

HeartBeat: An Outdoor Pervasive Game for Children

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ABSTRACT

This paper reports the design of a pervasive game for children to demonstrate the design vision of Head-Up games, a genre of pervasive games that puts outdoors play center stage, combining the benefits of traditional outdoor games with the opportunities for richer experiences and innovation offered by new media. The design of the game, called HeartBeat, explores the use of physiological sensing and more specifically heart rate measurement as input to the game and as an approach to enhance the pervasive gaming experience. Evaluation with 32 children outdoors showed how the game promotes physical activity and social interaction between children in ways one would expect from traditional outdoor games.

Author Keywords

Pervasive Games, Head Up Games, Physiological Sensing, Interaction Design and Children, Structured Observation.

ACM Classification Keywords

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

INTRODUCTION

Pervasive games occupy the intersection of two rapidly growing research fields concerning, on the one hand, computer gaming and, on the other, pervasive computing and communication technologies. Pervasive games are augmented reality games played outdoors, in large areas, ranging from playgrounds to cityscapes, as opposed to applications tied to sub-room size such as tabletop augmented reality or multi-modal interactions with video consoles, etc. Pervasive games described in the research literature target adult players. Early examples are Human Pacman [5] and Feeding Yoshi [3]; like many games of this ilk they are location-based games, played with GPS and/or WiFi-enabled devices.

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Fewer pervasive games target children players. Two well publicized examples are Savannah [4] and Ambient Wood [11]. Both are best thought of as supporting playful learning with pervasive technology rather than aiming for play as such. The potential of pervasive games designed for entertainment is underexplored.



Figure 1: Left: Two players chasing each other in a game session. Right: The game device.

There are growing concerns expressed by parents and media regarding children's growing engagement with video games which seems to exacerbate the sedentary nature of their daily life. This is often at the expense of playing traditional outdoor games which, as many argue, fulfill an important function in the social and physical development of children. Pervasive games could potentially address this issue, if they are designed so that play preserves some of the valuable elements of traditional outdoor games.

However, current pervasive games do not match this requirement; [13] comment on how pervasive games typically require players to use a mobile device 'head down', which does not support social and physical activities of the kind one expects children to engage in during their outdoor play. They advocate 'Head Up Games' referring to pervasive games played with minimal but flexible equipment, supporting physical activity, rich social interaction, flexible and open-ended game rules, space for imagination and role play. Their aspiration relating to Head-Up Games (HUGs) is that game-play should resemble playing traditional (non-computer

supported) outdoor games of the past as far as the opportunities for physical activity and social interactions offered to the players, while at the same time bringing the benefits of computing and communication technology into the game play (such as applying complex rules, timing, enhanced sensorial and interactive experiences, balanced rewards and challenges). The notion of HUG games emerged from the design and evaluation of Camelot [14]; Camelot showed how non screen based games could support physical activity and social interaction, but brought with it some limitations regarding the bulky game objects involved, the attention they demanded and a fixed game narrative that needed to be followed. The concept of Head-Up Games shares some motivations with the concepts of Exertion interfaces [9] (which often relates to indoor play, e.g., using the Sony EyeToy or the Nintendo Wii) and intelligent playgrounds [12] (which concerns a specific location-bound infrastructure).

In this paper we describe the design of HeartBeat a Head-Up game designed for children aged 8-12. The game explores the theme of creating simple and robust technology that does not require frequent or sustained visual attention by children and which explores the potential of physiological sensing as an input modality for pervasive games.

The potential of physiological sensing as a game input is attracting the interest of research into gaming. Games such as 'EmoTetris'[8] explore the relation between emotion sensing and gaming. 'Biofeed the Zombies' [7] aims to investigate the relation between affective gaming and the emergent game experience. Amazed [1] uses psychophysiological sensing as an input modality in the context of table-top augmented reality games. Perhaps because of the difficulty of obtaining reliable and robust measures without encumbering mobility, this type of input modality is still unexplored in the domain of pervasive games. 'Ere be Dragons' [6] is the only example to date of a pervasive game using physiological sensing as input. Like the other pervasive games discussed above, it targets adult users and is based on PDA as a hardware platform.

HEARTBEAT GAME

HeartBeat can be described as an adaptation of *Capture the Flag*, combined with elements of traditional games such as *hide and seek* and *tag*.

To play the game, each player is given a small portable device (figure 1). Players are randomly allocated between two teams; the attacking team (attackers) and the defending team (defenders). Initially all players are unaware of the role distribution. Once the game starts, players get 30 seconds to hide. After this period of time, their role is displayed to them through their device. At this point one player in the defending team is randomly assigned a virtual treasure.

During the game the attackers need to seek out defenders and chase them up (figure 1) in order to tag them (figure 2). Once an attacker tags a defender, the defender joins the attacking team. Importantly for children (and as they indicated explicitly during the iterative design of the game), players are not eliminated in order that they stay involved throughout the game. By physically connecting two of the gaming devices (top to bottom), player roles can be passed on from one player to another. This makes it also possible to pass on the virtual treasure in the defending team.

A game is played for a short duration; in our play-test sessions we set this to 4 minutes. If the player with the treasure is not caught within this time, the defending team wins the game. If the attacking team has been able to capture the treasure, they win the game.

The defenders can defend their treasure by teaming up. If one defender and the player with the treasure are together, two attackers are needed to tag them both.

HEARTBEAT GAME DEVICE

Players are aided by simple technology embedded in a small purpose made portable device. These devices communicate wirelessly over a range of approximately 20 meters. If a device picks up the signal from an opposing team it notifies the player through an auditory signal (a beep). Players are also equipped with a heart rate sensor worn around their chest, which transmits a pulse signal wirelessly to the player's game device. When a player's heart rate exceeds a preset value (in our play tests this was set at 100 beats per minute), the player's device broadcasts a radio signal. The result is that devices of the opposing team in range beep in the same rhythm as the heart beat of the aforementioned player.



Figure 2: Taking a tagged player into one's team (left) by bringing devices in contact (middle and right).

DESIGN PROCESS

The game was designed in an iterative process involving children from the very early stages. Initially a group of 5-7 children from the target age-group play-tested the game rules with paper prototypes. We went through 8 iterations play testing in a suburban outdoor environment trying out different game rules. Following these play-tests we ran another 6 play test sessions with children in a forested area, before arriving at a fun and playable set of rules.

The form design resulted in a casing that was printed on a 3D printer and fitted with a PIC-microcontroller (PIC18F4550) an RF sender and receiver and some actuators such as LEDs, a vibration motor and a buzzer. At this stage, the heart rate measurement did not work well so this function was simulated using a step-counter device. These technical prototypes were tested with 3 children in an urban setting addressing technical and interaction design details.

PROTOTYPE

To produce the larger number of devices required for group play, the casing was reproduced using a molding process. The final prototype is externally almost identical to the first, but is more robust and supports actual heart rate sensing. The software running on these devices is decentralized allowing devices to be added or removed dynamically as children join the play or leave it. The final prototype was built around a microcontroller board mounted with a PIC18F4550 programmed in C. An XBee-module connected to the microcontroller enables wireless communication. A wireless heart rate monitor shield is connected to the microcontroller to retrieve the signal from heart rate belts. Connectors on the front and back of the device support communication through a physical connection of the two devices (figure 2, right).

EVALUATION OF THE GAME

The evaluation was conducted at a park that is used as a play area for a primary school. Data collection involved structured observation based on video recordings to analyze play behaviour and interviews, questionnaires and focus groups to evaluate the subjective player experience.

Method

The evaluation was set up as a comparison of two versions of the game, one using heart rate measurement and one not. The difference between these two games was the beep presented to each player. In one game this beep was related to the heart rate of enemy player, in the other game it was a frequent signal, beeping every 1.5 seconds, independent of the heart rate of enemy players. Participants played the game in groups of 8 players. Each player experienced both versions of the game; the order of the games was counterbalanced between groups.

Eight game devices were used. A hand-held video camera was used for recording play sessions as well as two head-mounted cameras worn by two players. This was deemed necessary as much of the action would take place out of sight of the camera operator (when children would disperse to hide and seek). Two cameras were set up in separate rooms to record focus group sessions.

Participants were briefed 3 days prior to the experiment regarding the game rules and they were handed consent forms which their parents were requested to sign. On the day, the lead experimenter was assisted by two focus group moderators and a video operator. The study was planned

such that two groups (16 children) could be occupied at once. The game was explained to the participants a second time. They were given the equipment and they were assisted in wearing it correctly.



Figure 3. Icons representing game elements for the Fun Sorter exercise.

After the game sessions each group was invited to a focus group. In a separate class room, participants were given drinks. They were asked to rank icons representing game elements (see figure 3) regarding how much fun they were (applying the Fun Sorter technique [10]). After doing this individually they were seated as a group in a class room for a focus group discussion. The focus groups were seeded by an exercise where the children were asked to agree to a single ranking of the game elements as a group. Video equipment was used to capture the entire focus group for review later.

Two classes of eighth graders (48 children, ages 11 to 13) of a local primary school participated in the experiment. Bad weather and some technical glitches delayed the schedule. The result was that only 4 groups, instead of 6 completed in the experiment. (N=32, 22 girls and 10 boys). The researcher returned to the school on another day, so that the remaining 16 children could also get a chance to play the game; we did not collect though any data on this second occasion which was only for the benefit of the children.

RESULTS

In total video footage of 10 games was found suitable for analysis. This footage from head mounted cameras was analysed using the OPOS scheme [2]; and more specifically, the codes relating to physical activity and social interaction. Observations showed that most children engaged in an active form of game play; chasing or running away from other players. Video analysis showed no major differences in physical activity between the games (22,7% running in the game without heart rate monitor vs. 34,9% in the game with heart rate monitor, though a slight decrease in medium physical activity was observed in the latter). Social interaction was observed in all the games; communication in the game was found to resemble communication of traditional playground play, e.g., a lot of pointing, shouting and gesturing.

In total 26 rankings were handed in, resulting in the combined ranking order: Hiding, Tagging, Teamwork, Randomized Allocation to Teams, Audio Feedback. Agreement between players was significant ($W = 0.283$, $k = 26$, $N = 5$, $p < 0.01$).

Three focus groups were conducted with 8 participants and one with 3 participants. Video recordings were analysed qualitatively categorizing statements of participants according to the principles of HUGs. Extra clusters were added concerning heart rate monitoring and game rules.

Children related very well with the idea of gaming outdoors. During the discussion the moderator asked whether “*it matters where you play the game*”. To which one of the participants replied “*It would be more fun to play it in a forest*”. Numerous and varied comments were made regarding physical aspects of play. E.g., reasons to enjoy tagging were mentioned: “*Then you are most active*”. Reasons to like or dislike hiding: “*I like to sneak around*”, “*I can't stay put*”.

Views about social interaction were diverse. Some comments indicate that players valued the social interaction built in the game “*I think that teamwork is an essential part of a game*”. A participant commenting about the random team distribution: “*I liked it, if that wouldn't be part of it, it would be less exciting*”. Not all players appreciated the auditory notification produced by the device. Some didn't hear it while others enjoyed it: Opinions regarding the heart rate monitors were divided. Some did not use it or understand it: “*It didn't beep. You could only see it on your watch, but I didn't look at it, because I was so busy playing the game*”. Others were positive: “*I think it makes it more exciting.*”

CONCLUSIONS

The design of HeartBeat validates the conception of Head-Up Games by [13]. The game was developed iteratively with the participation of children. A summative evaluation of HeartBeat involved 32 children. Video analysis using the OPOS [2] scheme, confirmed how traditional patterns of outdoor play are manifested in this game. Children understood and enjoyed the game, were physically active and in social interactions engendered by the game. Heart rate sensing had a seemingly positive influence but the results were not unequivocal. Longer term evaluation studies are needed to examine what play patterns develop over time and outside the regulated set up of a moderated evaluation session.

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