevention project was to develop, evaluate, and compare the effectiveness of physical world face-to-face instruction and reinforcement via experiences in an IE. The curriculum integrated two years of PAN-FCS (Physical Activity, Nutrition, and Family and Consumer Sciences) intervention for obesity prevention, and was administered to adolescent soccer players (n = 500). Rippleville was the IE designed to reinforce the PAN-FCS, and administered only to the intervention group (n = 320).

2.2 Rippleville's Learning Objectives

First, the WAVE face-to-face learning objectives focused on teaching sport nutrition skills to high school soccer players. These learning objectives were then reinforced through an IE, Rippleville. The learning objectives were concentrated around the following key areas: (1) Knowing pre, during, and post-exercise hydration, fuel needs, as well as how to choose foods and beverages to meet these needs, (2) Recognizing the symptoms of exercise fatigue, (3) Balancing school and sport with appropriate food and fluid selection, (4) Understanding the component of body weight composition and image, and (5) Staying well (e.g. injury prevention).

3 Immersive Strategies

Participants were occasional computer users. Except for a few video game users, most were not familiar with IEs. Thus, Rippleville had the inherent risk of being perceived as foreign and counter-intuitive. We mitigated this risk by creating a mixed-reality model.

IE are defined by two criteria: synchronicity and reality. The synchronicity defines when the participants must be logged in for the simulation to function. If the simulation requires participants to be logged in at the same time, then this simulation is fully synchronous. If there is no such requirement to provide a complete immersive experience, then the simulation is asynchronous. In the case of Rippleville, the high number of participants (n = 320) required the creation of an asynchronous environment, since it would be extremely hard to coordinate all logging in at the same time. The asynchronous environment allows a participant to log in and experience the simulation at any time. If several participants were logged in at the same time, they could still interact with each other. However, this age group is not attracted to asynchronous designs (if one logs in and sees no one else, one is likely to never come back). Thus, a mixed-reality model was developed to address this issue. The reality of the simulation defines how an IE is grounded to the physical world. This was a strategy used to help participants identify with their avatar and increase engagement. In the case of Rippleville, the mixed-reality strategy had the IE transferred into the physical world. For example, orientation events (Sect. 5) occurred in the high schools, with the team and coach present. The participants received newsletters based on the narrative of

(a) Taco Buzz (b) Winter event

Fig. 2. Elements of Rippleville

Rippleville, and were invited to synchronous events (i.e. Halloween costume contest, New Year's fireworks, Fig. 2(b)).

4 Learning Strategies

In this section, we describe the learning strategies used to achieve the learning objectives presented in Sect. 2. First, we developed quests to entice the participants into practicing the sport nutrition knowledge and skills they learned in the classroom. Second, we designed real-time feedback for the participants to evaluate their performance, how their decisions were impacting overall health, and their ability to continue the quest. The feedback was given in real-time using a heads-up display called *RippleTracker*. Third, several hundreds of food and beverage items normally available to adolescent were provided in three frameworks: convenience/grocery stores, fast food/ restaurants, and food booths.

4.1 Quests

Rippleville was not designed to present educational content, but to reinforce decision-making process via actual practice. The participants exhausted their avatar during a quest, running and jumping, and thus must refuel during and after the quest. To entice the participants into immersive physical activity, we designed five quests to be played by the participants in any order, any number of times, and at any moment. This allowed for regular and realistic practice of planning before, during, and after the effort. The quests were started by selecting their poster from the *Activity Kiosk* (Fig. 3(c)) on the main square. Briefly, the quests and their learning objectives were:

(a) Kraken (b) Aerial view of the Rough Mudder (c) Activity Kiosk

Fig. 3. Elements of Rippleville

Missing Cat: Help a Rippleville citizen to locate her cat; Tour of Rippleville.
Mischievous Kraken: A clue hunting adventure with the Kraken (Fig. 3(a)), Rippleville's high school mascot and mischievous creature; applying good hydration behaviors.
Rough Mudder: Fantastic obstacle course race (Fig. 3(b)).
Shopping on a Budget: Groceries store race-shopping under constraints.
Pizza Jeopardy: Choose the best food option presented.

Reward System: The participants received a reward when completing a quest. The reward was dependent on their "health level" at the end of the quest based on the *RippleTracker*'s criteria. Reward differed per quest, reflecting the inherent difficulty of the quest (i.e. "Rough Mudder" was "worth" more than the "Missing Cat"). The reward was divided into two parts: (1) points, which accumulated throughout the simulation and were an indicator of the participation and quality of choices made, and (2) virtual currency, which could be spent on food and articles for the avatar. Each participant was associated with their physical soccer team, and the accumulated score was displayed in order on the *Leader Board*.

4.2 RippleTracker

The *RippleTracker* (Fig. 4) was a heads-up display on the participant's screen, which reflected the current health condition of the avatar. The parameters were hydration, added sugar consumed, minutes of physical activity[1] and average *Diet Quality*. Each parameter had a gauge divided in three levels: good (green), average (yellow), and bad (red). A pointer slid on each gauge to mark the level of the parameter, and a smiley face above the pointer reinforced the meaning of the color. The center of the *RippleTracker* had a large smiley face, which represented the overall health of the avatar.

Fig. 4. Rippleville tracker (Color figure online)

Simulating Human Physiology: The depletion or gain of each value reflects the virtual physical activity and virtual alimentation of the avatar, using the participant's physiological data as well as human physiology. These changes were real-time feedback.

[1] It's important to note that OpenSimulator allowed only two speed of physical activity: walking and running. Thus, the performance of the participants was their ability to stay fueled and hydrated within proper nutritional guideline.

However, time was wrapped in Rippleville to accelerate the effects of each behavior. For each minute a participant was using Rippleville, six minutes had passed for the avatar.

Constant Monitoring: The simulation of the human physiology and the monitoring of physical activity and alimentation lasted for as long as the participant was logged in, even when the avatar was not doing a quest. Therefore, if the participant chose not to do any quests, the avatar would still dehydrate and need nutrition. This was an important aspect for Rippleville's learning objectives: participants should think about their nutrition and hydration even when not exercising. The avatar's health would return to default level if the participant was logged out more than 12 h.

4.3 Food & Alimentation

Rippleville offered more than 350 consumable items modeled in 3D as an individual item (e.g. an apple) or a meal (e.g. hamburger and fries). The WAVE project's nutritionists created the food list and menus. These food items were representative of the many options normally available to our participants. The participants could buy virtual food from a convenience store, a grocery store, a mid-range restaurant, a pizzeria, an Asian-fusion fast food, a Mexican fast food, or a burger fast food. Finally, they could also get a home cooked dinner at one of the soccer coach's houses. The placement of food items was based on realism (e.g. candies in the convenience store, fresh fruits in the grocery store etc.). The placement of catering buildings was also based on a need for realism (e.g. it was easier to go to the convenience store than the grocery store). We defined the easiness as the distance between the participant's *Club House* (Sect. 5) and any other point. Finally, the product's brands were invented but gave a visual nod to existing brands that were familiar to the participants (Fig. 2(a)). This was essential for the transferability of knowledge.

Convenience & Grocery Store: The WAVE study's face-to-face intervention included how to read nutritional food labels required to appear on food items in the USA. Each food item in those locations was equipped with its corresponding food label sourced from the USDA food database.

Restaurants & Fast Foods: These food items did not have food labels, but instead have a score for *Diet Quality*, represented by a tricolor system: green (good), yellow (average), and red (bad) (Fig. 5(a)). When the participants selected one or several items in the menu, a traffic light lit up with green, yellow, or red. We used a weighted average to determine the diet quality of a collection of food items.

Food Booth: A Food Booth (Fig. 5(b)) helped the participant create a meal based on a themed (i.e. breakfast or snack). It presented several random selections of food items, which would appear in the larger plate above, as they were chosen. A tricolor traffic light indicates the average *Diet Quality* of a plate.

Food Consumption: Lastly, the participants consumed the food bought at their leisure. At purchase, the food items go into the participant's inventory. Eating any food or drinks would affect the *RippleTracker* immediately.

(a) Tricolor System (b) Food Booth

Fig. 5. Elements of Rippleville (Color figure online)

4.4 Learning Strategies Summary

The WAVE study and its immersive part, Rippleville, had ambitious learning objectives. We developed strategies to incentivize learning using gamification, familiarity, and non-standard ways of presenting educational contents. Our learning strategies are summarized as follow:

1. Use a narrative to entice participant into immersive physical activity.
2. Provide physiologically accurate real-time feedback using uniform signage.
3. Provide familiarity, realism, variety, and heterogeneous choices (i.e. food, catering) to facilitate transferability of knowledge to the physical world.

5 Engagement Strategies

In this section, we present our engagement strategies. The engagement of the participants in Rippleville's activities was crucial for the WAVE study. Firstly, their engagement exposed them to the decision-making process of nutrition and physical activity. Secondly, valuable data was collected to evaluate Rippleville's efficiency. Nevertheless, engaging high school students to use a new platform outside of class time is a challenge itself. Our piloting of Rippleville led us toward various strategies to facilitate and increase engagement. The main challenge with engagement was the technical barrier imposed by the OpenSimulator (OS). We mitigated this problem by adding an additional level to our mixed-reality model called "Rippleville LIVE". In the rest of this section, we also describe strategies for self-identification, self-regulation, socializing, narratives, and creating content.

Overcoming the Technological Barrier: The OS platform required some training to control the avatar, in addition to the functionalities we created for the project. Therefore, we implemented an orientation program consisting of a hedge maze with challenges to make what could be mundane interface learning more interesting and help participants understand how to navigate the environment. However, the initial piloting

(a) Orientation Maze (b) Reporting Station & Signage

Fig. 6. Elements of Rippleville

of this hedge maze (Fig. 6(a)) revealed that it was very difficult for the participants to figure out the controls and options by themselves. Consequently, we created "Rippleville LIVE", a mixed-reality synchronous intervention that took place in both physical and immersive world. This approach aimed at minimizing frustration and dropout rate, using physical world tutoring during the immersive experience. We physically went to the high schools and setup computers connected to Rippleville's server via Internet (using both the school's Wi-Fi, and cellular network). The immersive space of "Rippleville LIVE" was not located in Rippleville's main island, but on floating platforms in high altitude above the island. Each specific skill to be taught had a dedicated workshop (e.g. how to control the avatar, modify its appearance, and interact with Rippleville's world). We had workshops of 10 min each happening simultaneously. The participants were required to go through all the workshops, but in no particular order. The analysis of the data collected from these workshops (self-assessment of skills and emotional state, behavioral recording through video etc.) will be presented in a subsequent paper.

Self-Identification: Rippleville was a village with all the familiar elements of the daily life of our participants: visual nod to existing brands, high school, fast food, shopping centers, and natural spaces. We built dedicated Club *Houses* for each soccer team, identified by their high school's colors and mascot. This provided an identity link between the participants and their team, as well as a sense of ownership of the space. Finally, each team's accumulated score was displayed on a *Leader Board to* create a friendly competition between teams. In OS, one can alter and personalize one's avatar appearance. Several *Identity Shops* offered a selection of skins, hair, and eyes for the participants to customize their avatar appearance. Additionally, Rippleville offered a variety of clothing and accessory styles and shops to appeal to different tastes. The goal was to provide the participants with many opportunities to identify with their avatar, as well as gave them incentive to participate in the simulation: clothes cost WAVE dollars and only finishing quests provided WAVE dollars, a better performance in the quest maximized the gain, and so on.

Self-Regulation: The mixed-reality asynchronous model of Rippleville required the participants to decide by themselves what they wanted to do, and it might not be what we would have wanted them to do. It might also have been difficult for a participant evolving in a free-form non-linear narrative to figure out what was the next thing to do, and to relate that to learning. Thus, we implemented an engagement strategy based on self-regulation [4, 7, 10, 11, 15]. First, the *RippleTracker* provided verbal feedback on the current state of the avatar's health. When a gauge's indicator changed color zone, the *RippleTracker* prompted the participant with a message related to that change (e.g. "You are now 2 % dehydrated, be careful"). These messages were hints for the participants to maintain a proper level for each parameter. Second, we installed signage everywhere around Rippleville to facilitate navigation and to remind the participants of the *Activity Kiosk* (Fig. 3(c)) and various catering locations (Fig. 6(b)). During the quests, the participants were prompted hints about what to do by the *RippleTracker* as well as by Non-Playing Characters (NPC). Moreover, if the participants were to have additional problem with the simulation (i.e. technical problem, bullying etc.), they could use the reporting stations (Fig. 6(b)) to send an e-mail to the Rippleville's development team. Furthermore, the development team was clearly identifiable by wearing a blue WAVE shirt and a medallion above the avatar's head. During our experimentation, this has been very useful for helping participants to identify who could assist them instantly.

Socializing: The OS platform provided a system of profile pages and instant messaging which facilitated social interactions within Rippleville. Participants could messages each other, "friend"each other, and exchange goods. The *Club Houses* (with their mini soccer fields) as well as the *Dance Club* (with the dance floor) provided spaces to hang out and have fun. Additionally, we organized seasonal synchronous events (e.g. Halloween party, Winterfest, see Fig. 2(b)) to incentivize the participants to log in at the same time. We offered them limited edition objects when they joined us (e.g. Golden soccer ball).

Consistent Narrative: Each quest was built with elements linked to Rippleville's narrative. For instance, the quest "Find the Kraken" told the story of the Kraken, the mischievous mascot of Rippleville high school.

Creating Content: The OS platform allowed programming in Linden Scripting Language (LSL). Thus, we installed sandbox areas, where the participants could shape and program their own OS elements. This encouraged creative participation and personal contributions to the world (contained to these sandboxes however). We trained the participants how to build objects during one of the Rippleville LIVE workshops.

5.1 Engagement Strategies Summary

The engagement of participants with the simulation was crucial to answer our research questions. We have deployed several systems, tools, interventions, and infrastructure within Rippleville, summarized as follow:

1. Develop training and tutoring to reduce technological barriers.
2. Provide tools, infrastructures, and events to facilitate self-identification, self-regulation, and to promote social behaviors.
3. Develop coherent content, and allow participants to create their own.

6 Programming Strategies

Figure 7 summarizes our programming strategy; each avatar was wearing a *RippleTracker* (Fig. 4), which monitors the avatar's activity in terms of intensity of physical activity, which quest was active or completed, and what alimentation was taken. It computed the health information to be displayed as well as calculated the rewards. Finally, OpenSimulator was not fit to store custom data-bases, so the *RippleTracker* sent data outside of Rippleville, to our SQL database, which collected all the information about anything the avatar did while logged in. The analysis of this database will be presented in an ulterior publication.

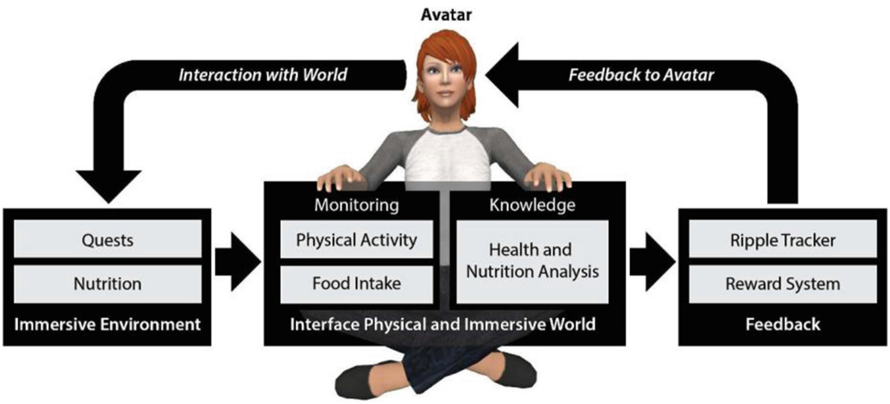

Fig. 7. The RippleTracker centralized Rippleville's programming strategy

7 Conclusion

The Oregon State University WAVE ~ Ripples for Change Childhood Obesity Prevention project was an interdisciplinary project examining whether health behaviors can be influenced using face-to-face instruction in the physical world paired with an IE called Rippleville. The project aimed to alleviate the negative transition behavior in adolescents by the introduction of PAN-FCS knowledge (Physical Activity, Nutrition, and Family and Consumer Sciences). Moreover, the WAVE project hypothesized that applying knowledge through an IE, such as Rippleville, could improve the learning outcomes and further influence behavioral change. The ability to answer our research question lied into the engagement of these adolescents in Rippleville. Firstly, their engagement exposed them to the decision-making process of nutrition and physical activity. Secondly, valuable data was collected to evaluate Rippleville's efficiency. In this paper, we described the strategies we implemented to achieve sufficient engagement from the participants. These strategies cover the immersive model, learning strategies, engagement strategies such as self-identification and self-regulation, and our programming strategy.

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