Evaluating Outdoor Play for Children: Virtual vs. Tangible Game Objects in Pervasive Games

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ABSTRACT
In this paper we report a case study where two versions of the same outdoor pervasive game were compared: one featuring a virtual game object and the other with a tangible representation of it. Our aim was to explore the effect on social interaction and physical activity; two characteristics of Head-Up Games. Based on evaluation with 27 children we can conclude that both approaches support Head-Up Games well, and offer different design opportunities that should be explored further.

Categories and Subject Descriptors
H.1.2 [Information Systems]: User/Machine Systems.

General Terms
Design, Experimentation, Human Factors.

Keywords
Children, pervasive games, outdoor games

1. INTRODUCTION
In [13] Soute and Markopoulos propose the concept of Head-Up Games (HUGs): outdoor pervasive games for children that support play patterns found in traditional game play. In contrast to current pervasive games that mainly use PDA's as gaming interfaces (e.g. [4,5,6]), Soute and Markopoulos argue that embedded gaming technologies can be designed without the need to attend to a screen and can fit seamlessly into play encouraging social engagement and physical activity.

Two possible approaches for representing a game object are a tangible and a virtual interface. An intuitive assumption is that tangible interfaces are engaging and enjoyable for children, since they provide a natural way of interaction [15]. In contrast, a virtual game element cannot be 'seen', but in dynamics is more similar to a computer game, which children also enjoy [14].

In this paper we describe the evaluation of a HUG in which a tangible and a virtual game object are compared to investigate the effect on social interaction and physical activity, and thus to see which type supports HUGs best. For evaluating the amount of social interaction and physical activity, the Outdoor Play Observation Scheme (OPOS) [3] was used.

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2. OBSERVATION SCHEME OPOS
OPOS was especially designed to evaluate outdoor games and defines four different classes of behavior: *physical activity* – distinguishes intensive, non-intensive and no physical activity; *focus* – deals with what the players are looking at: each other, game objects or something else; *social interaction* – codes the types of interaction with other players, such as functional (required to play the game), and non-functional interactions; and *general* – this class is not related to play behaviors but is meant for coding practical issues such as whether or not players are in sight.

3. THE GAME "SAVE THE SAFE"
We evaluated two versions of a Head-Up Game called "Save the Safe". This game is a refinement of the game "Stop the Bomb" by Hendrix et al. [7]. The original game concept had been only partly implemented. Given the successful evaluation of the game concept, we decided to continue development and re-evaluate the game. To avoid appealing to the violent fantasy element in the original game, it was renamed to "Save the Safe" and the narrative was adapted accordingly.

3.1 Game Play
At the start of the game players are randomly divided into two teams of 4 players each: the burglars and the guards. The game revolves around a safe and its key; the guards win the game when they successfully guard the key from the burglars for the duration of the game (5 minutes). The burglars win the game when they steal the key from the guards and unlock the safe.

3.2 Technology
Each player wears a belt (see Figure 1). The belt contains LEDs to indicate the player's team color. Furthermore it contains a vibration motor and an RF communication unit (Crossbow MICA motes [1]). At startup the motes automatically form a network that allows for easy communication between motes. Incidentally, the communication unit is not meant for communication *between players*, but is used for determining distances between players, by measuring the signal strength of nearby belts.

The game can be played in two modes: a virtual and tangible mode. In the virtual mode the key is represented by the vibration motor in the belt. If a player possesses the key, his or her belt will start vibrating. If another player comes sufficiently close, the key will automatically be transferred to that player's belt. In other words the output appeals to the haptic sense, and there is no tangible game object as such.

In the tangible mode, the key is represented by a physical ball. Players can pass the key around by throwing the ball to each other, and the burglars can steal it from the guards by intercepting the ball. The belts are used in this game only for indicating the team color.

Figure 1. Players chasing each other; inset: belt.

In the virtual mode, the interaction differs in several ways. No physical manipulation is required to obtain the key – just being in the vicinity of the key holder for approx. 3 seconds is enough. In the virtual mode the only player who is informed of the location of the key is the player who possesses it. In contrast, in the tangible mode all players see the transfer of the key because they can see the ball.

The safe is equipped with the same communication technology as the belts. In the virtual mode, when a burglar in possession of the key comes close to the safe, the key will be transferred to the safe, which ends the game. In the tangible mode the burglars 'open' the safe by touching the safe with the ball.

4. EVALUATION

4.1 Participants

27 children (15 girls, 12 boys) between 8 and 9 years old from a primary school in the Netherlands participated in the evaluation. As each game session required 8 children, some children participated in two game sessions. Boys and girls were evenly mixed over the sessions.

4.2 Procedure and Setup

All games were played outside on a school playing field. Two video cameras were placed at two corners of the field.

In total, 4 sessions were held and in each session 4 games were played: a training game, followed by both a game in the virtual mode as well as a game in the tangible mode, and finally a game in the mode of the participants' choice. The order of the tangible and virtual games was controlled for.

After all games were played, participants were taken inside to fill in a short questionnaire. They were also asked to rank 8 elements of the game, from 'most fun' to 'least fun'. Finally, the children were asked to repeat this task, however now as a group and we recorded the ensuing discussion for analysis. A moderator facilitated the conversation.

5. RESULTS

5.1 Observations

The footage of the cameras was annotated for each participant with OPOS using Noldus Observer [2]. A second coder coded 25% of the data, to calculate inter-rater reliability. This resulted in $K = 0.53$ for the category physical activity and $K = 0.43$ for focus. According to [10] these values indicate moderate agreement between coders. For social interaction $K = -0.24$, indicating poor agreement.

As each game had a different duration, the results have been computed to an average percentage of the total time for the classes 'physical activity' and 'focus'. For the class 'social interaction' results have been computed to average number of events per minute.

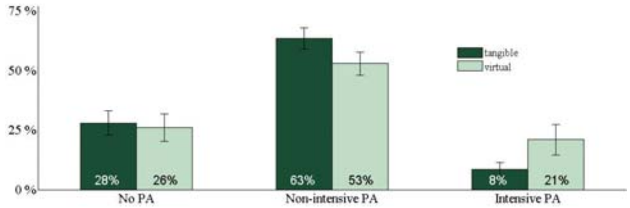

Figure 2. Results physical activity, with 95% confidence intervals.

A 2 X 2 mixed subject analysis of variance using game type (tangible vs. virtual) and game order (tangible first vs. virtual first) as independent variables and the average percentage of time on different types of activities for each child was performed. When analyzing the overall physical activity (intensive and non-intensive) it was clear that there was no main effect of game type, $F(1,22) = 0.884$, $p = 0.357$ and no main effect of game order, $F(1,22) = 2.613$, $p = 0.120$. Furthermore, no significant interaction was found, $F(1,22) = 0.051$, $p = 0.822$. Thus children are equally active in the two game versions.

However, when analyzing the percentage of *intensive* physical activity using a similar 2 X 2 mixed subject ANOVA it was clear that there was a significant main effect of game type, $F(1,22) = 12.278$, $p<0.05$. No significant main effect of order, $F(1,22) = 1.880$, $p = 0.184$ and no significant interaction, $F(1,22) = 0.137$, $p = 0.715$ were found. This leads us to conclude that in the virtual mode, while in both games children are overall equally active, children were more often intensely active than in the tangible mode.

From Figure 3 we can immediately see that there is a large difference in focus on 'looking at game objects' and 'looking at other players'. Using a similar 2 X 2 ANOVA it was clear that children focused significantly more often on game objects in the tangible mode than in the virtual mode, $F(1,22)=131.521$, $p<0.05$. No significant effect was found for order, $F(1,22)=1.546$, $p=0.227$, nor was the interaction effect significant, $F(1,22) = 3.186$, $p = 0.088$. The most likely reason for this is that in the virtual mode there are less game objects to look at. Since players look at each other significantly more often in the virtual mode, one could expect that this should lead to more social interaction; however this is not supported by the social interaction data.

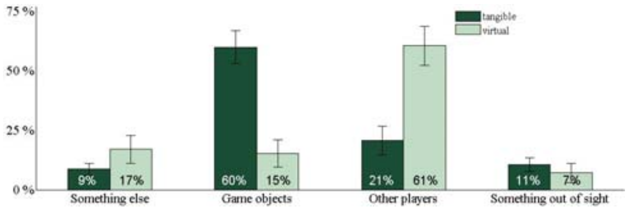

Figure 3. Results focus, with 95% confidence intervals.

There are no significant differences in social interaction per minute between the two game modes, except for 'interaction with non-players'. In the virtual mode there was more interaction with non-players; players asked questions or talked to the experimenter. Outcomes of the results of a 2 X 2 mixed subject ANOVA on the social interaction scores are presented in Table 1.

Table 1. Results for social interaction.

	Type		Order		Interaction	
	F(1,22)	p	F(1,22)	p	F(1,22)	p
Functional	0.536	0.472	0.249	0.623	0.021	0.886
Non-player	4.789	0.040*	1.535	0.228	2.702	0.114
Positive [a]						
Negative	1.565	0.224	0.634	0.434	8.062	0.010

* significant at 5% level   [a] too few observations

5.2 Again, again

The participants were allowed to choose which game mode they wanted to play in the final game. This is an adaptation of the 'again, again' method as proposed by Read and MacFarlane [12], and can be interpreted as a measure of fun. In three out of four sessions the virtual mode was preferred over the tangible mode.

5.3 Preference and Rankings

In a short questionnaire, we asked the children 1) which game mode they thought was most fun, 2) in which mode the physical interaction was most fun, and 3) in which mode the social interaction was most fun. The results are shown in Table 2.

Table 2: Which mode was most fun.

Most fun	Virtual mode	Tangible mode
Overall	23	4
Physical activity*	19	7
Social interaction	19	8

* one participant did not record his preference

Table 3. Ranking of game elements (1=most fun, 8 = least fun).

Item name	Individual ranking	Group ranking
Belt	1	2
Running	2	3
Playing together	3	1
Which team	4	6
Ball	5	5
Winning	6	8
Safe	7	7
Discussing	8	4

The participants were asked to rank eight game elements from 'most fun' to 'least fun', both individually as well as group-wise. From the rankings a combined rank can be calculated; the combined ranks are shown in Table 3..

5.4 Group Discussion

Children's comments during the group ranking were analyzed, using conventional content analysis [9], i.e. the coding scheme was built up during coding of the transcripts.

Many references were made to the belt and its impact on game play: "Nobody knows who possesses it [the key]", "It makes you run more", "I like the vibration. You don't see that in other games", and "You could not easily take it [the key] away from another player".

Concerning the ball (the tangible key) children mentioned "the ball is more fun, since it makes you play together more", "Everybody can see that you have it [the ball]", "With the ball you have to stand still [to throw it], with the belt you can keep running"

Children found it easier to discuss with each other during the game with the tangible element: "It's easier with the ball, since then you can stand still and you can discuss. If you move and run it's a little hard."

6. DISCUSSION AND CONCLUSION

Regarding the coding of the videos we found that the inter-rater reliability for social interaction was poor. The reason for this is that it was quite difficult to judge children's verbal utterances from the videos. A possible improvement would be to equip participants with small microphones, so each participant's speech is recorded separately.

From rankings, again-again and the group discussion, we conclude that children preferred the virtual game. We attribute this to the new technology introduced to the children, as many positive comments were made concerning the haptic feedback of the belt; children commented that it was new to them and that they enjoyed it very much.

The merits of tangible interaction have been argued manifold; but empirical research so far has produced limited evidence to substantiate these claims [11]. Still, the reader is warned not to conclude prematurely the case against tangibles. For one, many different definitions of tangibility exist [8]: both the belt and the ball could for some be considered as tangibles. The distinction between the two is that the ball is manipulated as a physical object while the belt provides a haptic output to the player. Children mentioned during the discussion how the direct manipulation of the ball was easier for them than the indirect manipulation of the key in virtual mode. This is in line with what Xie et al. [15] found and with what one would expect regarding the intuitiveness and usability of tangible objects.

Furthermore, the very physicality of the ball changes the game play dramatically. To ensure construct validity in a comparison between a tangible and a non tangible version of a game, the two should be identical in all ways apart from the physical manipulation of the artifact. In this evaluation, the visibility of the game object was unavoidably linked with its physicality: players could not see who had the key in virtual mode, while they could all see who had the ball in tangible mode. A straight comparison could be obtained if, for example, a light would indicate whether a player has the key or not in the case of the virtual version of the game. While such a choice could have lent higher construct validity to the conclusions, it would be at the expense of external validity. In designing a game, we have to make use of the advantages of each medium to design an enjoyable experience. Equalizing the games in all other aspects but the physicality of the key, would lead to losing the added suspense of discovering or concealing who is in possession of the virtual key.

Given the above one can conclude the following; head up games can be supported well both by using physical as well as virtual game objects. These two approaches offer different design opportunities; designers and researchers should not assume it as self evident that physicality is the appropriate approach to interaction design. Moreover, the relative advantages to both need to be explored in different design contexts. In the specific context of game design we saw that play resembled more traditional sport games when a ball was used; there is perhaps more opportunity to innovate and explore new experiences when virtual game objects are used. Further research is needed to obtain a more refined account of how physicality and virtuality of game objects impact social interaction, physical activity and enjoyment of the game.

7. ACKNOWLEDGEMENTS

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