Tangible interaction in tabletop games: studying iconic and symbolic play pieces

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ABSTRACT
In this paper, a study is described which investigates differences in game experience between the use of iconic and symbolic tangibles in digital tabletop interaction. To enable this study, a new game together with two sets of play pieces (iconic and symbolic) was developed and used in an experiment with 30 participants. In this experiment, the understanding of the game, the understanding of the play pieces and the fun experience were tested. Both the group who played with iconic play pieces and the group who played with symbolic play pieces were proven to have a comparable fun experience and understanding of the game. However, the understanding of the play pieces was higher in the iconic group and a large majority of both groups preferred to play with iconic play pieces rather then symbolic play pieces.

Categories and Subject Descriptors
C.0 [**Computer Systems Organization**]: General – *hardware / software interfaces.* H.5.2 [**Information Interfaces and Presentation (e.g. HCI)**]: User Interfaces - *Haptic I/O, Input devices and strategies (e.g., mouse, touchscreen), User-centered design.*K.8.0 [**Personal Computing**]: General – *games*.

General Terms
Design and Human Factors.

Keywords
Interaction design, tabletop gaming, tangible user interfaces, pervasive games.

1. INTRODUCTION
Traditional board games have been played for centuries already, providing a challenge, pastime, skills training, fun and social interaction. With the introduction of desktop PCs and game consoles, a new type of game appeared. Taking place in a virtual world, these games have many other possibilities than board games: e.g. levels with increasing difficulty, visual and auditory feedback and the 'save' and 'resume' option. Despite these advantages, computer games often lack physical activity and social interaction during game play. A new and growing gaming genre combines the benefits of both game types. This new genre is sometimes referred to as pervasive games. According to Magerkurth et al. [16], pervasive games are no longer confined to the virtual domain of the computer, but integrate the physical and social aspects of the real world.

Many examples of pervasive games use tangible play pieces to support interaction (e.g. [4, 10, 15, 17, 19, 20, 25]). Tangible interaction [7, 8, 13] is used in many application areas next to gaming, as an alternative for or extension to traditional graphical user interfaces. Classifying these tangible user interfaces, Ullmer and Ishii [27] proposed a framework based on possible object languages with collections of tangibles, which was later extended by Van den Hoven and Eggen [12], with a category showing the use of individual tangibles. One of the dimensions along which tangible interfaces are discriminated is based on the appearance of tangible objects. In this division, objects can either be iconic, representing their association to digital information, or symbolic, having an appearance that does not represent this association.

Pervasive games, especially tabletop applications, can support a diverse range of games using the same display, while traditional board games cannot. It is often assumed that iconic tangible play pieces clarify functionalities. Symbolic play pieces however, can be used in multiple games and are thus economically attractive. Although some have studied tangible interaction in game play, no studies are know to the authors in which different designs of tangible play pieces were studied. For it seems unclear what type of design would be more suitable, a study was performed to compare iconic and symbolic designs of play pieces.

To find the most suitable type of play piece, this paper discusses a user (who is the game player) evaluation on differences between the use of iconic and symbolic play pieces in table top games. This evaluation focuses on differences in game experience, which is divided into the understanding of the game, the understanding of the play pieces and the experience of fun during the game.

2. LITERATURE OVERVIEW
2.1 Digital Tabletops
Tables have always served various functional roles for people, e.g. for writing, dining or socializing. Due to the technological progress of the last decades, computers have evolved to a medium used for interaction and sharing information. A next step in human-computer interaction would be to combine these two ways

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of information sharing, the table and the PC, and to create digital tabletops [20].

Digital tabletops combine the digital world with physical interaction. As described by Mazalek [20, p.36], digital tabletops can detect physical objects users interact with, such as shown in the Digital Desk [29], ActiveDesk [7], metaDesk [26], Urp [28], SenseTable [21], Carreta [24] and PITABoard [6] projects, or can be touch-sensitive as seen in the DiamondTouch table [5] and SmartSkin [23]. Digital tabletops vary from touch screen displays to combinations of overhead projectors projecting the virtual information and video cameras to track the physical interaction such as seen in the VIP (Virtual Interaction Platform) [1]. The digital interactive tabletop platform used in this study is called the Entertaible [11] and combines both touch input and object detection with a flat LCD screen. Entertaible is under development at Philips.

The use of digital tabletops is diverse, which becomes apparent when looking at previous studies done in the area. For example, studies involving music control [14], multiplayer games [11, 17] and graphical applications supporting a more natural interaction by enabling the use of both hands [7]. An advantage of digital tabletops compared to PC-applications is the possibility of social interaction. The standard way of interacting with a PC is individual and focused at the display, whereas tabletop interaction allows multiple users to sit around the table, face-to-face, and interact with each other and the tabletop application.

2.2 Tabletop Interaction

Digital tabletops can support different types of interaction; by means of touch or objects, which differ greatly in possibilities. Physical objects make the digital world tangible and graspable (as in the field of tangible interaction), whereas touch can only be used to tap the display in a one dimensional way. Physical objects can have a link to a file and can have affordances (i.e. perceived action possibilities [9]) linking to a certain digital function. Different objects can represent different files or functions [20]; these representations are called digital associations [12].

Tangible objects can either have a symbolic or an iconic design [12, 27]. The appearance of symbolic objects does not represent the digital association, whereas the iconic object does resemble the digital association in any way possible. An example of an iconic reference is the icon which is used in Microsoft Windows for ‘My Computer’; it represents a computer and display, which is recognized as a computer by most people when seen for the first time. Examples of symbolic references are to be found on most modern media devices such as CD players; the stop function is associated with a button labeled with a square. This square has no link whatsoever with stopping a CD and therefore the link between the square and the stop function needs to be learned.

The study discussed in this paper focuses on the differences in game experience between symbolic and iconic play pieces in a digital tabletop game. This game experience is split up in 3 parts: the understanding of the game, the understanding of the play pieces used in the game and the fun experienced during the game. This will further be explained in section 4.

2.3 Tangible Interaction in games

Most traditional board games use physical play pieces for interaction. These play pieces can have many different functions [2], such as representing a player, providing a factor of chance or representing points or money. These play pieces can be iconic (e.g. the king of chess) or symbolic (e.g. a chip in a roulette game).

To combine the advantages of computer games with the social advantages of board games, some research projects explored the field of pervasive gaming, bringing physical movement and social interaction back into computer games [16]. Most of these games were developed to study new technologies or new possibilities in game play and used tangible play pieces for interaction. The hybrid game ‘Paranoia Syndrome’ [10] for example, uses tangible play pieces to represent weapons. This, however, uses no digital tabletop but takes place in a preset environment. The games ‘Smart Jigsaw Puzzle’ [4], FruitSalad [15] and the balloons game presented by Ulbricht and Schmalstieg [25] use real play pieces to interact with their virtual copy. The tabletop games ‘False Prophets’ [19], ‘KnightMage’ [17] and the STARS adaptation of Monopoly [17] use tangible play pieces to represent characters in the game. In the games ‘Pente’ [20] and ‘Springlets’ [20], tangibles are used as a tool to manipulate virtual information.

Although these games use tangible interaction, none of them have distinguished iconic from symbolic play pieces or described motivations for the design of the play pieces at all. Also no other studies are known to the authors dealing with symbolic and iconic play pieces in games.

3. THE WEATHERGODS GAME

In order to study differences between the use of iconic and symbolic tangible play pieces, a dedicated game was developed and implemented for the Entertaible gaming platform. The game is called ‘Weathergods’ [3] and can be played with a minimum of two and a maximum of four players. The setting of the game is the Arabic savannah. The weather gods are having a fight and therefore it has not been raining for several weeks. Since this draught is threatening the harvest, each of the four villages in the savannah has sent one camel rider on a journey to collect gold to buy offerings for the gods, who can influence the weather. Each of these four camel riders represents one of the four players. The first player to buy all the offerings, in the correct order, is the winner. The board displays a map that is divided into 128 square tiles and the camel riders can move across the map over these tiles (also see figure 1.).

Figure 1. The ‘board’ on-screen of the Weathergods game.

The game ‘Weathergods’ uses three different classes of tangible play pieces for interaction (see Table 1). Each class contains of two versions of play pieces; an iconic version and a symbolic version. The appearance of iconic play pieces represents their association to digital information. The appearance of the symbolic play pieces however, is more abstract; one is not likely to understand the digital association or function when seeing the play pieces for the first time. This makes two versions of the game as needed for the evaluation (see section 4); the iconic version that uses only iconic play pieces and the symbolic version that uses only symbolic play pieces. The board and messages that are displayed on screen are identical for both versions.

Table 1. Tangible play pieces used in the game Weathergods.

object class \ version	iconic	symbolic
camel rider		
bandit		
detector		

The first class of tangible play pieces is the camel rider. This play piece represents the player. Each player has one camel rider-play piece; it shows the location of the camel rider on the map.

The second class of tangible play pieces is the bandit who steals money from the players. There is only one bandit in the game, which is used by every player.

The third class of tangible play pieces is the detector. The function of this play piece is to reveal hidden gold. Each player has a detector and can place this play piece on one of the tiles near his/her camel rider. If gold is hidden underneath that tile, the crystal ball in the detector will show a yellow light, only visible to the player handling the detector at that moment.

4. USER EVALUATION

4.1 Goals

As explained in the section 2, this project studied the difference between symbolic and iconic play pieces in games. It focused on the difference in game experience, which is divided into three categories; the understanding of the game, the understanding of the play pieces used in the game and the fun experienced during the game.

The understanding of the game is defined as the ability to describe the rules of the game. It is assumed that this ability will increase when playing the game. At some point, the learning curve will have reached its top. From that point forward, the person will not get a better understanding of the rules of the game without any further explanation. The understanding of the play pieces used in the game is defined as the ability to name what the play pieces in the game represent and which functions they have. If the function is named correctly, it is assumed that the representation is also known. For example, if the function of the bandit is named as 'stealing gold' it is assumed that this participant knows it represents a thief or bandit. It is expected that the fun experienced during the game is partly dependent on the understanding of the game and the meaning of the play pieces.

In this study, our expectation was that people will learn to work faster with iconic play pieces over symbolic play pieces. Besides a faster understanding of the game and of the meaning of the play pieces, we also expected that the iconic version of the game would be experienced as more fun than the symbolic version.

4.2 Experiment setup

To study the difference between iconic and symbolic play pieces, a user experiment was set up. To check the procedure and timing of the experiment, a pilot experiment was done with four participants. As a result of this pilot, the explanation of the game and the time of playing were shortened in order to make sure the top of the learning curve was not yet reached after one playing session. If some participants would reach the top of their learning curve within 10 minutes of playing, it would be unclear how many minutes it really took them. Therefore it would be impossible to compare the results of these participants. The improved experiment was performed among a group of 30 participants. The group consisted of 16 male and 14 female participants, with ages from 19 to 50. Of the 30 participants, 15 participants (10 male, 5 female) were frequent game players and 15 (6 male, 9 female) were non-frequent game players.

As a part of the experiment, each participant played the game together with two experimenters. After 10 minutes of playing the game, the play pieces were replaced by the other versions. Half of the participants started with iconic play pieces and continued with symbolic play pieces (i→s), the other half started with symbolic play pieces and continued with iconic play pieces (s→i). From now on, we will refer to these first 15 participants as group i→s and to the second 15 as group s→i. Gender, age and frequency of play were nearly counterbalanced over the two groups. No participants played the game together, to make sure they would not influence each other. To extend the time before the top of the learning curve was reached, the participants did not receive the entire explanation of the game before playing. An example experiment setup is given below (see Table 2). See Figure 2. for an impression of the experiment.

To quantify the understanding of the game, the participants were asked to explain in a questionnaire (after the first playing session) how they thought the game had to be played and how they could win it.

For the understanding of the play pieces, the participants were asked for the functions of the play pieces twice; once before the first playing session and once after the first playing session. From now on, we will refer to these two points of measurement as respectively test 1 and test 2. For each participant, both tests are about the same versions of the play pieces; the iconic versions for the participants in group i→s and the symbolic versions for the participants in group s→i.

Table 2. The experiment setup for an s→i participant

00.00h	The participant reads the explanation of the game and is asked to name the function of the symbolic play pieces (test 1).
00.05h	The participant and two experimenters start playing the symbolic version of the game.
00.15h	The participant fills out a questionnaire, with questions regarding the understanding of the game and the play pieces (test 2) and the fun experience during the game.
00.30h	The participant and two experimenters continue with the iconic version of the game.
00.40h	The participant is interviewed about his/her preference regarding the fun experience during the game and his/her general preference.
01.00h	End of the experiment

To evaluate the fun experience during the game, 10 questions were put together based on both the 12 elements that provide enjoyability in games according to Prensky [22] and the heuristics for designing enjoyable user interfaces according to Malone [18]. These questions include the following 10 elements: enjoyment, involvement, motivation, learnability, satisfaction, excitement, creativity, difficulty, curiosity and ability to put oneself in the situation of the game. An example question would be: 'Did the game spark your curiosity and why?'. The questionnaire (filled out after the first playing session), containing the above mentioned questions, was used to compare the results among people who played the iconic game first (group i→s) and people who played the symbolic game first (group s→i). To evaluate the preferences of the participants regarding the fun experience during the game, each question was also asked during the exit interview, this time related to the difference between the iconic and the symbolic game. For example: 'Which type of game sparked your curiosity most, or were both games comparable?'.

Figure 2. An impression of the user experiment setup.

Besides the evaluation of the game experience, participants were also asked which of the two versions of the play pieces they preferred in general.

5. RESULTS

The experiment described in this paper studied three elements of the game experience: the understanding of the tangible play pieces used in the game, the understanding of the game itself and the fun experience during the game.

5.1 The understanding of the play pieces

As explained in section 4, the understanding of the play pieces was tested 2 times: the first time, test 1, was before playing the game and the second time, test 2, was after playing one version of the game. These two tests were evaluated by calculating scores for each participant. In both tests, three play pieces were shown and the participant was asked to name the functions of these play pieces. Each correct function was worth 1 point, or 0.5 points if only the representation was known (as stated before, if the function was named correctly, it is assumed that the representation is also known). For example, if the function of the detector is named to be 'revealing gold', the participant would get 1 point, if the answer 'crystal ball' is given, the participant would get 0.5 points. This results in a maximum score of 3 points per test.

To see how much each group learned between test 1 and 2 regarding the functions of the play pieces, a learning score per participant was calculated. Scoring 2 points in test 1 and 3 points in test 2 is assumed to be a greater achievement than scoring 1 point in test 1 and 2 points in test 2. Therefore the following formula was constructed: L (learning score) = (test 2 – test 1)*(test 1 + 1). For example, participant A had a score of 2 during test 1 and a score of 3 during test 2, while participant B had a score of 1 during test 1 and a score of 2 during test 2. Calculated via the formula stated above, participant A would have a learning score of 3 while participant B would have a learning score of 2.

Of each participant-group (i→s and s→i) the average scores of test 1, test 2 and the average learning score were calculated and subjected to a t-test for independent groups to calculate their significance. The means of test 1, test 2 and the learning score (L) per group are given in Table 3. The differences between the 2 groups in test 1 (t = 4.55, df = 28, $p < 0.001$) and test 2 (t = 2.87, df = 28, $p < 0.01$) proved to be significant but the differences between the groups in the learning score proved to be insignificant (t = 1.98, df = 28, *n.s*). Since alternative formulas to calculate the learning score can be used and since these might lead to different results for statistical tests, another t-test for independent groups (t = -0.10, df = 28, *n.s.*) was conducted with the results of the scores of test 1 minus the scores of test 2 to check whether the above calculated learning score differed from the mere difference between the two tests. The difference between the means of the two groups proved to be insignificant with these results.

Table 3. Average scores of the understanding of the play pieces (L = average learning score between test 1 and test 2, n = number of participants, M = mean, s = standard deviation).

Group	Test 1	Test 2	L
i→s (n = 15)	M = 1.10 (s = 0.57)	M = 2.23 (s = 0.62)	M = 2.17 (s = 1.29)
s→i (n = 15)	M = 0.27 (s = 0.41)	M = 1.43 (s = 0.88)	M = 1.25 (s = 1.30)

Group i→s scored higher than group s→i in test 1 and test 2. The function of iconic play pieces is understood better than the function of symbolic play pieces, both before and after playing the game for 10 minutes. However, since the difference in learning scores (L) proved to be insignificant, we can conclude that both groups learned the same amount since test 1.

A correlation of 0.69 was found between the scores of understanding the play pieces and the scores of understanding the game of group i→s and group s→i together. A t-test proved the significance of this correlation (t = 5.06, df = 28, p < 0.001). It can be concluded that there is a relation between the understanding of the game and the understanding of the play pieces. Participants who had a high understanding of the game, also had a high understanding of the play pieces.

5.2 The understanding of the game

For the understanding of the game, questions were included in the questionnaire, filled out after the first playing session. The answers given to these questions were compared to a checklist with all the rules of the game. This checklist was created by the authors. The rules were divided into three categories, see Table 4 for the categories and some examples.

Table 4. Explanation of categories of the rules used to evaluate the understanding of the game.

Category of rules	Example rule	Points given if mentioned
1 - without these rules, the game cannot be played	The game has players	6
2 - without these rules, no game strategy can be set up	The land can contain a trap	3
3 - these rules do not need to be remembered to set up a game strategy	A trap can result in waiting one turn	1

Since rules in category 1 were assumed to be much more important than the other rules, those were worth 6 points. Rules in category 2 were more important than those in category 1, so those were worth 3 points. The remaining rules were worth 1 point. Simply giving 3 points for category 1 rules, 2 points for category 2 rules and 1 for category 3 rules would not give the most important rules enough influence in the total score.

The total score for each participant was expressed in a percentage of the maximum possible score (406 points). The average of each of the two groups (i→s and s→i) was calculated (see Table 5).

Table 5. Average scores (on a scale from 0% understanding to 100% understanding) of the understanding of the game (n = number of participants, M = mean, s = standard deviation).

Group	Average score (%)
i→s (n = 15)	M = 41.3 (s = 15.5)
s→i (n = 15)	M = 36.2 (s = 15.0)

As can be seen above, group i→s had a higher average score than group s→i. This difference proved to be insignificant after conducting a t-test for independent groups (t = 0.91, df = 28, *n.s.*) and therefore it can be concluded both group i→s and group s→i understood the game equally well after playing the game for 10 minutes.

5.3 The fun experience during the game

The 10 yes/no-questions considering the fun experience during the game were evaluated via personal scores. The questions in the questionnaire (filled out after the first playing session) could either be answered positive (meaning a positive fun experience) or negative. If a participant answered one of the questions in a positive way, this would be worth 1 point. Since there were 10 questions, the maximum score is 10 points. For each group the average score was calculated, as is seen in Table 6.

Table 6. Average scores of the fun experience during the game (n = number of participants, M = mean, s = standard deviation).

Group	Average Score
i→s (n = 15)	M = 5.8 (s = 1.32)
s→i (n = 14)	M = 5.5 (s = 1.34)

The means of both groups do not differ much and after checking the significance of the difference between these means with a t-test for independent groups (t = 0,61, df = 27, *n.s.*), it can be concluded that there is no significant difference between group i→s and group s→i regarding their fun experience. Both groups experienced the game as equally fun, regardless of their different scores in understanding the play pieces.

5.4 Preferences of the participants

During the exit interview, the participants were asked to answer similar questions regarding their fun experience but this time they had to answer with which version of the play pieces they experienced the most fun (also see section 6.2). The results can be found in Table 7.

Table 7. Average scores of play pieces regarding the fun experience during the game.

Given answer	Group i→s (n = 15)	Group s→i (n = 14)
Iconic	M = 4.13 (s = 1.73)	M = 4.07 (s = 2.97)
Symbolic	M = 0.47 (s = 0.64)	M = 1.14 (s = 0.95)
No difference	M = 5.40 (s = 1.72)	M = 4.79 (s = 3.09)

There are only small differences between the average answers of group i→s and group i→s. The difference between these results was checked for significance by conducting a Chi square test (χ^2 = 0.32, *df* = 2, *n.s.*) and proved to be non significant.

On the whole people either answered that the iconic play pieces were the most fun to play with or that it did not make a difference. Even though both groups proved to be equal regarding their fun experienced during the game, almost half of the questions were answered with 'iconic' as providing most fun during the game.

The final questions that were asked to the participants were their general preference regarding the classes of play pieces. Even though the fun experience did not differ between the two types of play pieces after the first 10 minutes of playing the game, the majority of the participants (27 out of 30) preferred to play with the iconic play pieces after having tried both types of play pieces. Most frequent motivation (13 out of 27) was the compatibility with the theme of the game.

6. DISCUSSION

The study presented in this paper raised some points for discussion, including the design of the play pieces, the experiment setup and the experiment results.

6.1 The design of the play pieces

Some of the participants (n = 4) discussed the appearance of the symbolic play pieces. Although these play pieces do not resemble their digital association, they are not completely abstract either. For example, the symbolic camel rider is often mistaken for a signpost. The symbolic play pieces might have looked like iconic play pieces and may have misled the participants. If the symbolic play pieces had abstract shapes like simple cubes, this problem could have been prevented. An additional advantage of more abstract play pieces is that participants could be familiar with such play pieces since they are used in many physical board games, such as Trivial Pursuit and Settlers of Catan.

6.2 The experiment setup

During each experiment, both versions of the game were played for 10 minutes. Because of this time limit, not every participant experienced the same events during the game. Different participants had different strategies to learn the game. Some would try out everything immediately, while others would take their time to think over their actions. Although this could have been solved by ending a playing session after a certain number of events rather than after 10 minutes, we intentionally chose to use a time limit. Ending the sessions based on events would cause similar problems, only this time people who think over their actions have an advantage. Also the chosen approach is more practical planning wise.

The participants were selected to form a mixed group, between 19 and 50 years old: 16 male and 14 female, 15 frequent game players and 15 non-frequent game players. Despite this selection, most of the frequent game players were male (10 out of 15) and most of the non-frequent game players were female (9 out of 15). Also, the frequent players were not equally divided over the two groups: group i→s had 9 frequent players while group s→i had only 6.

To see if board game experience influenced the scores in understanding of the game, the average scores of the frequent players and the non frequent players were calculated as well (see Table 8).

Table 8. Average scores (on a scale of 0% understanding to 100% understanding) of frequent board game players and non-frequent board game players (n = number of participants, M = mean, s = standard deviation).

Type of board game player	Average score (%)
Frequent (n = 15)	M = 46.1 (s = 11.5)
Non-frequent (n = 15)	M = 31.4 (s = 15.2)

A t-test for independent groups (t = 2.99, df = 28, p < 0.01) proved the significance of this difference. Frequent players have scored higher on average than non-frequent players.

The unequal division of frequent players over the two participant groups (i→s and i→s) could have caused the insignificant difference between the two participant groups, in the average understanding of the game (explained in section 5.2). A more equal division could have decreased this difference.

6.3 The experiment results

The evaluation shows that the understanding of the game is not influenced by the appearance of the play pieces. Some of the participants (n = 6) argued that the understandability does not depend on the play pieces, but on the visuals on-screen. Some events are accompanied by clear textual feedback (for example getting robbed by the bandit) while others are only supported by a displayed color (for example finding gold with the detector). The first type of feedback (text) is much more elaborate than the second type (graphics). The textual feedback type used for the bandit could have caused a better understanding of this play piece in comparison to the detector. The more indicative look of the iconic bandit, compared to the iconic detector, might also have contributed to this better understanding. Besides that, participants could have been familiar with a bandit character from other games (for example the 'thief' in Settlers of Catan). The concept of a detector is not that well known, which could explain the low scores for the detector in the tests related to the understanding of the play pieces. In test 2 (performed after the first playing session), only 3 out of 30 participants explained the function of the detector correctly, compared to 19 out of 30 for the bandit.

In both tests related to the understanding of the play pieces, three play pieces were shown and the participants were asked to name their functions. Without having played the game yet, some participants answered functions correctly in test 1. Naming the same correct functions in test 2 results in a learning score of 0; they already knew the functions before playing, so the game did not contribute to this knowledge. Despite this last conclusion, we will never know whether any of the answers were guessed correctly or simply known. Although this is an unpreventable problem, we assume it did not influence our main results.

As explained in section 5.2, the above-mentioned learning scores did not differ on average between group i→s and group s→i. Remarkable is that group i→s scored much higher than group s→i in both test 1 (before playing) and test 2 (after playing for 10 minutes). The high score in test 1 could be explained by the appearance of the play pieces; the participants could have recognized some of the elements named in the explanation of the game when they saw the iconic play pieces. When comparing the understanding of the game after 10 minutes to the understanding of the play pieces per participant at that moment, there appears to be a link. Participants who scored high on the functions of the play pieces (in test 2) also scored high on the understanding of the game. Since group i→s had a much higher average in test 2, one would expect that they also scored a higher average on the understanding of the game. Although a difference was found (41.3 for group i→s vs. 36.2 for group s→i) the average score of group i→s was not significantly different from the average of group s→i. This issue might be caused by the large variance of the individual scores for the understanding of the game, when compared to the variance of the score for the understanding of the play pieces.

Despite the fact that both the understanding of the game and the fun experience during the game are not influenced by the type of play pieces used, still 27 out of 30 participants prefer iconic play pieces for this game. Apparently, the choice of play pieces does not depend on the understanding or the fun, but relies on other issues. Further research is needed to identify these issues.

This study was based on tangible interaction in digital tabletop gaming. In traditional board games, however, tangible play pieces are also used in similar ways. In board games, the king of chess is an example of an iconic object, while the play pieces of Trivial Pursuit clearly are symbolic objects. Therefore the results of this study may also apply to traditional board games.

7. CONCLUSION

The focus of this study was to investigate the differences in game experience between the use of iconic and symbolic play pieces in games. Game experience was split up in the understanding of the game and play pieces and the fun experience.

Regarding the understanding of the game, no difference was found between group i→s and group s→i. In both tests, group i→s had a higher understanding of the play pieces than group s→i. Both groups gained an equal amount of understanding between the first and the second test.

Half the participants thought the game was more fun with the iconic play pieces, while the other half experienced no difference between the two versions of the play pieces. Most participants preferred to play with iconic play pieces and half of them preferred to have new iconic play pieces with each game, even while knowing symbolic play pieces can be re-used in different games.

Neither iconic nor symbolic play pieces seem more suitable regarding the understanding of the game or the experienced fun. However, iconic play pieces are preferred, presumably because they fit with the theme of the game and their appearances are recognizable. Therefore, when the medium is used for one game only, iconic play pieces are more suitable. When the medium is used for multiple games however, there is no clear preference for iconic or symbolic play pieces. Further research is needed to find the most suitable type in that situation. Both versions seem to have advantages; iconic play pieces might be visually more attractive, whereas symbolic play pieces could be preferred for financial reasons.

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9. REFERENCES

[1] Aliakseyeu, D., Martens, J.B., Subramanian, S., Vroubel, M., and Wesselink, W. (2001). Visual Interaction Platform., in *Proceedings of Interact 200* (July 2001, Tokyo, Japan). 232-239.

[2] Bakker, S. and Vorstenbosch, D.(2006). *Entertaible: tangible interaction for games*. Internal student report at the Dept. of Industrial Design at the Eindhoven University of Technology, the Netherlands.

[3] Bakker, S., Vorstenbosch D., Hoven, E. van den, Hollemans, G, and Bergman, T. (2007). Weathergods: tangible interaction in a digital tabletop game, accepted for publication in *Proceedings of Tangible and Embedded Interaction 2007 (TEI'07)* (February 2007, Baton Rouge, USA).

[4] Bohn, J. (2004). The Smart Jigsaw Puzzle Assistant: Using RFID Technology for Building Augmented Real-World Games. *Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004* (April 2004, Vienna, Austria).

[5] Dietz, P., and Leigh, D. (2001) DiamondTouch: A Multi-User Touch Technology. In *Proceedings of the 14th Annual Symposium on User Interface Software and Technology (UIST'04)*. ACM Press, pp.219-226.

[6] Eden, H. (2002). Getting in on the (Inter)Action: Exploring Affordances for Collaborative Learning in a Context of Informed Participation. In *Proceedings of Computer Support for Collaborative Learning 2002 (CSCL2002)*. Boulder, 2002, CO, 399-407.

[7] Fitzmaurice, G. W., Ishii, H. and Buxton, W. (1995) Bricks: Laying the foundations for Graspable User Interfaces. In

Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'95) (New York, USA). ACM Press, pp. 442-449.

[8] Fitzmaurice, G.W. (1996). *Graspable user interfaces*. Ph.D. Thesis, Dept. of Computer Science, University of Toronto.

[9] Gibson, J. (1979) *The ecological approach to visual perception*, Houghton Mifflin.

[10] Heumer G., Carlson D., Kaligiri S.H., Maheshwari S., Hasan W., Jung B., and Schrader A. (2006). Paranoia syndrome – a pervasive multiplayer game using PDAs, RFID and tangible objects. Retrieved 29 December 2006, from: http://www.ipsi.fraunhofer.de/ambiente/pergames2006/final/PG_Heumer_Paranoia.pdf

[11] Hollemans, G., Sander van de Wijdeven, S., Bergman T., and,van Loenen, E. (2006) Entertaible: The Best of two Gaming Worlds. In *MST News international newsletter on micro-nano integration, special issue on Fun and Recreation with Microsystems*, H. Strese (Ed.), (3/06), 9 - 12, VDI/VDE - Innovation + Technik GmbH, Berlin, Germany.

[12] Hoven, E. van den and Eggen, B. (2004). Tangible Computing in Everyday Life: Extending the Current Frameworks for Tangible User Interfaces with Personal Objects. In *Proceedings of the European Symposium on Ambient Intelligence 2004 (EUSAI 2004)* (8-10 Nov, 2004, Eindhoven, the Netherlands). LNCS 3295, pp. 230-242.

[13] Ishii, H. and Ullmer, B. (1997). Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'97)*, 234-241.

[14] JazzMutant Lemur, Retrieved 29 December 2006, from: http://www.jazzmutant.com/lemur_overview.php

[15] Jung, B., Schrader, A., and Carlson, D.V. (2005). Tangible interfaces for pervasive gaming. In *Proceedings of the Second Digital Games Research Association International Conference 2005 (DiGRA 2005)* (16-20 June, 2005).

[16] Magerkurth C., Cheok A.D., Mandryk R.L., and Nilsen T. (2005). *Pervasive games: bringing computer entertainment back to the real world.* ACM Computers in Entertainment, Vol. 3, No. 3, July 2005, Article 4A.

[17] C. Magerkurth, M. Memisoglu, T. Engelke, N.A. Streitz: Towards the next generation of tabletop gaming experiences. In *Proceedings of Graphics Interface 2004 (GI'04)* (17-19 May, 2004, London (Ontario), Canada,). 73-80, AK Peters.

[18] Malone, T.W. (1984). *Heuristics for designing enjoyable user interfaces: lessons from computer games.* In Thomas, John C. & Schneider, Michael L. (ed.) Human Factors in Computer Systems, 1–12. Norwood NJ, Ablex Publishing.

[19] Mandryk, R.L., Maranan, D.S., and Inkpen K.M. (2002). False prophets: exploring hybrid board/video games. In *extended abstracts on Human factors in computing systems of the ACM Conference on Human Factors in Computing Systems (CHI '02)*. 640-641.

[20] Mazalek, A. (2005) *Media Tables: An extensible method for developing multi-user media interaction platforms for shared spaces.* Ph.D. thesis, Massachusetts Institute of Technology, Cambridge.

[21] Patten, J., Ishii, H., Hines, J., and Pangaro, G. (2001). Sensetable: A Wireless Object Tracking Platform for Tangible User Interfaces. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (*CHI 2001), ACM Press.

[22] Prensky, M (2001). *Fun, Play and Games: What Makes Games Engaging*. Chapter 5 of McGraw-Hill, Digital Game-Based Learning.

[23] Rekimoto, J. (2002). SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2002).*ACM Press, 113-120.

[24] Sugimoto, M., Hosoi, K., Hashizume, H. (2004).Caretta: A System for Supporting Face-to-Face Collaboration by Integrating Personal and Shared Spaces. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2004).*

[25] Ulbricht C., and Schmalstieg D. (2003). Tangible Augmented Reality for Computer Games. Retrieved 29 December 2, from http://www.cg.tuwien.ac.at/research/publications/2003/Ulbricht-2003-TanX/

[26] Ullmer, B., and Ishii, H. (1997) The metaDESK: Models and Prototypes for Tangible User Interfaces. In *Proceedings of Symposium on User Interface Software and Technology (UIST'97)*. 223-232.

[27] Ullmer, B. and Ishii, H. (2000). *Emerging frameworks for tangible user interfaces*. IBM Systems Journal, 39(3-4), 915-931.

[28] Underkoffler, J., and Ishii, H. (1999) Urp: A Luminous-Tangible Workbench for Urban Planning and Design. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'99),* ACM Press, 386-393.

[29] Wellner, P. (1993) *Interacting with Paper on the Digital Desk.* Communications of the ACM, July 1993, Vol. 36(7), 87-96.