Designing Pervasive Health Games for Sustainability, Adaptability and Sociability

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ABSTRACT
Active video games (AVG) have become widespread as more physical interfaces are introduced in video games. Lab based studies have indicated that AVGs can increase the amount and intensity of physical activity compared to non-active games and TV, however, the long-term effectiveness of AVGs has yet been established. In fact, most of the existing studies show a reduction of interest and participation over time. This paper presents our findings from a long-term, multi-site deployment of a pervasive health game, the American Horsepower Challenge (AHPC). Similar to previous studies, our findings also show reduced effectiveness of the game, but on a much larger scale. Moreover, we analyze reasons for this and report what kind of game related online and offline activities happened during the deployment. We argue that a shift of evaluation metrics and design goals is required to make real-world sustainable behavior changes. Based on empirical data, we propose three goals for AVGs—sustainability, adaptability and sociability. Behavior-changing games can learn how to achieve these goals from existing game genres, such as alternate reality games, location-based games, family games, and multiplayer online games etc.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors, Design.

Keywords
Pervasive games; Physical activities; Active Video Games; Long-term study.

1. INTRODUCTION
With the rapid development of pervasive interface technology (e.g. sensors, mobile devices, physical interfaces) and the heated discussions on "gamification" [10, 19], we are seeing a surge of interest in serious games that try to persuade players change everyday life behaviors and attitudes [4]. For instance, active video games that take strenuous physical activities as input, have shown initial positive results increasing the amount and intensity of physical activity compared to non-active games and TV [12, 14, 15, 20]. However, most of these studies are performed in a lab environment, where the researchers decide when, how long, and with whom the games are played. In contrast, when deploying AVGs in real world settings, such as the home, where users decide how they play AVGS, researchers found a loss of interest and significantly reduced usage over time in recent studies [16, 17, 21].

This gap between the effectiveness of AVGs in controlled and natural settings urges researchers to rethink the metrics for evaluating AVGs in the real world context. In the lab settings, players' voluntary participation, natural surroundings, and physical/social context of gameplay are missing, all of which have been established to be critical to people's physical activity level and attitude [9, 18, 31, 32]. To take these critical factors into account, we study a real-world, large-scale, and multi-site deployment of a pervasive game for promoting youth physical activities. We propose three dimensions that AVGs need to be measured against and designed for, including *sustainability, adaptability* and *sociability*. We not only present the quantitative difference of physical activities before and during the game deployment, but also to explore what activities and interactions emerge from such gameplay. By doing so, we understand AVG as part of the larger socio-ecological system in which daily routines and environments impact its effectiveness. This perspective is informed by and consistent with the ecological model of health behavior change [33].

Based on the empirical findings along these three dimensions, we provide design implications drawing inspirations and examples from the rich literature of game design and research, including alternate reality games, family games, location-based games, and online game community research. Although these games may not be designed to change health behaviors, they provide valuable lessons toward achieving the goals of sustainability, adaptability and sociability.

2. RELATED WORK
Active video games, as compared to non-active games, require players to move their body rather than simply manipulating a game controller by hands. There are different types of active video games. Console-based active video games often involve a physical interface that can track the real time body movements, such as the *Wii controller, Sony Move, and Microsoft Kinect* commercial systems and academic projects like *SNAP* [35] and *Neverball* [1]. These games are usually played on a fast game console in a fixed location because of computing-intensive tasks. Another category of active games is the pervasive games where players wear portable sensors, such as *Nintendo Pokéwalker*[1],

[1] http://bulbapedia.bulbagarden.net/wiki/Pok%C3%A9walker

FDG '12, May 29-June 1, 2012 Raleigh, NC, USA.

Fitbit [2], so that physical activities can be collected anywhere. Players can check their status on a mobile device or on a computer. This kind of active games is not limited to a preconfigured space, time, or set of activities [23]. In this paper, we focus on the latter kind of AVGs. Because of its pervasive nature, our research on such games has the opportunity to reach the larger scope of a player's everyday environments in which such games are played.

2.1 Studies on AVGs

The goal of studies on AVGs varies among different research communities. In the game research and human-computer interaction community, the game system has been the focus of interest. Researchers have tried to understand how different game design elements impact physical activity levels, such as incentive structures [1], social play [24], difficulty levels [11] etc. However, most of these studies did not discuss how the context of play affect the enjoyment and effectiveness of AVGs, even though some of the studies were conducted in natural settings such as schools and homes.

In the public health community, games are most often treated as a black box, and the focus of interest is on measurable quantitative physiological data changes, such as energy expenditure [2] [12, 14, 15, 20], time of usage [6, 17], and BMI [16, 21]. However, for game designers, it is unclear which game design element leads to what outcome, limiting the possibilities for generating design implications from such studies.

In this paper, our focus is on understanding AVGs as part of the socio-technical system that players are embedded in. We unfold how the game system interplays with existing daily routines, the physical environment and social relationships.

2.2 Ecological Models of Health Behaviors

This paper takes an ecological perspective on AVGs. Instead of treating health behaviors as personal responsibilities, ecological models emphasize the environmental, social, and policy contexts of human behaviors. The multiple levels of influence from intrapersonal, interpersonal, organizational, community, physical environment all impact the health behaviors [32]. Sallis et al. synthesized prior work and created an ecological model specifically for physical activities. It includes four main domains for active living—recreation, transport, occupation, and household. The AVGs fall into the recreational domain. With the pervasive interface and networking technology, AVGs can expand into the other three domains and repurpose some other physical activities as part of the gameplay. In our study, we found this ecological perspective informative especially for the youth population that is going through developmental phases [5]. Recently, researchers have expanded the ecological model to include the technology systems to understand the role of information technology plays in child development [13].

However, this ecological model has not yet been widely adopted in the AVG design and research community. The prevalence of physical interfaces seems to signify the success of AVGs. However, as game researcher Ian Bogost points out, "If exergames don't start wrapping physical activity in credible social experiences, they will become as miserable and forgettable as any session with the exercise bike or the treadmill." [3] Our research is one of the first attempts to situate AVGs research in the larger scope of socio-technical systems that players are embedded in.

[2] http://www.fitbit.com/

Figure 1. A student viewing school status on the AHPC website (left); Pedometers clipped on the shoes (upper right); Wireless station that collects data from pedometers within range (lower right).

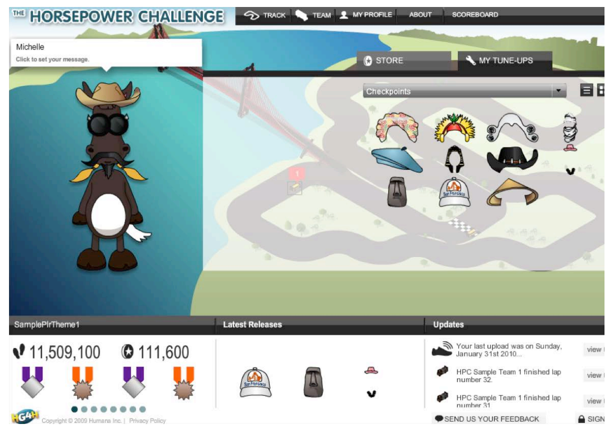

Figure 2. Avatar customization, racetrack in background. Status message bubble appears above the avatar.

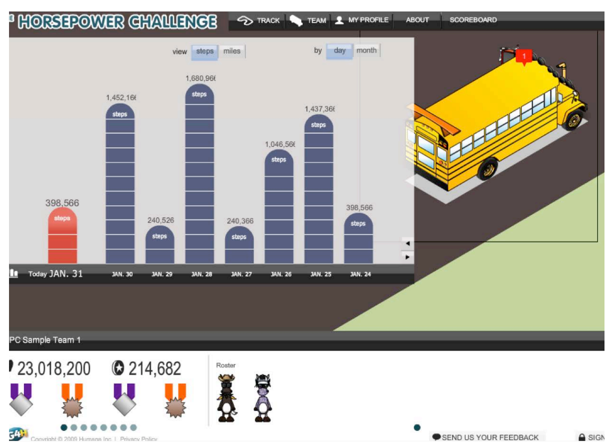

Figure 3. Step counts for the school in one week.

3. THE AMERICAN HORSEPOWER CHALLENGE (AHPC)

To study how pervasive AVGs are adopted in the real world context,, we present our case study of the American Horsepower Challenge (AHPC), a pedometer-based pervasive health game created by Humana's Games for Health and sponsored by The Humana Foundation. The AHPC was a multi-month school-based competition to encourage students to increase their daily physical activity levels both inside and outside of school.

3.1 The AHPC Game

The goal of the game was to win a virtual "race" against other schools participating in the program. Students in the competition wore on-body sensors to collect and feed step count information into a web-based game. When a student participated in physical activities, such as walking and running, he or she earned points for their school. To determine each school's rank in the competition, step counts from all students on a school's team were aggregated daily and the position on the racetrack was updated accordingly.

It is important to note that the AHPC was *not* intended as an intervention to improve body composition but to change physical activity behaviors. As such, the program does not use body composition information as an input for the game, nor did the research team collect body composition measurements at any point during the study. Instead, the game focused on increases in physical activity.

3.1.1 Technical Components

The AHPC has three technical components: a wireless pedometer worn on the shoe to collect step data (Figure 1. top right), a base station in the school to wirelessly collect step data when students were in range of the device (Figure 1. bottom right), and a password-protected website accessible from school or home (Figures 1. left).

On the website, the schools are represented as school buses on racetracks while the students are represented as horse avatars. The avatar is customizable using a virtual currency earned by taking steps throughout the day (Figure 2). When using the website, players can check bus positions in the race, purchase items for their avatars, update their individual status messages, or view graphs depicting their recent step history.

3.1.2 Incentive Structure

The AHPC is designed to motivate players to be physically active on group and personal levels. The following table summarizes:

Table 1. How AHPC motivate participants to be more active

Game mechanics	Goal
School competition	Motivate the students on group level
Point system	Tie physical activity to online activities
Avatar customization	Motivate students to earn more points
Achievement	Notify the students about their progress

3.1.3 Deployment

Before our research group's involvement with the project, the Humana Foundation recruited eligible schools. Public middles schools in US with high participation in the National School Lunch Program, a government-sponsored program offering affordable meals to low-income students, were invited. Schools participate on a voluntary basis. Sixty-one schools participated, with thirty-seven continuing through all phases of the program. The game was deployed in three "heats" between April 2009 and Feb 2010, each heat lasting 4 to 5 weeks. In total, 1,743 students with the age range of 10-13 participated in at least one of the heats of the AHPC. The majority of the schools had 20 participants each. Within individual schools, there were varieties of mechanisms to select participants, such as first-come-first-served (e.g. students who returned permission slips first) or explicit teacher selection from a pool of student volunteers.

4. METHOD

As part of a larger research initiative, our group independently evaluated the AHPC; full details of this evaluation are available in our tech report [20]. Note that our research team did not create the game, recruit schools, choose players, or take responsibility for the upkeep of the game. Nor did we have control over the length of time the game was played or the ways it was distributed to the schools.

We applied a mixed method approach to collect qualitative and quantitative data about the physical activity levels, participants' self-reported behavior and attitude about physical activity, teachers' and parents' feedback of the program, perceived social support for participating in the challenge, demographic information, and neighborhood characteristics. In total, 577 students (33%), 380 parents (22%) and 19 teachers (51%) responded to our surveys. We also gathered website usage and pedometer log data from each child to supplement self- reports. In total, we examined 14 weeks of individual and aggregate data from two school years. To understand the day-to-day interactions related to the AHPC, members of our research team also visited 15 schools participating in the AHPC, speaking with over 200 students and teachers. The profile of the 15 schools we visited was representative of the overall group socioeconomically (71.8% of students receive free or reduced lunch), demographically (male-female ratio=1.03, similar ethnic makeup), and regionally (covering 8 states and a mix of rural/suburban/small town/city schools). At each school, we conducted a student-only focus group, teacher interviews, and individual student interviews and wrote field notes with observations of interest. We analyzed these data using an iterative, inductive qualitative analysis approach in which all members of the research team worked to achieve consensus.

5. FINDINGS

Through our observation and interview with multiple sites and the game log and self-reported feedback about the participation of the AHPC, the following three dimensions stand out. Compared to existing studies with AVGs, these three aspects are not directly related to the psychological outcomes of AVGs, but the ecological environment in which these games are deployed.

5.1 Sustainability

It is challenging to sustain behavior changes. As pointed out by the Prochaskas, the authors of the transtheoretical model of behavior changes, "change is a process that occurs over an extended period of time, often imperceptibly, sometimes disruptively" [28]. Although a few studies have pointed out the problem with long-term usage of AVGs, such as boredom, reduced frequency and duration of gameplay [16, 17, 21], more research need to be devoted to understand why such problems happen and how to deal with it in the design. Moreover, most of the existing studies were conducted in home environment only with a relatively small sample size (under 50).

5.1.1 Reduced Effectiveness over Time

We find reduced effectiveness from the large sample size, multi-site deployment AHPC, over the course of 11 months. Moreover, compared to prior work, we collected players' physical activity level in different locations, including school and home environments rather than a fixed single location, such as homes or lab environments only. As shown in Table 2, the overall effectiveness of the AHPC dropped over three heats, when compared to the one-week baseline data we collected prior to the deployments of the AHPC. For the 89 longitudinal participants who started from the very beginning and stayed for all three heats, their average daily step count in the third heat has dropped below the baseline ($t(88) = 4.57$, $p < .001$) (see table 1). The interpretation of this data is further explained in the next section.

Table 2. Pairwise comparison between the daily average number of steps logged during the pre-game baseline period and each of the three heats, for all participants participating in each period (all participants; using Tukey's HSD) and for a subset of students who participated in all four periods (longitudinal participants; using repeated measures t-tests).

All participants	**Mean difference**	**Standard error**	**Significance**
Baseline – Heat 1	-1400.03	62.43	$p < .001$
Baseline – Heat 2	-809.43	68.62	$p <.001$
Baseline – Heat 3	-315.57	69.78	$p <.001$
Longitudinal participants	**Repeated measures t-test**		
Baseline – Heat 1	$t(88) = -5.72$		$p < .001$
Baseline – Heat 2	$t(88) = -2.01$		$p = .048$
Baseline – Heat 3	$t(88) = 4.57$		$p < .001$

5.1.2 Reasons

Based on survey feedbacks and our site visits, we find several reasons why effectiveness of the AHPC reduced, including reduced interest in the online interactions, technical glitches, schedule mismatch, and weather change.

During the focus group, the students themselves expressed their boredom with interactions on the AHPC website. Customizing horse avatars had become less interesting over time due to the limited options. By the end, the students mostly used the website for checking their personal and school step counts. Our analysis on the game log data also showed that there was a significant positive correlation between the number of times students logged onto the AHPC website and the step count ($r = .49$, $p < .001$). This indicates that the students who logged onto the AHPC website more often tended to have more steps, suggesting that interest in online game is related to the amount of offline physical activities.

In the teacher survey (19 responses), teachers also confirmed the observation that the students reduced interest over time. Thirteen (68%) agreed with the statement "the students were very excited to participate when first starting the Challenge", but the majority also agreed that the excitement faded out over time (75%). Teachers gave a few reasons that may lead to reduction of participation and interest, including technical glitches (malfunctioning pedometers), schedule mismatch between teachers and students, and weather changing to be cold and rainy.

In summary, analysis on step count log, combined with teacher and student feedback, shows that although AHPC did increase the step count of the students, its effectiveness reduced over time, especially for the students who participated for a long time. The reasons include factors within the design scope of a serious game, such as sustaining interest in online games and technical robustness, and also factors beyond the control of the game itself, such as weather or school schedule changes each semester.

5.2 Adaptability

Bogost critiqued the model for current design of active video games, such as Wii games, for not considering incorporation into everyday life rituals; instead, the majority of games aim to maximize performance and minimize time (the same model as going to the gym) [3]. However, with a few exceptions, most of the studies on AVGs do not take into account the physical and social environment, the ability of a game to adapt to the routines, home and school environments, unequal resource availabilities. We had the opportunity to hear stories from different schools and their teachers and students, about how they adapted the AHPC into their everyday routines of PE and non-PE classes, repurposing other activities, and in resource scarce environments.

5.2.1 User-Defined Game Activity

With the pervasive interface of the AHPC (wearable pedometers and web-based games), the physical activities that participants have done as part of the gameplay are highly varied, including walking the dog, shopping with their family, running laps with classmates, and doing chores around the house. Many of these actions were not normally taken as exercise, but the AHPC gave the students a lens to rethink their daily activities as ways of getting points for the Challenge. The following example showed the effect of this lens:

> *"I felt kind of weird because when I would walk somewhere I would think I'd get steps. 'Cause I would think I was still in school and I'd walk somewhere. Like I'd go to see my grandma and I'd walk there and think, 'Oh, I'm just gonna go to school, scan my foot steps and I realized I didn't have my pedometer on."*

In this example, the boy described his experience during the winter break when the AHPC was not being played and the pedometers were kept in school. He kept the habit of viewing the activity ("walk to see his grandma") as points, even without wearing the pedometer.

This change also affected the social group around the students. Below is an example showing how parents persuaded their children to do certain things by reminding them about the AHPC.

> *"Sometimes my mom's like, 'Come shopping with me. If you walk around the stores for like three hours then you can get more steps.' So we're just walking around the stores, just stop and shop for three hours."*

The girl also told us that she did not like shopping herself, but she was still persuaded by her mom to do this activity because of the AHPC. These activities mentioned above were not purposed for health promotion. But through the lens of the AHPC, the students repurposed them as part of the gameplay, therefore having more physical activities as a result.

5.2.2 Integrated Into Daily Routine

Besides the efforts from students, teachers also tried to incorporate the AHPC into their regular school schedule. The flexible and loose structure of the game was creatively integrated into the relatively rigid daily schedule of the middle school students.

For example, in school L (anonymized), we observed that the PE teacher embedded an AHPC ritual into their PE seminar everyday—the whole class (including the AHPC and non-AHPC participants) checked the steps and rank of the school on a projected display. They cheered together if the rank increased. At the same time, the AHPC students walked in circles within the classroom to use every minute to get more steps.

In school A, the math teacher took 20 minutes from her one and half an hour-long class, and brought her students to the gym, where she obtained extra access time because she and the PE teacher had a good partnership. Her students taped the worksheet on the gym wall, and mixed running, rope jumping, and solving math problems together. At the end of the exercise, those who got their worksheet done correctly received applause from the class.

In above examples, the teachers took the initiatives to integrate the AHPC into their educational agendas. More discussions about how the AHPC is adapted into middle school environments can be found in [27].

5.2.3 *Adapted to the Locations*

The schools involved in the AHPC were distributed in 14 states in US, introducing a great variety of historical and geological differences. In school S, the teacher and students were all excited to share with us their experience of walking as soldiers in the civil war in one of their history classes and gained a lot of steps for their school in the AHPC. Below are the quotes from the teacher interview:

> *"It was – that last quarter mile, they were being – we were reenacting Pickett's Charge and they were being shot at. So, of course, not really, but they were imagining it, 'cause we've been studying the Battle of Gettysburg. So, that last lap, our field is a quarter mile, the last lap, they were so cute, they'd like fall down and then, they'd get up, but they'd be wounded and so, they'd be dragging. It was – I should have videotaped that. It was very cute… But we put on – everybody put on a mile that day… Yeah, the kids were looking at their steps and said, oh, that's the day we went outside."*

This teacher creatively merged the educational goal of civil war history and the AHPC. She led the students to role-play the scene from an important event they learned in class, gained more steps for the AHPC, and created a good memory for the group to share. This example is inspiring, since it combined location, history, physical activities, education, role-playing, having fun, all together.

In summary, in this section we introduced the creative ways that the health game of the AHPC is adapted to the students' everyday life and physical environments. This kind of "productive play"—creative production for its own sake rather than for hire [26], generates solutions and experience of adapting AVGs to a resource-scarce environment. Many game examples along this line, such as location-based games, alternate reality games, have shown the value of adaptability of games, in the next sections we discuss how active video games can learn from them.

5.3 Sociability

The direct and indirect social context influences health behavior and outcomes significantly. In the famous Framingham Heart Study that collected 32 years of biometric data, researchers found that obesity is "contagious" and spread across the social network [7]. In Mueller's framework for exertion games, sociability, exertion and engagement are supporting and reinforcing each other [25]. In our research with the AHPC, we found that the game involved more social participation and interaction than what it was initially designed for. In the following section, we focus on the social interactions between the players and their teachers, and the interactions with the remote players. Neither of these was directly supported by the AHPC. The discussion about the social interactions and play among the participants in the same group is discussed in related work [37].

5.3.1 *Teacher's Participation—from Peripheral to Central*

In the schools where AHPC was deployed, the students participated on a voluntary basis, but only 20 students in total could participate. The social cohorts of the participants, such as their peers, teachers, parents, and siblings, also played different roles. Among these participants, teacher's role stood out as being more significant than what was expected in the AHPC design. Comparatively, parents were not as actively involved.

Initially, the teachers' role in the AHPC game was just as a facilitator (more information about how the teachers support the AHPC to run properly can be found in [22]). In the current interaction, the teachers can use their online account in a more administrative role, such as helping the students to setup their passwords and changing the look of the school's online avatar (a school bus). However, it turned out that most of the teachers played a more active role in the AHPC—they helped to find more resources for exercises, organized group activities, and changed the student's daily routines after the AHPC started.

However, during the three semesters of the AHPC deployment, many of the original teachers involved with AHPC moved on to teaching other classes and no longer taught the participating students. Without the shared schedule, it is hard for the teachers to organize activities or find time for the students to exercise more. This was consistently mentioned in the teacher survey, and this mismatch between teacher and students schedules was what many teachers believed to be a major reason why students lost interest over time.

Comparatively, the participants reported that their parents' role was mostly to remind them to wear pedometers. To triangulate this feedback, we also found that participant's physical activity level in weekends when they were off school was not increased in any of the three heats statistically. Although the students could wear the pedometer at school or home, during weekdays and weekends, the effectiveness of the AHPC was limited by how it was introduced. The fact that the AHPC was introduced at school rather than in the homes seems to have a strong effect on the involvement of participants' social cohorts' involvement and the locations where the participating children change their behaviors.

5.3.2 *Rivalry towards Remote Competitors*

The primary competition structure of the AHPC was the competition among remote teams. The computer-mediated environments, social representations, and perceived audience created the sense of believability necessary for fostering a competitive spirit. On one hand, the competitive design increased the motivation to get more steps. In our focus groups and interviews, students reported that they tended to keep track of the steps of the competitors whose step counts were close to theirs or from the same geographical area. On the other hand, we found that there often existed rivalry between different schools, especially those in the same district or having similar rankings. Sometimes this rivalry became over-competitive and less constructive. Some students blamed other schools cheating because they themselves did not get more steps. When the students did encounter competitors from other schools in real life, they took the competitiveness in the game to real life. In the following example, the students we had a focus group with first commented on how mean the other AHPC school's students were to them during a district sport tournament. Then one of the students said,

> *"This year, me and XX – we found XXXX (another school in the AHPC)' pedometer. And then we kept it till, like, the end of the game. And then we gave it back. We were like, 'Here you go.'"*

As part of the game, these actions are understandable. But as part of the intervention program, the rivalry may hurt the effectiveness of AVGs. Winning the game become a more dominant goal rather than getting more physical activities. Because the game is structured to be competitive between the schools, the students did not realize that they share the same goals with their remote competitors in other schools, which is simplified and quantified as numbers on the AHPC web page.

6. DESIGN IMPLICATIONS

With the empirical findings we have, we call for more design and evaluation metrics that shifts from intensity and amount of the physical activities, to the sustainability, adaptability and sociality of the AVGs. Existing games genres and game research have provided a rich pool of literature for us to learn from, such as alternate reality games, location-based games, family games, multiplayer online games and their communities etc. We are going to discuss the design inspirations that these games can give to the AVGs that target to change players' physical activity behaviors.

6.1 Sustaining Long-term Interest

Our study with the AHPC suggests the lack of sustaining interesting in the online interactions to be related to the reduced amount of the off-screen physical activities. In this section, we visit a few games that successfully sustain players' long-term interest by tracking and responding player's change of play activities and context. We discuss these games for the goal of long-term health behavior change.

6.1.1 Tracking and Responding to Player Physical Activities

With the AHPC and many other off-shelf AVGs, the reduction of player interest and usage has not been explicitly designed for in the game. But these games have the ability to keep track of player physical activities.

Other pedometer-based health promotion hardware and software, such as *FitBit* and *Jawbone Up*[3], have put more emphasis on the data analysis and information visualization that remind players of the fluctuation of their physical activity levels over time, and the difference between the pre-set goal and actual activity. AVGs need to design for the tracking and responding to player's physical activities, not only using charts and numbers, but also integrating them into the gameplay.

Social network games such as Farmville give a new model of data-centric game design. Instead of designers deciding what players may want, in most of the Zynga games for social network users, the logged data was collected and analyzed in real time to provide new design directions [36]. For example, Zynga does hundreds of comparative tests on virtual goods. The design that gets more clicks and purchase will be chosen.

For significant behavior change, a user may need to go through multiple phases of precontemplation, contemplation, preparation, action, and maintenance, as proposed in the transtheoretical model [28]. It is important that the AVGs are able to detect different phases, especially when players appear to lose their interest after the initial novelty effect of the game runs out.

6.2 Adapting to the Players' Everyday Life

The AHPC was deployed in schools with a high percentage of free or reduced lunch programs. The socio-economics status and the school funding for physical education were not sufficient in many of these cases. Yet, we have seen and heard a great variety of ways that teachers and students creatively adapted the AHPC into their school life. The AHPC had high flexibility and openness, which enabled it to be adapted to the resource differences and rigid schedules. From the empirical examples where students and teachers have tried to adopt the AHPC into their everyday life, we have seen the needs to design for the adaptability of health games.

6.2.1 Encouraging User-Defined Activities

In the AHPC, we have seen that players changed their views about their daily activities. Small actions, such as walking up stairs instead of taking an elevator, are easy to change and can make a difference with persistence. This kind of physical activity, referred to as opportunistic physical activities [8], can be easily integrated in players' everyday life. In the AHPC, the pervasive interfaces of pedometers and online website allow this kind of opportunistic physical activity to happen anywhere and anytime, and to be collected and measured by the game in real-time.

However, in the current game design of the AHPC, all activities are simplified to numbers. There is no record of what activity the student performed to get more steps. For example, the activities that players have creatively thought of themselves and tried out did not get captured in the game itself. Nor could the meaningful choices participants made between different physical activities.

To encourage users to create, explore and choose their own activities, designers can learn from successful examples, such as the alternate reality game *Chore Wars*[4]. This is a game for people who share a household to define and choose the household chores, and then get experience points from doing the chores over time. This game repurposes chores into character leveling up activities, turning the repetitive work into progressive play. It also leaves players great flexibility to decide and negotiate the activities that count as game-related activities, which are then tracked via the website. Players can dramatize the chores by creatively writing about them. When players have the freedom to make meaningful choices of the chores, the voluntary participation makes chores more enjoyable [18]. In this case, players complete "secondary designs" [30] based on their specific environment, conventions, resources, and social relationships.

In summary, to make the user-defined physical activities more enjoyable, we need to support the process of players defining, negotiating, documenting, and making meaningful choices of physical activities that naturally occur in their everyday life.

6.2.2 Adapting the Game to Meaningful Locations

Physical activities happen in the environments that are safe and easy to access to the participants [29]. Moreover, these locations provide a stage where gameplay happens, and players can take advantage of the landscape or arrangement of the space to customize their game activities accordingly. In the AHPC, we have seen examples where teachers engage students in both

[3] http://jawbone.com/ups

[4] http://www.chorewars.com/

physical activity and learning by introducing location-specific role-playing. Pervasive AVGs have the potential of adapting the game to the specific location and occasion to engage the players.

In location-based games, the content and challenges in the games are customized to the place where participants live. For example, in the location-based team-building game, *The Go Game*[5], the designers customize the puzzles and challenges of the game based on the specific city in which it is deployed. Often it includes landmark architecture and historical sites of that city so players can recognize and solve the puzzles. Players need to run around between multiple locations to complete the whole game.

We can combine this design suggestion with the user-defined activity design, so that players can define their own location-based challenges. These challenges can be recorded, announced and shared on the website of pervasive health games.

6.3 Remote and Co-located Play Community

6.3.1 Incorporating Social Support

In the AHPC, we found that the teachers play a critical role in the game. Rather than just facilitating the game to run properly, they organized game-related activities, found resources and time to fit in more physical activities, and motivated the students to be more active. This emergent role of teachers shows the importance of engaging the target group's social cohorts to support their behavior change, especially for the schoolchildren who have less agency to change their own schedule or environment.

Designing for different demographics in one game is not a strange task for game designers. Schell revealed the design thinking and iterations for the family game *Pirates of Caribbean* [34]. To actively engage both parents and their children, game designers created different roles and multiple categories of tasks based on the kind of gameplay that different demographics might enjoy. Similarly, our findings show that the active participants for the AHPC include children and adults, which are not limited to the group that the game was originally designed for. We have seen that teachers played a proactive role in the AHPC, a game deployed at school with no initial intention of including teachers as players but only as facilitators. Considering different ways that teachers have used to motivate the kids, we can design multiple role-playing choices for teachers, such as captain, cheerleader, and bus drivers etc. By recording and representing teachers' effort online, they can enjoy the game more, and feel like being part of the team. This kind of online representation is important since the teachers may not always stay with the same group of students following the change of school semesters. This way they can keep their online relationships with these students even if they don't teach them any more.

6.3.2 Sharing with Online Play Community

In our study with the AHPC, we found rivalry among schools in the competitive game structure. But competitions are not the only way to motivate the schoolchildren to be more active. With the same goal of defeating sedentary life style, they can also play collaboratively by sharing their constructive, productive and creative activities with each other to become inspired. Sharing and evolving these practices will be meaningful, especially in the settings of resource scarce schools.

In alternate reality games, such as *World Without Oil*[6] or *Evoke*[7], the game raised fictional scenarios about tough real world problems, such as energy, hunger, and war; players created and shared their solutions by text, pictures, and videos through the Internet. Here, player-generated contents are critical for the enjoyment of the game. Players post their stories in the form of pictures, videos, comics, narratives etc., and other people can be inspired by their story and even build on top of them.

We find that this kind of collaborative play has not been paid enough attention when designing active video games. One possible mental block is that people associate physical activities closely with sports. The sports that get broadcast the most are national and international competitions, such as tournaments. We propose that AVGs need to broaden the game design to other types of social games, such as cooperative and collaborative games. A game can also be designed to combine competition and cooperation. For example, in the board game *Settler's of Catan*, players can strategically choose to collaborate with or compete against other players depending on their status. This collaborative and cooperative gameplay needs to be explored in AVGs.

7. CONCLUSION

The contributions of this paper are two-fold from both the evaluation and design perspective. Through the large-scale, multi-site, and long-term deployment of the pervasive health game of the AHPC, we identified several challenges along the dimensions of sustainability, adaptability and sociability. These dimensions are also informed by the ecological model of health behaviors, which takes serious game as part of larger socio-ecological system. As the active video games become more prevalent to a larger audience, we believe that studies with ecological perspective is timely and well-needed for making AVGs more enjoyable and effective in real world settings. Based on our empirical findings, this paper also gives concrete design suggestions. We learn from the rich literature of game design with a wide spectrum of game genres and target audience, to fulfill the goals of enhancing the sustainability, adaptability and sociability of AVGs.

8. ACKNOWLEDGEMENTS

We are deeply appreciative to Humana Games for Health and the Humana Foundation for their guidance and support. We would also like to thank the students, teachers, and parents who took our surveys, participated in focus groups and interviews and welcomed us into their schools.

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