User Interfaces for Pervasive Games: Experiences of a Formative Multi-Method Evaluation and its Implications for System Development

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Abstract. This paper presents a formative multi-method evaluation on future gaming systems. Following a scenario-driven approach, quantitative and qualitative methods are employed to elicit feedback from different target user populations. Based on the results of the different evaluation parts, a set of design requirements for future home entertainment systems is derived. These requirements are then used to guide the development process of a ubiquitous computing gaming platform. To demonstrate the usefulness of the gaming platform, a sample application is discussed, which is described in the last section of this paper.

Keywords. User Interfaces, Pervasive Games, Evaluation, System Development, Tangible User Interfaces, Human Computer Interaction

1 Introduction

With the emergence of ubiquitous computing technologies, our physical work and leisure spaces are augmented with computing functionality that unobtrusively assists its inhabitants [1]. While early projects focused mainly on supporting productiveness and efficiency in work environments, most current projects aim to foster long-term and low-pace communication and interaction between people in home environments. For example, the *ASTRA* project investigated an asynchronous awareness system that helped related and distributed households to stay in touch with each other [2]. A similar approach was taken in the *interLiving* project [3], which aims at developing technologies that facilitate communication between different generations of family members living in different households. Other projects as, e.g., *EasyLiving* [4] and *Aware Home* [5] concentrate on more fundamental challenges of intelligent home environments.

In addition to these communication-related aspects, future home environments also address fun and entertainment as important driving forces for the permeation of ubiquitous computing technologies in the home. As mentioned above, ubiquitous

computing is concerned with the integration of information technology into our everyday lives, thus bringing the computer back to the real world. This inclusion of real-world aspects in entertainment applications opens up a large space of possibilities to create novel interaction experiences that bridge the gap between virtual and physical worlds.
However, it still has to be investigated if future users of such technologies will adopt their full potential or if contemporary forms of entertainment and gaming are already sufficient. From a user interface perspective, we can clearly perceive that computer games focus the users' attention mainly on the computer screen or 2D/3D virtual environments, and players are bound to using keyboards, mice and gamepads while gaming, thereby constraining interaction. By bringing more physical movement and social interaction into games, we might be able to utilize the benefit of computing systems while at the same time make the games accessible for ordinary people including elders, who were not socialized with playing computer games and who, consequently, do not participate significantly in contemporary computer entertainment. The formative study presented in this paper hence investigates, if there is a demand for future home entertainment technologies that emphasize the physical realities of the players, and if yes, how such technologies will have to be designed in order to have a maximal impact with different target groups.

2 The Formative Evaluation

2.1 Introduction

The evaluation described in this chapter was part of an empirical cross-cultural study [6] conducted at six different sites in five European countries in the context of the EU IST-IP project Amigo, Ambient Intelligence for the Networked Home Environment (http://www.amigo-project.org). While the goal of this evaluation was to elicit feedback from a target user population on concepts for intelligent home environments, this paper concentrates on novel game concepts. It is aimed to obtain feedback from potential users on the usefulness and attractiveness of different game concepts for smart home environments.

2.2 Materials and Methods

In order to get quantitative as well as qualitative feedback, the evaluation was subdivided into two parts with distinct methods and measures. For both parts, a scenario-driven approach was chosen to elicit feedback from a target user population. In the first part, the participants had to evaluate a fictitious scenario regarding its usefulness and attractiveness. In the second part, single aspects of the scenario were discussed in a structured focus group session. To explain individual components of future innovative game concepts to the target users a scenario was used (see Table 1 for core scenario elements).

Table 1. Scenario elements describing the functionality of a future gaming system.

a) It asks for parental permission.	e) It lets the game player interact with body movements.
b) It downloads and shows game play lists.	f) It recognizes friends at the front door and lets them join in the game.
c) It adapts the lights and the sounds of the home to the environment of the game.	g) It recognizes and integrates the game devices of the friend.
d) It displays a video wall to show the game and other players.	h) It downloads the profile of the friend.

Scenario Evaluation. To collect quantitative feedback on the different concepts, the scenario was visualized and shown to the participants in an exhibition-like setup. The participants were asked to rate each scenario element regarding its usefulness and attractiveness and to list the advantages as well as disadvantages of each concept. The stimulus material consisted of visualizations of the scenarios, with a corresponding text as an introduction. Two neighboring rooms were furnished as a reception room with tables and chairs, refreshments, paper, pencils and as an exhibition room showing the visualization of the scenarios. In the reception room, the participants received a general introduction and a short instruction on the tasks that they had to perform in the exhibition room.

Fig. 1. Presentation of stimulus material (left) and assessment of scenario elements (right).

The participants were instructed to form small groups with 2 to 4 people. When they entered the exhibition room, each group was instructed to assess the scenario and its elements. After fulfilling these tasks the group moved to the next scenario. The participants were asked to rank the elements for each scenario according to their perceived usefulness and to list advantages and disadvantages of the elements.

Focus Group. The goal of the focus group discussion was to get qualitative feedback on the concepts described in the scenario and to investigate the expectations and needs for future gaming applications. The discussion was guided by structured questions focusing on the specific aspects of the scenario. The participants first were asked about their current entertainment preferences and then they were asked to develop ideas on how to improve the entertainment experience in the future. The discussion was supported by a metaplan technique. All ideas and comments of the

participants were collected on cards, than clustered and labeled by the participants, and finally rated concerning importance.

2.3 Participants and Schedule

The evaluation was conducted with N=10 participants of two different age classes (see Table 2). One group consisted of three men and two women aged between 16 and 25 and the other group consisted of two men and three women aged between 32 and 38.

Table 2. Overview over participants.

Group	Participants	Gender	Age
Group 1	1	male	15
(15 – 25 years)	2	female	24
	3	male	23
	4	female	15
	5	male	25
Group 2	6	male	35
(32 – 38 years)	7	female	32
	8	male	35
	9	female	32
	10	female	37

The overall schedule for the quantitative and qualitative evaluation session is shown in Table 3.

Table 3. Schedule for the evaluation (3 hours).

Duration	Activity
5 min	Arrival, introduction and explanation
10 min	Warming up
15 min	Presentation of scenarios
20 min	Questionnaires
40 min	Lunch break
50 min	Focus group discussion
10 min	Coffee break
20 min	Clustering and rating of the focus group results
10 min	Unwinding, cooling down, debriefing

3 Results

3.1 Quantitative Results

The questionnaires provided different types of data. In the following sections, the results of the ranking tasks are presented, first regarding the usefulness of the scenario elements, and then regarding their attractiveness. In the subsequent section the general feedback as well as the list of advantages and disadvantages are illustrated.

Usefulness. In the first part of the questionnaire, the participants had to rank the scenario elements regarding their usefulness (1 being the most useful scenario element, 8 the least useful). Table 4 gives an overview over the ranking results.

Table 4. Ranking of scenario elements regarding their usefulness.

Element	Sum	Average	Median	SD
A	28	2,8	2	2,300
B	53	5,3	4,5	1,829
C	36	3,6	3	2,319
D	51	5,1	5,5	2,558
E	42	4,2	4	2,098
F	64	6,4	6,5	1,430
G	40	4	3,5	2,625
H	43	4,3	4	1,767

Table 5 shows the number of participants, which rated each scenario element in one of the first three ranks.

Table 5. Frequency of participants who rated each element in one of the first three ranks.

	Rank 1		Rank 2		Rank 3	
Element	Freq.	Perc.	Freq.	Perc.	Freq.	Perc.
a	4	50%	2	25%	1	12,5%
b	0	0%	0	0%	1	12,5%
c	2	25%	2	25%	3	37,5%
d	1	12,5%	1	12,5%	0	0%
e	1	12,5%	1	12,5%	1	12,5%
f	0	0%	0	0%	1	12,5%
g	2	25%	3	37,5%	0	0%
h	0	0%	1	12,75%	3	37,5%

The evaluation of the ranking task showed that the standard deviation for most scenario elements is rather high. In order to get valid results, the ratings of the first three ranks were accumulated, before prioritizing the scenario elements.

Table 6. Prioritization of scenario elements regarding usefulness.

Priority	Scenario Element	Top3
1	a) It asks for parental permission. c) It adapts the lights and the sounds of the home to the environment of the game.	70%
2	g) It recognizes and integrates the game devices of the friend.	50%
3	h) It downloads the profile of the friend.	40%
4	e) It lets the game player interact with body movements.	30%
5	d) It displays a video wall to show the game and other players.	20%
6	b) It downloads and shows game play lists. f) It recognizes friends at the front door and lets them join in the game.	10%

Attractiveness. In the second part, the participants had to rank the same scenario elements regarding their attractiveness. See Table 7 for an overview of the results.

Table 7. Ranking of scenario elements regarding their attractiveness.

Element	Sum	Average	Median	SD
A	48	4,8	6	3,155
B	50	5	5,5	2,160
C	25	2,5	2,5	1,354
D	48	4,8	4	2,486
E	37	3,7	4	2,163
F	62	6,2	6	1,549
G	45	4,5	5	2,121
H	45	4,5	5	1,900

Similar to the previous part, Table 8 shows the number of participants, which rated each scenario element in one of the first three ranks.

Table 8. Frequency of participants who rated each element in one of the first three ranks.

	Rank 1		Rank 2		Rank 3	
Element	**Freq.**	**Perc.**	**Freq.**	**Perc.**	**Freq.**	**Perc.**
a	2	25%	1	12,5%	0	0%
b	0	0%	2	25%	1	12,5%
c	3	37,5%	3	37,5%	3	37,5%
d	0	0%	2	25%	4	50%
e	2	35%	0	0%	1	12,5%
f	0	0%	0	0%	0	0%
g	2	25%	0	0%	0	0%
h	1	12,5%	2	25%	1	12,5%

Table 9 shows the prioritization of scenario elements, based on the accumulated ratings of the first three ranks.

Table 9. Prioritization of scenario elements regarding attractiveness.

Priority	Scenario Element	Top3
1	c) It adapts the lights and the sounds of the home to the environment of the game.	90%
2	d) It displays a video wall to show the game and other players.	60%
3	h) It downloads the profile of the friend.	40%
4	a) It asks for parental permission. b) It downloads and shows game play lists. e) It lets the game player interact with body movements.	30%
5	g) It recognizes and integrates the game devices of the friend.	20%
6	f) It recognizes friends at the front door and lets them join in the game.	0%

Advantages and Disadvantages. The discussion of advantages and disadvantages mainly reflected the quantitative results from the ranking tasks. The feedback on the different scenario elements could be clustered into three domains:

Adaptiveness of the Environment. The idea of adapting light and sound to the current game situation was the concept most often addressed by the participants of both age groups. Adapting the physical environment to the virtual game atmosphere was regarded as one of the major building block for an enhanced gaming experience and increased realism.

Enhancement of the Social Situation. The idea of extending traditional video games into the real world and thereby enabling rich social interactions between the players was regarded as an attractive feature for new gaming applications. In this context,

easy integration mechanisms for additional players and devices were widely appreciated. Being used to the small effort necessary to participate in traditional board games, the integration of players and control devices into current video games, seems to be a major problem for the average user.

Automatic Control and Security Mechanisms. Although the topic of automatic security and control mechanisms was addressed quite often, the expressed opinions regarding the usefulness of such mechanisms varied considerably. Most users, and especially those with children, liked the idea of automated age control, and regarded this feature as useful assistance in protecting children from inappropriate game content. In contrast, others feared that such autonomous control mechanisms this might lead to a depletion of social contacts and an erosion of parental authority. Although automation was widely appreciated in order to minimize the installation effort for game devices and players, the majority of participants feared that too much automation might lead to a loss of control. Especially functions like the automated access control (scenario element f) raised serve concerns among the participants.

3.2 Qualitative Results

For clarity, the feedback gained during the focus group discussion is subdivided into five groups.

Needs and Requirements. Most participants felt satisfied with existing entertainment devices and remarked that it would be hard to convince them of the benefits of a new entertainment system. Both groups were rather satisfied with traditional board games and therefore quite reserved concerning the need for new entertainment systems. Especially the group of older participants mentioned, that new systems has to be really innovative to be of any interest. A simple improvement of existing features would not be enough to convince them. The younger group was more open for innovations, but noted that existing systems cover all their needs. Hence, the acceptance of future entertainment systems will strongly depend on their functional quality. The older participants further remarked that new systems are likely to be interesting in the first moment, but that classical board games might be favored in the long run.

Basic Qualities. The participants cared most about the compatibility, extensibility and usefulness of the system. They clearly want a flexible system with upgrade options. Both groups remarked that it has to be possible to take the system with them if they move into another house. They would only buy a new system if it offers various functions and a possibility to extend it, so that they will be able to use it for a long time. During the rating task, both groups generated a cluster labeled “extensibility”. This cluster included multiple items claiming options to add new functionality, possibilities to integrate further game parts, as well as an update opportunity for the operating system. All participants agreed that future entertainment system must combine various functions. Similar to modern game consoles, which offer possibilities to watch DVDs, to communicate and to listen to music, a new

entertainment system must also combine various functions related to entertainment. The group with the older participants also remarked that the system must save power. They asked for low power consumption in general as well as an automatic stand-by function, which automatically turns off the system if it is not used for a certain period of time. There was also a common agreement, that such systems must not be too expensive. A price comparable to the price of today's games consoles was considered as appropriate.

System Design Goals. All participants agreed that there has to be a simple way to disable automatic control mechanisms completely. Generally, it was regarded as very important that the user is always in control of the system and never the other way round. Most participants emphasized that the interaction must be easy, quick and intuitive. Some suggested an interface with speech input and output. Therefore, intuitive interaction mechanism mentioned for all situations, ranging from the setup of the system, over its configuration to the daily interaction. In addition, the system shall save time by supporting activities the user would do anyway. Another requirement was to have service persons to deliver and install the system, to give some basic training on how to configure and use each feature, and to be available afterwards to help if problems occur. Furthermore, the system shall not require any maintenance after being installed. Both groups used traditional tabletop games as a benchmark to judge new entertainment systems. Participants in both groups noted that the game board should remain as a physical object. This requirement was explained with the rich social situation while using tabletop games. The participants claimed that they want to play together with their friends, although the system shall offer the opportunity to function as an additional player. One participant explained that real game pieces and game boards would enable a haptic experience and generated an atmosphere on their own, which he appreciated very much. Another participant suggested that the system could add sound or special effects to traditional board games or represent the game board in form of a projection. Another topic, which was addressed by many participants, was security and safety. Most participants were concerned about (software) attacks from outside as well as about potential accidents caused by malfunctions of the system.

Content Design Goals. As mentioned above, both groups emphasized the social aspects of playing games. Generally, the system should help to foster a sense of community between users. This must be considered for each application, no matter if it is a game, a communication system or a movie. Games must offer a single-player mode as well as a multi-player mode for various numbers of players. The system must be able to replace missing human players as well as an option to control non-player characters. All participants expect that future entertainment systems provide better graphics and a more realistic game world than current systems do. Although this was mentioned as a clear requirement, one participant remarked the ambivalence. On the one hand the participants would appreciate an immersive game world, but on the other hand they fear that this may cause losing contact to reality.

Features. Generally, the participants want a useful combination of features realized in independent components. The users should be able to decide on their own, which

features they need and than be able integrate them into the system. But the system should only focus on entertainment. Completely different features of smart home environments, like for example housekeeping functionalities, should not be integrated in the system. Future gaming applications should be able to control the physical environment, e.g. light or sound, in order to adapt the room to the current game situation. The system should also include new technologies, like 3D projections and speech interfaces. Furthermore, the systems should improve traditional board games with additional feedback in form of acoustical and visual effects, and provide an option to simulate additional players. Finally, the applications should represent remote players, who play from a different location, like they were in the same room.

3.3 Resume of the Evaluation

The focus groups showed that an entertainment system must be designed with care to convince people of all ages. Furthermore, all features must be useful and the system must provide an added value to existing entertainment systems. Mediating personal communication and connecting people is regarded as a very sensitive topic. A feature to connect distributed people is only appreciated if the contact would be less intensive or non-existing without the system. But if a direct interaction between people is possible, the system must never replace that. The major goal of an entertainment system is to support a rich social situation with as much direct interaction between users as possible. Additionally, the system should provide a more realistic entertainment experience for games as well as for movies or other content.

4 Derived Design Implications

Given the results of both parts of the evaluation, implications for the design of a future home entertainment system can be derived. These requirements form the basis of the development of a ubiquitous computing gaming platform [7] that evolves from the work within the aforementioned Amigo EU project.

Support for Graphical and Physical User Interfaces. Entertainment applications traditionally make strong use of graphical output to support the immersion into the game. Many of the innovations both in 3D rendering algorithms and rendering hardware are in fact driven by the highly competitive games market. As the participants of the study noted, game applications need to provide both rich graphical output to appeal to the users and additionally integrate non-standard physical interfaces that support the social dynamics of the involved players and link between physical and virtual worlds without requiring exclusive attention. Hence, different forms of interaction, different user interface concepts, and multiple and heterogeneous devices are required as well as a content-adapted presentation including the ambient light and sound condition in the immediate environment.

Flexible Device Configuration. As indicated by the participants of the formative evaluation, the setup of interaction devices in a future game session can vary greatly, depending on what is available at a user's site. Solutions tailored to one specific site that is mostly static in its configuration might make sense in a business context, but since home entertainment naturally aims at mass market deployment the developer of a ubiquitous computing game cannot anticipate the device setup of the end user. One user might possess a certain interaction device, while another user owns a different one. When both participate in the same game session, they should be able to bring their own devices and make use of them. As the participants of the study note, this should involve basically no integration overhead. Accordingly, the game application should be able to operate on a minimal device setup, e.g. a single desktop PC, and adapt to a myriad of additional input and output devices.

Runtime Adaptability. In a home entertainment setting, interaction situations are very little structured with participants joining and leaving at any time. Due to this dynamic nature of the interaction situations, interaction devices need to be flexibly integrated and be added and removed at any point in time, which the participants of the study explicitly point out. Since it cannot be taken for granted that private devices are always available in sufficient quantities (see flexible device configuration), the gaming application must also be capable of dynamically reassigning private devices to different users. In addition to the device configuration, also the game applications themselves need to be adaptable during runtime regarding their modeled rules and game mechanics. This relates to the notion of "house rules" that allow participants of the game to change certain game mechanics as a result of their own playing history. The runtime adaptability of traditional tabletop games is one of the reasons for their continuing success despite the technical superiority of computer entertainment. This point clearly relates to the participants' notion of traditional board games as benchmarks for future gaming systems.

User Interface Orchestration. Lights and sound should be adaptable to the contents of the current entertainment application. Obviously, the orchestration of user interfaces is a crucial point in ubiquitous computing gaming applications. For dramatic reasons, it is important to make effective use of the various mostly output devices in a smart space. For instance, story-telling elements such as the infamous cut-scenes from contemporary computer games demand for large public displays to have the intended immersive effect. When heterogeneous interaction devices with different interaction characteristics are integrated in a smart home environment, it is essential to utilize each single device in accordance with its interaction affordances. Hence, a coordination infrastructure needs to be aware of device characteristics in order to distribute user interfaces among interaction devices.

Appropriate Modeling of the Social Space. As the participants of the study remarked, it is essential for a future entertainment system to support the interaction between humans in their natural environments, instead of forcing humans to communicate via a computer. Consequently, when dealing with multiple users, an inherent distinction between private and public information must be made. Notes taken in a negotiation meeting, for instance, must not be directed to a public display.

For entertainment applications, it is often favorable to further introduce multiple degrees of privacy for game events, so that different degrees of shared, public and individual knowledge in the social space can be utilized by a game application to foster cooperation and competition between human participants. The gaming platform must therefore inherently address information representation and information flow to ensure that the social space is appropriately provided with information form the virtual domain (cf. user interface orchestration).

5 A Platform for Future Home Entertainment Applications

The requirements deducted from the user evaluation that were discussed in the previous section, inform the development of a smart home gaming platform that integrates various physical interaction devices and adapts the ambient parameters of the players' rooms accordingly. This allows the realization of immersive, stimulating entertainment applications without having to deal with the complexities that ubiquitous computing environments introduce to the development of interactive applications.

Fig. 2 demonstrates how the ambient parameters of the players' environment are adapted to the atmosphere conveyed by the gaming application. This alteration of the physical reality enhances the immersion of the gaming experience. According to the preferences of the subjects in the study, this is an important feature beyond traditional computer and video games needed to convince the more hesitant population of older consumers (group 2).

Another prominent requirement found in the study was the easy integration of various physical interaction devices in a game session. Since board games were nominated in the study as references and benchmarks, the physical devices supported by the platform mainly relate to interaction metaphors found in board games. In the following sections, two such devices are discussed.

5.1 The Smart Dice Cup

A heavily augmented version of a traditional dice cup called Smart Dice Cup is used for representing the central act of rolling dice in a ubiquitous computing game. Dice are crucially important components of a wide range of games. They are used for creating variations in the game flow. By rolling dice, an element of chance is introduced to an otherwise static and deterministic flow of game actions. The chance in the dice, however, is not equal to the generation of a random number. Rolling dice involves both a physical act and skill (some people and some dice roll better results than others) as well as a social mechanism to supervise and control the physical act, because cheating is a common phenomenon associated with this particular way of adding variability to games. The Smart Dice Cup is shown in Fig. 2.

Fig. 2. Adaptation of light and sound for immersive experiences (left) and the Smart Dice Box (right).

The interaction was designed to be as similar to a traditional dice box as possible. To generate random numbers, the device is lifted, shaken, put on a plain surface upside down, and then finally lifted again to see the results. However, in contrast to traditional dice, the sum of the spots is not counted from the physical dice after being tossed on the surface of the table. Instead, the spots are displayed via light emitting diodes (LEDs) on the surface of the dice box top. Shaking the device also emits a sound mimicking the sound of shaking a traditional dice box, although the integrated sound hardware does hardly deliver sound of acceptable quality. Since the smart dice box is capable of communicating with the environment via radio transmission, it is more preferable to let another sound source outside the device perform the respective audio output. In addition to the basic interface of shaking, dropping and turning the device, there is also a conventional button interface with a graphical display integrated in the top surface of the dice box. The button interface is used for advanced configuration of the device when no other, more sophisticated interface such as a respective GUI application (running on a nearby PC) is available or when single dice are to be “held” or “released”, i.e. when they are to be included or excluded from tossing. Each of the five dice displayed on the surface of the dice box consists of seven red LEDs that represent the spots of the respective die. Whenever the device is shaken, the respective light patterns change in accordance to the tossed result. A small green LED is used to indicate whether the respective die is held or released, i.e. if its face changes when the device is shaken. To toggle between holding and releasing a die, a small button is associated with each die that turns the respective green LED on or off with each press, thus ensuring an intuitive way of changing the individual held states by providing visual feedback. The Smart Dice Cup is an important physical building block for ubiquitous computing games. Since rolling dice is a central component in many tabletop games, the transition between the physical act of rolling dice and the respective virtual processing is crucial for realizing effective hybrid games.

5.2 Sentient Game Boards

Another class of custom-built interaction devices also relate directly to the domain of board and tabletop games. The interaction design of board games is proven to support social group situations effectively [8], partly due to the horizontal orientation of the display. This facilitates direct face-to-face communication among players. The common turn-taking, slow-paced game styles let the board interface only briefly and infrequently demand exclusive attention from individual players. The interaction with a sentient game board that conveys its physical state to a virtual application should be as natural and simple as with a traditional game board. Physical objects should simply be put on a dedicated horizontal area and hereby represent their own positions. Due to the augmentation with information technology, it might be possible to achieve additional benefits to the mere sensing of the physical artifacts. For instance, in contrast to a traditional game board, a smart board might be used as an additional output device and display dynamically changing game boards, if it includes a screen, or convey information via LEDs or other means. Likewise, playing pieces might be equipped with additional functionalities. This includes a simple memory or unique identification capabilities by e.g. integrating RFID tags or even integrating entire particle computers. Some platforms such as Smart Dust are only a cubic millimeter in diameter, thus allowing for being integrated into small-scale artifacts such as typical playing pieces. There are multiple potential realizations for sentient game boards each having unique advantages and drawbacks. In the following sections, two examples are presented.

Magnetic Fields. Magnetic game objects can be sensed very inexpensively by magnetic field sensors built into a game board. These simple reed sensors are triggered, whenever a magnetic field of a certain strength is sensed. Building a respective game board thus comes down to finding the matching relation between the strength of the magnets integrated in the playing pieces and the sensitivity of the reed sensors. While a position recognition based on a grid of reed sensors works robustly, such sensors can not be used to determine an object's identification, i.e. objects would have to be identified by the strength of their magnets, however, as the field strength decreases with the distance to the sensor, variations in positioning would result in different field strengths at the sensors. This lack of object identification capabilities is, of course, a severe drawback to the technology. As an augmentation to the simple and inexpensive reed sensors, Hall Effect sensors can be applied that measure magnetic fields perpendicular to the Hall element, i.e. a single magnetic object results in differing sensor magnitudes depending on its orientation. Thus, the orientation of playing pieces can be sensed in addition to their positions. This allows for interesting new game elements as e.g. in spy games, where players can try to sneak past guards that face to a different direction unable to "see" them.

Electric Resistance. One of the benefits of magnetic field sensors is their wireless operating mode. It is sufficient to put or hold a piece near a sensor in order to detect it. This advantage cannot be realized with any solution involving electric current. However, when electricity flows through playing pieces, varying resistors built into them allow for a cheap, robust and fine-grained identification of an arbitrary amount

of pieces. The real strength of electric current however lies in the extreme simplicity of providing playing pieces with discrete states that change within individual pieces. For instance, as shown in the prototype board in Fig. 3, the chest piece is currently open. By closing it, the virtual representation of the physical piece would change from an open to a closed state. Similarly, continuous state changes such as pieces' orientations are possible. The wizard and the blue creature are facing towards distinct directions as visualized in the virtual counterpart application. By turning the physical objects, the virtual representations would rotate accordingly. Such discrete and continuous state changes are simply implemented by integrating switches and potentiometers into the pieces that alter the objects' resistances.
Apart from the disadvantage of the necessary physical contact of the pieces, the technology offers significant advantages over magnetic solutions including object identification and the unique feature of having discrete object states. Otherwise, its features are comparable to magnetic solutions, both are cheap, can interoperate with simple output mechanisms such as LEDs, mobile boards can be realized, and they work robustly enough.

6 Sample Application

With physical interaction devices such as game boards and dice boxes, one can develop future home entertainment applications that provide the features asked for by the participants of the study. One such gaming application called "In Search for the Amulet" [9] was created as a proof-of-concept demonstrator.

Fig. 3. A Sentient Game Board (left) and sample application 'In Search for the Amulet' (right).

With this prototype, the aim was to develop a simple, yet challenging game that average visitors in an open house situation can grasp immediately. It should show the potential of hybrid games by presenting a believable and beneficial distribution of game elements along virtual, physical, and social dimensions. The game prototype revolves around a physical game board on which a map of 64 fields is shown. The game board functions as an interface between real and physical world in that an array of integrated RFID sensors transmits the positions and identities of playing pieces to a software application. Two players move their physical playing pieces over the map to

search for shards of broken amulets and other items hidden on the map. Once a player collects all the shards of a single amulet, she wins. Several events and also virtual characters aggravate this endeavor. For instance, a wicked kobold moves around the virtual representation of the game board and talks to the players from time to time, e.g. telling one player what items the other player has collected so far or stealing items from one player and selling them to the other. Apart from the physical game board and the dice box, each player has a small display that shows private information the other player is not allowed to perceive, such as the content of her bag or the effects of private events (meeting with virtual non-player characters, being caught in a trap, etc). To further underline the integration of both virtual and physical elements, the weather conditions present in the game world (players can take less steps in storm or lightning), are also represented as physical effects. For instance, in sunny weather, a lamp shines directly on the game board, whereas real wind is created via a fan controlled by the game logic. To ensure the game play to profit by the provision of direct face-to-face interaction between the players, trading items between both players is a central element of the game, since one player might have found an item the opponent is in need of and vice versa. It requires a great deal of negotiation and pretence skills to convince the other player to give away her shards without arousing suspicion that exactly these shards might mean sudden victory for the opponent.

7 Conclusions

In this paper presented a formative evaluation on future home entertainment systems. A scenario describing a future gaming environment was used to illustrate new game concepts and interaction techniques. In a two-step evaluation process, the scenario was presented to a target user population of two age groups. In order to elicit from the participants on the different scenario elements, questionnaires as well as a structured focus group discussion were employed. The user feedback was used to define a set of design requirements for future home entertainment systems, which were than materialized in form of a ubiquitous computing gaming platform. The usefulness of this gaming platform was confirmed through the development of a sample application.

The approach taken to develop pervasive gaming applications that are comprised by a distributed set of heterogeneous interaction devices has the implication that the single components, such as the dice cup or the game board, are interchangeable. By decoupling UI components from the actual gaming applications, it becomes irrelevant, if e.g. a physical game board, a 3D rendered display of the board, or a simple magnified 2D GUI control e.g. for visually impaired people is used to control the movements of the playing pieces. In this sense, the approach follows the notion of “universally accessible games” brought up by Grammenos et al. [10]. By explicitly taking tangible interaction devices into account that go beyond traditional graphical user interfaces, accessibility among non-computer gamers should be improved, as e.g. the affordance of a dice cup is to simply shake it, which requires no previous computer interface knowledge. Ullmer and Ishii [11] point out the inherent feature of a tangible interface to unify representation and control, which makes a TUI faster and

more intuitive to use than most graphical interfaces. This applies also to game related interfaces such as [12], which discusses a magic wand, or [13] which deals with smart playing cards as supportive interfaces.

So far, we have developed the platform from the requirements of our evaluation' subjects with the flexibility to support different interaction devices for different user groups. The next step will be to evaluate the platform with different user groups in order to gain more insights on which kinds of gaming interfaces appeal most to which user groups.

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