Gemini: A Pervasive Accumulated Context Exergame

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Abstract. Exergames encourage physical activity, but generally require specialized hardware and prescribed activities; whereas pervasive accumulated context exergames (PACEs) allow players to choose their type of exercise, but have limited depth of play. For mass commercialization of PACEs, facilitating long-term behavioural change, we propose two requirements: that PACEs support large-scale and flexible deployment; and that the design of PACEs support staying power through long-term playability. From these requirements, we motivate six PACE design principles and use these principles to develop a multiplayer roleplaying PACE. Results from a week-long study of our game showed that by satisfying the six design principles, we can create a PACE with scalability and staying power. Our results are the first step toward creating PACEs that promotes long-term game engagement, which is needed for activity-related behaviour change.

Keywords: exergame, pervasive game, activity sensing, accumulated context.

1 Introduction

Obesity rates are on the rise, due in part to recent decreases in physical activity [1]. This decreasing trend of physical activity is particularly salient for college-aged adults in the 18-24 year-old age range, who spend significant amounts of time engaged in sedentary leisure activities such as watching television and playing video games [1] and have the sharpest increase in subscriptions to massively multiplayer online (MMO) games like World of Warcraft [2].

Given that 68% of American households play video or computer games [3], the negative potential impact of digital play on physical activity is clear. To address the lack of physical activity, game designers and researchers have created exergames – video games that use exertion as part of the activity required to play [4]. Exergames have been shown to be effective in getting players to exercise, and to be more fun than a corresponding level of standard exercise [5]. Although exergames can promote physical activity, these games often use specialized hardware, prescribe that users engage in a specific type of exercise, and require a dedicated time and space for play [6,7,8,9,10,11]. While these systems can provide immediate exercise benefits, the associated games are often simple systems that may not hold a player's interest long enough to create positive activity-related behavioural changes.

To address these shortcomings, researchers have proposed exergames that continually accumulate player activity levels through pervasive sensing, and incorporate these levels into subsequent game play. Although these previous systems have successfully dealt with the issues of specialized hardware, specificity of exercise, and particular play time, they are linked to simple games that do not have the potential to engage players in the same way as popular commercial titles such as World of Warcraft. Without sufficient engagement with the game, players will not commit to playing for long enough to support effectual changes to physical activity.

In a pervasive accumulated-context exergame (PACEs) the collection of activity occurs continuously in the background, and play occurs in a traditional digital game. Activity impacts the game at the beginning of each play session, instead of altering the game during play. While researchers have investigated preliminary properties and effects of PACEs [12,13,14], they did not consider commercially viability. To create PACEs that will be appropriate for mass commercialization, engendering long-term behavioural change, we propose two primary requirements: 1) that PACEs support large-scale and flexible deployment; and 2) that the design of PACEs support staying power through long-term playability.

Because the digital portion of a PACE must function as a stand-alone game, standard game design principles apply. We describe additional design principles here to highlight those game design components most tightly coupled with accumulated activity. Based on the two requirements above, and drawing from well-known design principles [15], we identified six design principles for commercial-grade PACEs:

1.1 Unobtrusive pervasive activity monitoring
1.2 No expensive or specialized hardware
1.3 Flexibility in choice and time of exercise so that exercise is integrated with life
2.1 Integration of exercise with dramatic elements of the game
2.2 Limited imposition on preferred play style
2.3 Replayability through complexity of the objectives and sources of conflict

Using these six design principles, we created a multiplayer role-playing PACE called Gemini. Our game measures activity levels pervasively via sensor motes (as stand-ins for sensor-enabled smartphones) to conform to requirement one, and has a sophisticated game design to support requirement two. Through analysis of a week-long series of play sessions with a single group of players, we evaluated the design of Gemini, the resulting engagement of players, and the process of accumulating activity levels pervasively. We found that Gemini was compelling, contained enough strategic depth to maintain player interest, and that our approach to pervasive activity sensing was effective. We also find that while players see the collection of activity as part of the overall game experience, they cannot articulate the ludological role it has within the game. Our results are the first step toward creating PACEs that promote long-term game engagement, which is necessary for eventual activity-related behaviour change.

2 Related Work

Many initial exergame systems use specialized sensors to promote physical activity. The exergame research community grew in earnest after the publication of Mueller et al.'s Breakout for Two – a breakout-based distributed and competitive game using a soccer ball and a custom-built sensor wall [4]. Mueller's group continued to produce exergames using custom sensors including the mat in Remote Impact [6], the table in Table Tennis for Three [7], and the force input device in Push and Pull [4]. Custom sensors were also used in Nautilus – a large-screen projection game played on pressure-sensitive floor [8] and Kick Ass Kung Fu – a large-screen projection martial arts game played using free body movement sensed using cameras [9]. Alternatively, stationary bikes were used as input in Life is a Village [10] and Virku [11].

Although these games all promote physical activity, they require specialized hardware. In addition, they specify what type of activity is to be performed. We argue that for large-scale commercial deployment of exergames, the hardware must be inexpensive and the type of exercise performed needs to be flexible. One solution is to create a middleware layer that allows for many types of input to be used in the exergame, which was demonstrated by Brehmer et al., in their GAIM toolkit [16]. An alternative to specialized hardware is to use cheap and available sensing devices, such as heart-rate monitors, as the measurement of exercise in a game.

Heart-rate has been used as an exergame input to directly control player characters and indirectly control game elements. In TripleBeat, joggers are rewarded during a run with high scores for maintaining an appropriate target heart rate [17]. In Nenonen et al.'s biathlon game, heart rate was used to control the speed of the skier during the race portion and the steadiness of the aim during the shooting portion [18]. Indirect use of heart rate in a game includes Masuko and Hoshino's boxing game, where content is adjusted to keep the player in their target heart rate zone [19], and Buttussi et al.'s use of heart rate to adjust game difficulty in two sample games [20]. To deal with heart rate control issues including lag and age-related differences, Stach et al., created a formula to differentially map heart rate to in-game speed in a racing game called Heart Burn [21]. Although these heart-rate-based games may not require specialized hardware or specify activity, they do require that users exercise during a dedicated play time. Activity sensing and play occur simultaneously, so although users get fit through play, they do not learn to integrate exercise into their lives. To encourage people to exercise, but reward them using exergame design, some researchers have instrumented users with sensors and used the sensed activity levels as input to a game.

The closest analogues to PACEs in the literature and industry are pervasive fitness games. Neat-o-games used accumulated activity to change the base speed of the player's avatar in a simple racing game [12]. Because of the simplicity of the game Neat-o is closer to a visualization tool like Ubifit Garden [22] than a PACE. Neverball uses cumulative activity to modify the speed of an avatar and the duration of a game [14]; however, the accumulation of activity only takes place while playing the game. Persuasive RTChess used accumulated activity gathered via sensing mote to change the speed and power (attack and defense) of chess pieces in a real-time networked multiplayer chess game [13]; however, the game suffered from poor activity-game mappings, and lacked the needed strategic depth to maintain player interest.

Two commercial games have started to explore the PACE space: Pokewalker and 4square. Pokewalker allows players to accumulate a virtual currency within the Pokemon games. The core mechanic of game play does not change from previous versions, but the superior Pokewalkers have an advantage over their peers. In 4square, players report their positions to a central server to earn badges. While not designed as an exergame, 4square could potentially encourage people to get out more.

The two commercial games have demonstrated the requirements for a broadly deployed PACE. Pokewalker uses an inexpensive pedometer to monitor players' activity and 4square is entirely a software entity that runs on players' smartphones, echoing our contention for the use of simple hardware platforms (design principles 1.1-1.3). No existing PACE games utilize game design to leverage scaffolding, likely contributing to their poor adoption compared to MMOs or popular social media sites.

3 Experimental Setup

To explore the design of RPG-based PACEs (RP-PACE), we designed, implemented, and tested a game that collects and accumulates players' activity levels pervasively and incorporates them into a multiplayer RPG.

3.1 Pervasive Activity and Context Sensing

Activity was measured in both studies using a MicaZ wireless base (commonly called a mote) with an MTS310 sensor board containing accelerometers, light, and temperature sensors. The motes communicated wirelessly (using the Zigbee protocol) with base stations placed strategically throughout the work areas of the participants. Data was logged and either opportunistically or manually downloaded through a base station to a central server. Our mote approximates the capabilities of a modern smartphone with built in accelerometers, camera and Bluetooth. Although we implemented the study on more specialized hardware based on availability, our implementation is directly portable to increasingly-common consumer devices, thus satisfying design principle 1.2. Players wore the motes anywhere on their person by attaching the motes with a Velcro strap. In this way, our technology was designed to be unobtrusive, supporting design principle 1.1.

While any contextual measurement such as position, social situation, or even local weather conditions could be used as input to a PACE, our game uses accumulated activity level as the primary player context because it is an obvious component of an accumulated context exergame designed to promote physical fitness. We adopted a broad definition of activity. Participants were considered active if the variance of their acceleration over a given time window was higher than a pre-defined threshold. We used additional sensors to characterize the players' activity for integration into the RPG. Light and temperature data was used to determine whether people were indoors or outdoors. Wireless packets passing between two motes were used to determine whether other players were nearby (within 10 m).

Because activity and context are continuously monitored in the background, players can schedule activity whenever they desire, explicitly satisfying design guideline 1.3, and providing compliance with the requirement that PACEs support large-scale deployments. To ensure that this monitoring results in long-term behavior change we must also account for the playability of the digital game portion.

3.2 Game Description

We implemented a multiplayer online roleplaying game (RPG) using the Neverwinter Nights 2 (NWN2) Aurora toolset. Leveraging the Electron toolset and NWN2 graphics and game systems provided us with a compelling experience based on the canonical and well-balanced Dungeons and Dragons rule set. We felt that integrating activity into gameplay using an RPG would allow us to create believable mappings that integrated with the formal and dramatic elements of the game, thus supporting design principle 2.1. Additionally, our design allowed us to leverage the compelling social and competitive elements of commercial MMOs, which provided a different platform from the toy examples in section 2, and supported design principle 2.3.

In the game, players were told that they have been condemned to a kind of purgatory, where their soul has been split into two. The primary soul portion, vested in the player-created PC avatar, is anchored to the purgatory in which they currently find themselves. A smaller portion of their subconscious remains linked to their physical form and manifests as an animal companion. Their opponents from the war that led to their condemnation are also in purgatory, but only one faction can escape.

In keeping with design principle 2.2, we designed the game to cater to all of the major MMO player types as described by Bartle [23], and further by Yee [2]. The game play is focused on team-based PvP combat, providing desirable experiences for Socializers and Killers. The game scope and size is significantly larger than the exergames described in section 2 and provide a suitable outlet for Explorers. The mix of play and capacity to build the primary character, animal companion and compete in the PvP portion provides a mechanism for Achievers to interact with the game. The playable zones in our implementation are shown in Fig. 1.

Base Zones and PVE Zones. Players spawned into the base zones when they joined a game, when they were killed and when they were removed from the temple at the end of a temple round. The base zones contained an NPC vendor and a second NPC who provided teleportation service to a point near a tower in the center zone, if the tower was under faction control (dashed lines in Fig. 1). While all zones permitted player versus player (PvP) play, the green zones (1-4) were designed for simple player versus environment (PvE) play. Monsters respawned every few seconds within these zones, providing an opportunity for players to level their primary characters through combat. Zones 3 and 4 provided low-level monsters, while zones 1 and 2 provided more challenging opponents. The intention of providing both PvP and PvE areas was to support multiple play styles and satisfy design guideline 2.2.

Player Versus Player (PVP) Zones. PvP play was added to the game for two reasons: first to provide competitive incentive for players who prefer team competition; and second, to provide a source of immediate conflict to make the game more compelling. However, simply adding PvP mechanics is not enough to satisfy our two requirements. Support for individual playstyles and long-term replayability is needed. Finally, a mechanism that allows activity to affect the game, while not creating a dominant strategy [15] or dictating playstyle [15] is required. We achieved these multiple design objectives by subdividing the PvP into zones. The center zone

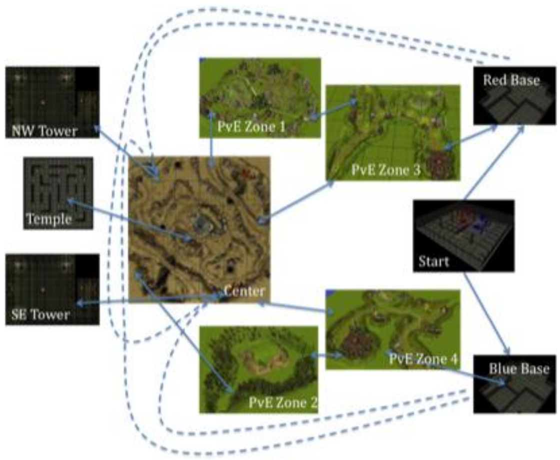

Fig. 1. Zone Configuration. Arrows denote persistent (*solid*) or contingent (*dashed*) transitions

(beige) was the primary PvP zone. While the zone itself did not have any intrinsic value, it contained the access to both tower zones and the temple zone, which were crucial to the PvP game.

Each tower zone contained four switches and a vendor. A team that had all three perimeter switches simultaneously thrown to their team's colors (either red or blue) controlled the tower. The center switch caused all opponents in the zone to be paralyzed for six seconds, with a one-minute cooldown. Controlling a tower provided a bonus to the score in the temple domination minigame, provided access to more powerful items, and allowed for teleportation from the base zone to the central zone.

Battles within the temple generated team points. Players did not control their character avatar within the temple; instead, they controlled their animal companion. Player-controlled animal companions competed in a team Bomberman-style minigame. Animal companions were given three different bomb types that damaged, slowed down, or decreased the resistance of their enemies. Points were scored by hitting or killing an enemy, possessing a tower, and for being in the temple; points were lost by hitting yourself or a teammate. The first team to reach 700 points, or the team with the highest score when time elapsed won the game. Winning the most rounds of the temple game ensured your team's escape from purgatory, making contesting the temple the primary PvP activity.

The Animal Companion/Daemon. The animal companion (or daemon) did not gain levels through traditional RPG in-game activities; instead, it leveled through the measured real-world activities of the players, mapped onto the existing NWN2 class system. All daemons were triple-classed characters with levels in the Barbarian, Monk, and Bard classes. Different types of activity leveled the daemon classes as shown in Table 1, as well as the damage from and resistance to different bomb types in the temple minigame. Daemon leveling was artificially linearized because, in traditional D&D rules, geometrically more experience points are required to achieve the next level. While additional effort should be required to gain each daemon's level, players cannot be expected to maintain geometric growth in their physical activity.

Table 1: Activity context to daemon ability mappings

Activity	Class	Bomb/Effect	Bomb Resisted
Outside	Barbarian	Fire/Damage	Magic
Inside	Monk	Frost/Slow	Fire
With Other Player	Bard	Magic/Decreased Resistance	Frost

The daemon is meant to aid the player without dictating their play style. In PvE play, the daemon is a versatile computer-controlled companion who can provide either direct combat enhancement through barbarian and monk classes or support through the bard class. In tower PvP play, the daemon is primarily a target to be defended and a combat assistant. Finally, daemons are an integral part of the temple minigame where they are directly controlled by the players. The design of the daemon-activity interaction satisfies all the design guidelines for both primary requirements for PACEs. Activity is monitored cumulatively and continuously in the background using mobile sensors (1.1, 1.2, 1.3), and is mapped to a secondary character that plays a central but optional role tied directly to the game narrative and strategy (2.1) in multiple ways (2.3), while still allowing players to determine the playstyle for their primary character (2.2).

3.3 Game Evaluation and Player Demographics

The study lasted five days and involved eight participants (male, aged 19 to 24). On each day of the study, participants met at 4:00pm for an hour to play our game. Players were divided into two teams of four for the duration of the experiment. The temple domination game was only active during scheduled sessions, but players could log into the computers at any time to level their characters in the PvE zones. The first day was primarily tutorial on the game and background on the activity mappings.

After each session, the players were interviewed as a group. On the last day of the study, we carried out an extended group interview, and users completed an online survey. All participants used computers for more than two hours per day, played video games at least weekly, and had little or no experience with NWN2.

4 Results

The proof-of-concept system described above was used to evaluate the efficacy of our design principles (DP). The principles we derived were meant to satisfy the two additional requirements we identified for PACEs: that they be mass-market friendly, and that they support long-term play to facilitate scaffolding. This section presents initial evidence that the design principles can be leveraged to create a viable PACE.

4.1 Mass Market Capacity

To determine whether the game concept has mass-market potential, we asked players to rate how much fun the game was and how much fun having the daemon was on a 5-point scale (strongly agree to strongly disagree). Players generally responded positively (1-Srongly Agree (SA), 7-Agree (A)) in response to the questions "The game was fun to play" and "Having both the daemon and my character in the game was fun" (1-SA, 6-A, 1-Neutral(N)). In player interviews it was revealed that a player's role was determined by their skill as a player (e.g., combat expertise guarded the tower) and by the skill of their animal companion (e.g., most active player fighting in the temple). We also wanted to determine whether players entered a flow state, indicating an optimal balance between skill of the participant and challenge of the activity [24]. Using the flow state scale [25], we determined that users were significantly above the flow threshold (one-sample t_7=4.7, p=.001).

To determine the potential of the mote as a proxy for a smartphone-based activity sensor, we asked players if they were "comfortable wearing the mote" (1-SA, 4-A, 3-N), and if the "mote interfered with their daily activities" (1-A, 3-N, 4-disagree (D)). These findings indicate that players were comfortable wearing the mote and having it record their activity. This is encouraging because the mote constitutes a more invasive activity and context collection device than a player's own phone, which is where we believe activity-monitoring technology is headed. Furthermore, when asked if they "thought about NWN strategy while wearing the mote", 6 of the 8 players answered "No", indicating that the mote did not cognitively interfere with the player. Taken together, our measures indicate that the activity collection was sufficiently in the background, the game was fun enough to support a large user base, and the game design supported players entering a state of flow.

4.2 Replayability for Scaffolding

Our second requirement was that the game provide extended playability or replayability to facilitate long-term changes in activity. By leveraging an existing game and building a larger, more sophisticated game than the previous PACE examples, we created a game with more extended play. There are several methods of extending play, one of which is providing a richer set of strategic balance and gameplay options over prior PACEs. We evaluated the strategic depth through both survey responses and gameplay analysis. Players tried to use strategies (3-SA, 4-A, 1-N), and "tried to use collaborative strategies" (1-SA, 6-A, 1-N) in the game, which included "trying to interpret what [the other team's] strategy was and do the opposite, "trying to capture both the towers with two people and have two people in the temple," "[trying] to spread false intelligence to the enemy players," and considering "individual abilities and character strengths." This strategic diversity over the experiment session was apparent in heatmaps of activity in the PvP zones. The central zone and one tower for the final three days are shown Fig. 2, where green dots represent player locations, and red x's represent the location of a PvP battle.

It is apparent in Fig. 2 that players had not settled on a single strategy by the end of the experiment. On day 3, the central zone and southern tower (shown) were contested. On day 4 the temple and southern tower were contested and on day 5 the center zone, northern tower and temple were contested, clearly indicating that players were experimenting with different PvP strategies even after a week of regular play. Player comments supported these observations: "the multiplayer aspect was very fun, and required a decent amount of strategy"; "…there was strategy…I find that only one week was not enough time to really investigate the strategy of the game."

Together, these results indicate that there was sufficient complexity in the design of the objectives and conflict to promote extended and continued play.

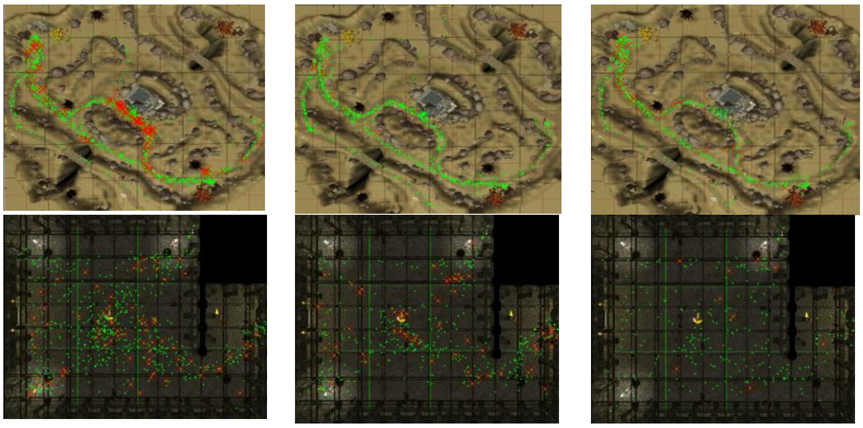

Fig. 2. PvP Combat in center and tower zones on day 3 (right), day 4 (center) and day 5 (right). Dots represent locations, X's represent battles.

The purpose of the second requirement was to provide a sufficient duration of play to facilitate behavior change through scaffolding. While a single week is too short to actually observe scaffold-induced changes, we asked players if the mote and game changed their perception of activity. When asked if "wearing the mote caused me to think about my daily activities more than usual," players answered in the affirmative (6-A, 2-N). When asked if "having my daily activities impact the daemon settings caused me to think about my daily activities more than usual," players also answered positively (6-A, 1-N, 1-D). Player comments also indicate that having activity level the animal companion caused them to reflect on their activity, "The daemons provided immediate feedback for actions which I knew were, in the long run, good for me"; "When I was doing exercise, I did think it was cool that my daemon was leveling up". Overall, our PACE encouraged people to think about their activity levels and make small changes to their behaviours: "given the choice I would opt to (say) walk to the store rather than drive"; "…most lunch hours I'm stationary; with the mote, I decided to use the time to go on walks. On one occasion I didn't bother taking my bus home because of the mote. The resulting walk took nearly two hours."; "I was more inclined to take stairs instead of an elevator, walk somewhere nearby instead of driving, or to go somewhere a little farther than I usually go to for lunch."

4.3 The Role of Activity in the Game

As an additional research question, players were asked to identify the role of the activity mapping in the game. When asked "If you chose to exercise when wearing the mote…were you playing NWN or training for NWN?", four players chose "I don't know", 3 players chose "neither" and 1 player chose "training". The player who chose training left a comment that indicated he was also somewhat neutral: "If I had to chose between the two motivations, I would say a little of both, but leaning towards the 'training' - it was more indirect than the competitive sessions, and so I felt it more of an extension to the game than a core element of the game itself." This apparent ambiguity is interesting as it indicates that accumulated context, unlike the direct activity sensing employed in other exergames, has a new ludological role.

5 Discussion

We have demonstrated important concepts in this paper: first, that PACEs designed using our requirements and design principles can result in compelling gameplay experiences where the accumulation of activity complements rather than dominates the experience; and secondly, that while players enjoyed having the activity-linked companions, they were unsure as to the exact ludological role of the activity mapping.

Because the digital experience in PACEs must function as a stand-alone game, good game design principles apply. The six design principles provided here are meant to highlight the aspects of game design that are most tightly coupled with the addition of activity measurement. Setting aside the possibility of gaming the activity collection itself, the addition of activity should not generate trivial winning conditions and not compromise players' ability to adopt a play style of their choice. These constraints were met by the separation of the accumulation of activity from the progression of the player's primary character. Additionally, by providing myriad game-play opportunities, we have allowed the player flexibility in how the exercise affects the advantages provided by the animal companion.

Perhaps the most fascinating results we have obtained relate to the unknown ludological role of the animal companion and its associated activity mappings. This confusion is important for the design of PACEs as players explicitly rejected characterizing the activity recording as play, making it, by definition, outside of the magic circle [26], and therefore not subject to the same privileged social space as the game itself. Players also rejected the notion that activity accumulation was training, like the exercise regimens employed by athletes. This further implies that designers must be especially careful with the perceived impact of the activity mappings. If players perceive that activity mappings provide a significant or dominant advantage, they may object, or even perceive high activity levels as a form of cheating because, as neither play nor training, it has no place in the game. However, players enjoyed the activity mapping, and felt it added to the game, so it is also obviously not an unwelcome component. The exact role of activity sensing in PACEs and players' understanding of it is an interesting future research topic.

Synthesizing our design criteria and the finding of ludical ambiguity, it should be possible to create PACEs in a number of genres. In many ways a single player experience would be easier to balance, as the players would be less concerned about relative differences in activity-ability mapped parameters (because parameter mismatches between players would not affect other players' games). However, multiplayer games, and MMOs in particular tend to have larger staying power and the added incentive of social dynamics for behavior change, making persistent multi-player experiences a more compelling match to the PACE requirements described here. This concept could be mapped to multiplayer shooters through access to better equipment, common to many games in the genre, or to online communities like

Second Life through avatar appearance, almost like an ambient life blogging exercise. We feel that PACEs have a great deal of potential to both enhance physical activity and provide compelling game-play experiences.

6 Conclusions

Traditional exergames are limited by the requirements for specialized hardware and dedicated play times. To alleviate these, we proposed PACEs, games that accumulate activity for digital rewards inside a game. We motivated two requirements for PACE design: that they have mass-market potential and that they support long-term play. Based on these two requirements, we identified six design principles that were used to design a multiplayer RP-PACE. We conducted a week-long evaluation of our game based on game logs, player surveys, and player interviews. Our results showed that a game designed using our six principles is scalable and of sufficient strategic depth to support long-term play, which are necessary requirements to engender behaviour change on a large scale. In the future we intend to perform longitudinal studies to evaluate the persuasiveness of a PACE to increase physical activity, to further investigate the ludological role of activity monitoring, and to deploy this system on smartphones to provide interactive feedback.

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