Role Assignment Via Physical Mobile Interaction Techniques in Mobile Multi-user Applications for Children

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Abstract. The development of engaging user interfaces that support collaboration is a great challenge – in particular if users are children. We consider mobile phones as appropriate devices for multi-user interactions with a system because novel forms of physical mobile interaction techniques with smart objects yield lots of benefits, such as being intuitive and playful to use, but also addressing children's needs for curiosity. In this paper, we introduce our approach to multi-user game-like scenarios within an ambient intelligence context which are controlled via different mobile phones and their supported interaction techniques. By providing children with multiple mobile phones we structure interactions in multi-user settings and prevent undesirable situations, such as dominant users or off-topic actions. Children get access to various physical mobile interaction techniques for interactions with smart objects which are all required to fulfill one common goal. In this way, social interaction arises in a natural manner. In order to motivate and evaluate our approach, we developed two ambient intelligence applications called *The World Explorer* and *The Escape*. Results of a user study showed that children liked working in a group and that physical mobile interaction techniques are a promising approach to increase engagement and foster social interactions but also to prevent chaotic situations by balancing the distribution of activities in multi-user settings.

1 Introduction

Mobile phones have successfully become part of our everyday life and are the first pervasively available interaction device. Almost everybody owns a mobile phone and primarily uses it as a channel for human-human communication, such as exchanging text messages or making phone calls. Nevertheless, we see lots of unused potential of mobile phones for human communication and social interactions especially in context of ambient intelligence applications.

Recent mobile phone technologies facilitate the development of user interfaces that offer more natural interaction styles, such as *pointing*, *touching* or *tilting*, based on a growing number of built-in sensors. The objective of this paper is to explore the potential of multiple physical mobile interaction techniques as a means to stimulate face-to-face collaboration between children and give developers the posibility to balance distribution of activities within multi-user settings. As Druin points out in [1], children want to use technologies which support their curiosity, their love of repetition and their need for control. The new physical mobile interaction techniques address several requirements for children because they are intuitive and playful to use but also less obstructive for real world interactions [2]. Children may freely move around in the physical environment with their mobile phones, interact with real instrumented objects, for example, by *touching* them with their mobile phone, and engage in face-to-face conversation with other children.

Zagal et al. [3] distinguish between spontaneous and a stimulated social interaction in multi-player games. Spontaneous interaction occurs naturally and is not forced through the game arrangement whereas stimulated social interaction is mandated by the game. In our case, we aim at stimulating social interactions by distributing several mobile phones with different technical features. That is not all children will have the same interaction possibilities. As a consequence, they will only be able to accomplish a task, such as solving a puzzle, if the technical features of all available mobile phones are combined. We defined role assignment via physical mobile interaction as follows. A task is split to more elementary actions. These elementary actions are assigned to several users. Thus, we force children to collaborate because only by working together they can successfully complete a task which is their common goal. As a consequence we assume that by forcing children to share resources and to arrange and agree on actions, collaboration should occur in a natural manner. The distribution of mobile phones directly corresponds to an assignment of roles which makes children aware of the overall performance as a team and each individual's contribution. In addition, mobile phones may be handed around in order to involve other members of the group in a decision and re-assign roles in a spontaneous manner.

To study the impact of multi-user applications controlled via mobile phones, we implemented two ambient intelligence indoor scenarios: *The World Explorer* and *The Escape*. *The World Explorer* is a computer-based quiz where children may collaboratively acquire knowledge through interactions with their environment and answer questions on different countries. *The Escape* is an interactive story telling environment where children jointly watch a scene on a public display and collaboratively decide on the continuation of the story. Both applications are pervasive multi-user games which enable interactions with real instrumented objects in the children's physical environment as well as virtual characters on public displays. In both scenarios, children may take on certain roles which are reflected by the use of a specific mobile phone that enables certain forms of interaction. The children only succeed in the two games if they are willing to collaborate.

In the next section, we first discuss interaction styles for ambient intelligence environments that may be easily realized by making use of novel mobile phone technology. After that, we report on earlier studies that investigate how to foster multi-user interactions by appropriate interaction techniques. We then describe the typical technical implementation of a multi-user application based on role assignment.

In particular, we discuss how different roles can be assigned by making use of multiple mobile phones' technologies. Finally, we report on an empirical study that has been conducted with the aim to explore the potential benefits of our interaction techniques for social interactions between children but also usability issues and engagement of children.

2 Physical Mobile Interaction

Recent mobile phones support several network interfaces as access to infrastructure-based networks (GSM/GPRS/UMTS) or ad-hoc-based networks (Bluetooth/Infrared/NFC). These network capabilities and a growing number of built-in sensors such as cameras, accelerometers and temperature sensors support novel forms of mobile interaction techniques. These progresses in technology are the basis to build novel mobile interaction techniques [2. 4]. One example is called *touching* which uses the mobile phones network interface NFC (Near Field Communication). NFC enables selections of instrumented RFID-objects. There are several further physical interaction techniques such as *scanning* and *pointing* [2, 4]. Ballagas et al. give a comprehensive overview on various possibilities to use a smart phone as a ubiquitous input device [5].

These new forms of mobile interactions can address some usability problems of mobile phones, such as the reduced amount of information that can be displayed on miniaturized screens and the limited input functionalities of a mobile phone's keyboard. The benefit is that interactions with the mobile phone are directly mapped onto interactions with the physical world surrounding users. Thus, interactions with the real world are called *physical mobile interaction techniques*.

Until now, research with physical mobile interaction has mainly concentrated on the development of new interaction techniques and their comparison, but did not use several phones and their supported physical mobile interaction techniques as interfaces to multi-user applications for children. Ballagas et al. [6] used a mobile phone and its built-in camera as an input sensor to control a mouse pointer on a public display, a technique which is called *sweep*. Another technique called *point&shoot* enables a selection of widgets [6]. We describe in [2, 20] techniques called *scanning*, *pointing* and *touching* which can be used to select objects in a smart environment. They used these techniques in user experiments to analyze in which context which interaction technique is preferred by the user [2, 7, 20]. This paper extends our previous work by not only concentrating on single-user interactions with smart objects. We decided to use existing physical mobile interaction techniques and investigate multi-user settings for children. Moreover, we want to find out whether children have any preferences for a mobile interaction technique represented by a role and finally if children feel engaged when interacting in our application settings. Thus, our three main research goals were to investigate the children's level of engagement and their social behaviour when interacting with different physical mobile interaction techniques as well as usability issues.

A significant amount of work has been devoted to location-aware applications until now. In these applications mobile phones and information about users' location are used in multi-user settings. Examples include pervasive games, such as *Savannah* [8], *Can you Hear me* now [9] or *Paper Chase* [10]. In contrast to our work, these examples only used the users' location as real-world input, but did not include physical mobile interaction techniques which must be performed explicitly. Moreover, they did not assign user roles via different mobile phone technologies.

Beale [11] described different multi-user applications for human-human communication using mobile phones, such as a Bluetooth dating service or a bogging service. In contrast to our work they did not use mobile phones to allow for interactions with the physical world and their applications were not directed to children.

We see benefits in combining different physical mobile interaction techniques as a basis to create hands-on to use, curious and playful user interfaces for children. In particular, we expect that multiple physical interaction techniques increase fun and enhance the children's willingness to interact with a computer system through their ambient intelligence world but also prevent dominant users and decrease off topic tasks by balancing the activity level of all involved children in a multi-user application.

3 Multi-user Interaction

CSCW researchers regard the assignment of roles as an important means to structure collaboration between the single members of a team. We consider role assignment via physical mobile interaction techniques a promising way to foster social interactions between children. Kirschner and Van Bruggen argue that social relationships can be built if children establish a joint understanding, trust, and responsibility [12]. We suppose real world roles can address these three requirements. Children need to agree on the distribution of roles and the responsibilities associated with them. They need to trust each other because each child is required to achieve a common objective and finally all children are responsible to make best use of their roles for group success. Apart from supporting the establishment of social relationships, role play might enhance the attractiveness of the software since children can swap their roles when applications are played more than once.

A number of collaborative interfaces for children have been developed, such as *KidPad* [13] and *Teatrix* [14], that allow children to collaboratively create stories on a virtual stage. These applications make use of multiple mice or tangible interfaces, but in contrast to our work, role assignment is not based on the distribution of interaction devices. For instance, in *Teatrix* [14] children may select the roles of characters that they control in a story, such as the role of a hero or that of a villain, but role assignment is done via a GUI. There are also a number of game-like environments which make use of role assignment. Savannah [8] is a pervasive game where children take on the role of lions. Other examples are the pervasive games *Paranoia syndrome* [15] and *Virus* [16]. *Paranoia syndrome* defines three different kinds of role. Children can take on the roles and skills of a technician, doctor and scientist, but these definitions are not based on physical mobile interaction techniques as in our case. In *Virus*, children take on the role of a virus and transmit it via their mobile devices by getting within proximity of other users. In this way, complex algorithms can be learnt in a simulation. These three examples provide evidence of the fact that children like role playing games.

Of particular interest to our own research are studies that investigate how collaboration between group members may be supported by appropriate use of interaction devices. There is empirical evidence that children seem to be more engaged and more active when playing on a computer with multiple input devices and cursors than when using a computer by themselves. Inkpen and colleagues [17] observed that giving each child an input device had a positive effect on collaboration even if only one child could interact at a time. Mandryk and colleagues [18] investigated the use of handheld devices to foster collaboration between children in a game. A study revealed that children preferred to play the game with friends than by themselves and that the children spent a great deal of time interacting with each other. We assume that similar effects will be achieved if children are equipped with various mobile phones to interact with an application. That is several mobile phones are distributed and used as interaction devices within their ambient intelligence world. In our case, interaction devices are, however, used in an asymmetrical manner. That is not all users are able to accomplish the all steps of a task to complete a goal because the phone that is assigned to them might not support a specific activity.

Based on this research, we came up with the following idea. We decided to create multi-user applications controlled by mobile phones and their supported physical mobile interaction techniques. To prevent dominant users and chaotic interactions in multi-user applications we decided to split a task in more elementary user interactions and assign these different interactions to different user roles. We use a simple task to illustrate role assignment: A user first wants to request information and therefore selects an object, then he interprets the received information about the object by evaluating it on several aspects and finally reacts to the interpreted information by executing an option. The example illustrates that the task requires three basic actions of the user: Initiation, Evaluation and Execution. Our idea of role assignment is using these three required actions to successfully complete a task and assign the three actions as user roles to children. In the example we have the role called *initiator* who is the requester of the information, the *evaluator* who receives and interprets information and finally the *executor* who is selecting an option. These roles can be mapped to physical mobile interactions techniques in several ways. We decided to map the role of the initiator to the physical mobile interaction technique called *touching*, the role of the evaluator to *scanning* and the executor to *tilting*.

4 Multi-user Applications

Based on our ideas about role assignment in multi-user applications within an ambient intelligence world, we have implemented two prototypes: (1) *The World Explorer,* a mobile Computer Supported Collaborative Learning (mCSCL) application and (2) *The Escape,* an interactive storytelling system. We implemented two types of applications that address different content, but employ similar interaction techniques to realize the role concept in order to investigate whether the type of the applications has any impact on social behavior, children's engagement for a physical mobile interaction technique and usability issues. In the following we describe the basic concept, the mapping between roles and physical mobile interaction techniques and an abstract description of the architectural implementation of our two applications.

4.1 Applications

The World Explorer is a mobile and pervasive learning software that supports multi-user interactions for children by combining several physical mobile interaction techniques. We assigned the role of the initiator, evaluator and executor via the techniques *touching*, scanning and *tilting*. The objective of this application is to enhance learning about aspects of different cultures in a playful and entertaining manner by a virtual journey around the world. In *The World Explorer*, different physical locations in the classroom represent different countries in the world. Thus, children can move in their physical environment which corresponds to a virtual travel to a certain country. Once children have moved to one of these countries, they can find different physical objects representing several themes, such as music or geography (see Figure 1).

Fig. 1. Smart Objects as Interaction Target for Physical Mobile Interaction *touching*

Children can select a topic and ask for information related to the topic in terms of a multimedia presentation or they can directly request a question related to the topic and try to answer it. We expected *The World Explorer* to support collaboration between children by defining different fields of activities that correspond to a particular role (initiator, evaluator and executor). The distribution of roles was supposed to stimulate social interactions because each role and the associated skills are required to fulfill a team's common objective, namely to answer as many questions correctly as possible. Figure 2 shows the role assignment of the initiator, evaluator and executor in *The World Explorer*. The initiator selects a country and its topic by interacting with smart objects in the ambient world via the technique *touching* which initiates a request for information about that topic. The evaluator receives information via the technique *scanning* which can help answering the question and the executer can answer the question displayed on the public display via the technique *tilting* (see Figure 3).

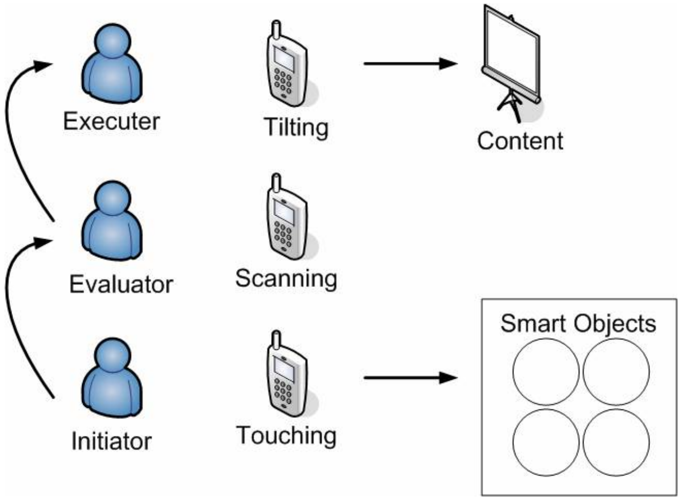

Fig. 2. Role Assignment of The World Explorer

Questions and answers are presented by a team of virtual reporters on the public display. These reporters guide the children during their world travel by introducing countries, themes and questions, but also by providing help during the game itself. For example, they inform the children if one role has not yet been occupied.

Fig. 3. Virtual Conference with Reporters

We can use our approach of role assignment for other applications as well. To illustrate the generic approach we developed another application called *The Escape*. It is a story telling software which automatically generates interactive 3D animated stories. This story is told from the perspective of a dwarf who is held prisoner by the orcs. Apart from the dwarf, there are two further virtual characters: an elb and an orc. In our stories, the dwarf wants to escape and asks at certain decision points the children what strategy to follow. In particular, the dwarf can choose out of three different options which are represented as smart objects. The common goal for children playing *The Escape* is helping the dwarf to successfully escape.

Children can decide on the progress of the story by selecting one of the smart objects, but they do not know exactly which actions are associated with them and the resulting consequences for the story, because the usage of the objects depends on the current story context. Thus, children first select one of the supported smart objects to request hints and interpret its usage for continuing the story on the consequence for the dwarf. Thus, children can jointly discuss the single options and hints to agree on which option to select. Finally, an object can be selected and the story goes on. For *The Escape* we defined two real world roles to take on the initiator and the combined role of the evaluator and executor.

The initiator can apply the physical mobile interaction technique *touching* and pick up one of the offered real world objects, which are physical objects augmented with RFID-tags. We used several smart objects such as a stone, a sword or a key representing progress of the story. The combined role of evaluator and executor automatically receives hints from the oracle regarding the smart objects in the current context of the story because of her physical mobile interaction technique *scanning*. Thus, she gets an idea about the consequences of the different options.

Overall, *The Escape* is a storytelling application that aims at encouraging social interactions between children, because children have to collaboratively decide on the best strategy for the dwarf.

4.2 Architecture

In the following, an abstract architecture for applications, such as *The World Explorer* or *The Escape*, is described to provide a better understanding of the general concepts underlying our implementation (see Figure 4). For user interaction, we deploy several mobile phones, each of them requiring different physical mobile interaction techniques that correspond to the roles of the initiator, the evaluator and the executor.

The initiator requires a mobile phone which enables him to initiate a request. In case of *The World Explorer* the initiation is done by selecting a smart object in the physical environment via the technique *touching* which requires a mobile phone with a built-in RFID reader. We used the Nokia 3220, its NFC shell and the Nokia NFC & RFID SDK.

The evaluator uses a mobile phone that enables him to receive information. We used the interaction technique called *scanning* on the mobile phone of the evaluator and pushed information (text, image, audio or video) via Bluetooth to the phone.

The executor requires a mobile phone that enables him to trigger an event. In our case the executor selects an option via scrolling through options and selecting one of them. We used the technique called *tilting* to scroll through options via *tilting* the phone to the right and to the left or up and down. The Samsung SGH E760 supports a built-in accelerometer and an API to receive such *tilting* events.

Apart from the mobile phones and the smart objects a GUI on a public display is required to present the virtual world and a file server is required to support the evaluator with the relevant information. Moreover, a server is needed to control the logic of the application which particularly includes the coordination of the different user roles.

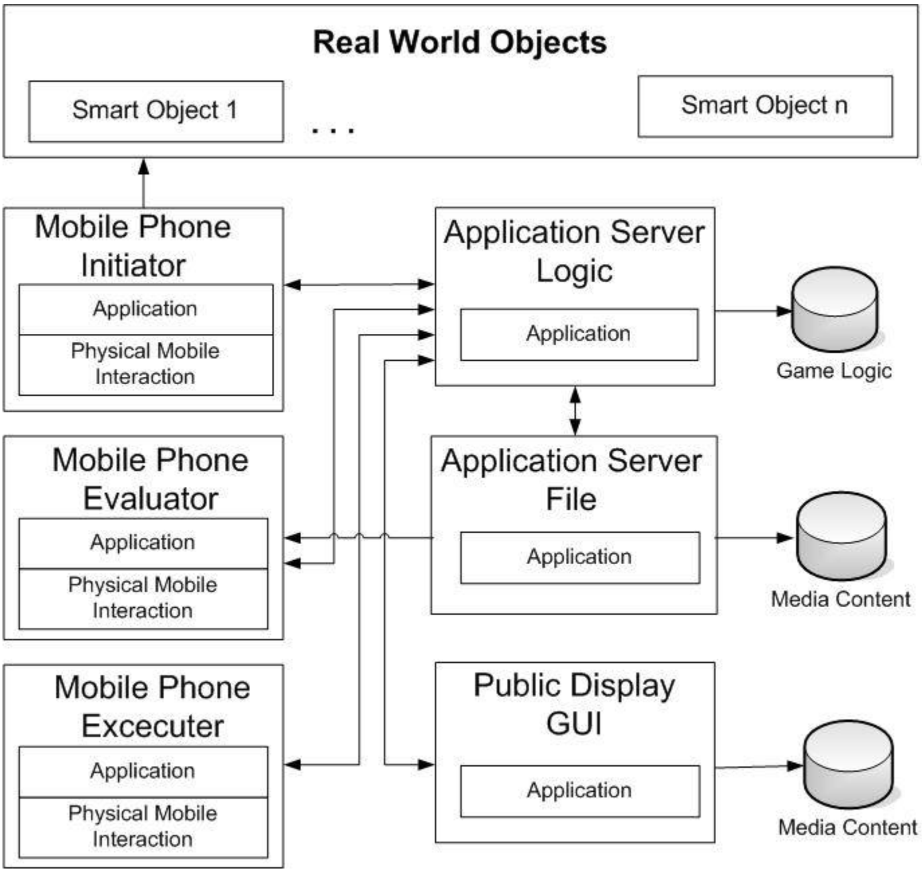

Fig. 4. Abstract Architecture

5 Evaluation

We evaluate our approach to multi-user mobile interaction by means of the two applications: *The World Explorer* and *The Escape*. In particular, we conducted a user study with 48 children at the age of 9-15 years with an average age of 12.43. 11 of the subjects were male and 37 female. We used two applications for our evaluation in order to investigate in how far our findings may be generalized. In the following, we outline the experimental setting and discuss our results.

5.1 Experimental Setting

First of all, we were interested in the children's attitude towards multi-user applications that are controlled via different mobile phones and their physical mobile interaction techniques.

Via questionnaires and video observation, we investigated whether children found find it curious and engaging to use mobile phones and mobile interaction techniques or not and if there are any preferences for specific physical mobile interaction techniques. We compared these results to former results of a studies described in [2, 20].

Moreover, we hoped that the results of the analyzed video recordings would help us to identify potential usability issues regarding the different physical mobile interaction techniques.

Finally, we aimed at investigating the social behavior of children when roles are assigned to them via physical mobile interaction techniques. In this vein, we captured videos of the tests and analyzed them focusing on on- and off-topic communication, social interactions as well as the distribution of user activities. In sum, our user study addressed the following three goals:

- Engagement in form of preferences for a physical mobile interaction technique which is evaluated via a questionnaire and video observation
- Usability issues for children when using physical mobile interaction techniques which is evaluated via video observation
- Social interactions in form of group activities and the influence of role assignment via physical mobile interaction which is evaluated via video observation

Each test was structured in four phases. First, we asked children general questions about mobile phones, computer games and their media usage in general. Before starting the tests, we showed and explained the two applications, the mobile phones, and the corresponding physical mobile interaction techniques. Then, the children tested in groups of three or two both applications and each role of *The World Explorer* and *The Escape*. Children could freely use the applications. We only switched the roles after some interactions. We alternately started with *The World Explorer* or with *The Escape* for the different groups to prevent any biases. After the children had finished their tests, we asked them specific questions about the two applications to investigate their level of engagement for a physical mobile interaction technique and for the single applications

5.2 Results of Questionnaire

In the general part of our questionnaire we asked children for their background in mobile phone and media usage. Only 12 out of the 48 children did not own a mobile phone, but all of them had already played games on mobile phones or on a computer. They spent at least two hours per day alone watching television or sitting in front of a desktop PC playing games. As we were highly interested in social interactions and group activities, we first asked the children rate on a scale from one to five how much they like group activities for problem solving where one means not at all and five means very much. The average value of the result is 4.58 which was significantly above the average value of three ($t(47)=17.892$, $p<0.001$).

Figure 6 and 7 present the results of the questionnaire we gave the children after performing the tests to determine their level of engagement and their preferences regarding a specific mobile interaction technique.

Touching. The results illustrate that most children liked best *touching* in *The World Explorer* (27 children) and in *The Escape* (31) which was represented by the role of the initiator. Some of them told us that they preferred *touching* over other physical mobile techniques because it is easy to use, highly active and curious which is in line with the results we obtained in an earlier evaluation [2, 20]. Children liked to easily pick up real world objects.

Tilting. 7 children liked *tilting* represented by the role of the executor most in *The World Explorer* and pointed out two reasons. On the one hand they liked the special usage of the mobile phone and on the other hand they liked the ability to interact with the public display and log in answers.

Scanning. Finally, in *The World Explorer* 9 (11 in *The Escape*) children liked *scanning* represented by the role of the evaluator. They preferred the role of an evaluator because they considered it as advantageous to get hints from the system and thus acquire more knowledge which they can give to other children.

Overall, we can say, that children liked *touching* most as an interaction technique which is independent of the specific application. We interpret the results as follow. Children want to take over a highly active part in games which includes innovative interactions with mobile phones, but the interaction technique should still be quick and easy to use. In comparison to the results, we reported on in [2, 20], we identified an additional factor that determines a user's preference for a specific mobile interaction technique. Not only a user's physical location and current activity is important, but also the novelty of a mobile phone must be considered. Curiosity and the level of activity can increase or decrease the motivation of users and consequently their preference for a physical mobile interaction technique and its associated role. Table 1 shows overall children's attitude towards the three physical mobile interaction techniques regarding usability, activity level and innovation. The table is based on the verbal feedback we got from the children.

We also compared the children's preferences regarding the two applications. We asked them to rate several catchwords between one and five where five represents the best rating. The averaged results showed that the children considered the *The World Explorer* and *The Escape* as fun (*The World Explorer*: 3.98 / *The Escape*: 4.15), cool (3.92 / 4.25) and exiting (3.42 / 4.08). t-tests for one sample revealed that all values were significantly above the average value of 3.0 ($p<0.015$ for exiting in the case of the *The World Explorer*, $p<0.001$ in all other cases). A paired samples t-test revealed that the differences were significant for exiting ($df(47)=-4.363$, $p<0.001$) and cool ($df(47)=-2{,}141$, $p<0.037$). These results were also confirmed when asking the children for their preferences. Overall, 55 % children preferred *The Escape* whereas only 21 % preferred *The World Explorer* and 24 % liked both applications at the same level.

Table 1. Children's classification of the different Physical Mobile Interaction Techniques

	Usability	**Usability**	**Innovation**
Touching	Easy to Use	Highly active	Curious
Tilting	Difficult to Use	Active	Curious
Scanning	Easy to Use	Very Passive	Ordinary

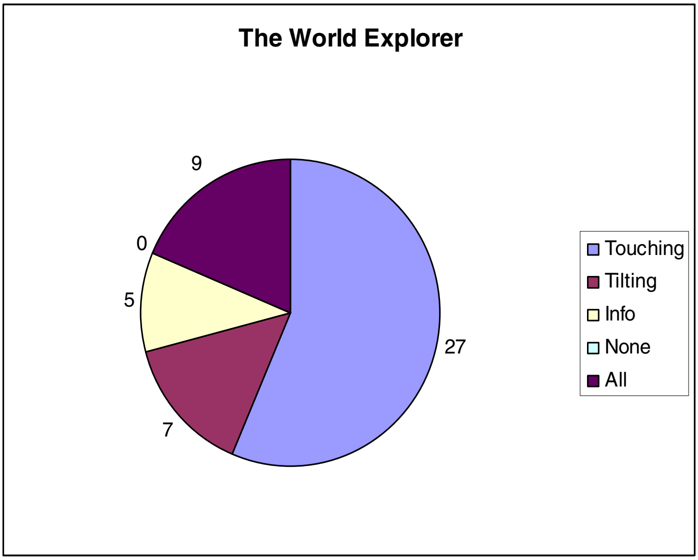

Fig. 5. Preferences for Physical Mobile Interaction Techniques in The World Explorer

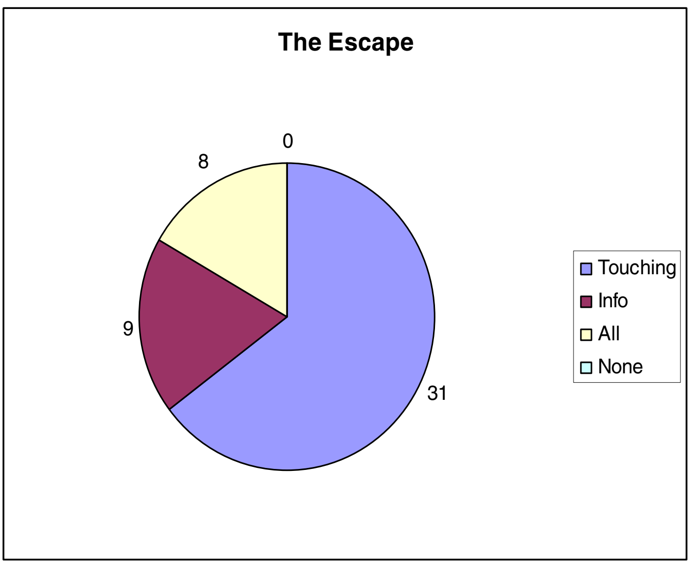

Fig. 6. Preferences for Physical Mobile Interaction Techniques in The World Explorer

5.2 Results of Observations

During the tests we captured the children and afterwards analyzed the videos to investigate the children's level of engagement and social interactions as well as to detect potential usability problems.

Engagement. The analysis of the video revealed that children were very attentive and engaged. Almost all children watched the displayed content of our applications very observantly, but also had fun and laughed during the tests and were eager to play our games again (see Figure 7). Regarding preferences for a specific physical mobile interaction technique we found out that the activity level of the supported interaction technique is an important aspect. Children were more engaged whenever their assigned role involved a lot of active interactions. Thus, the results of the questionnaire are confirmed by the video observation. Children were more attentive when employing the techniques *touching* or *tilting* than when employing the more passive technique *scanning*.

Usability. Another goal of the analysis was to shed light on the children's usage of physical mobile interaction techniques. Children did not have any problems with *touching* or *scanning* whereas *tilting* was for some children a bit tricky (see Figure 8). It was not very easy for them to tilt the phone in the right way to scroll through the single options. Another interesting and unexpected aspect was the children's usage of the mobile when taking over the role of the evaluator in *The Escape*. They intuitively held the phone on their ear to hear the messages as they are used to it from traditional mobile phone usage (see Figure 9).

Furthermore, an important aspect we observed is that children liked visual, auditory and haptic cues. Using these cues involves different senses of the children: see, hear and feel. Apart from the factor curiosity, the cues also provide a system with feedback which helps to increase the children's attentiveness and decrease off-topic activities. Children have a direct feedback about actions of the system, such as that *touching* has been successfully performed.

Social Interaction. The third goal of our videos analysis was to investigate which kinds of social interaction occur. Every time when our applications required a user interaction, we observed group activities. Children turned their bodies towards each other and discussed the different options (see Figure 10).

Overall we observed two forms of collaborations. On the one hand, the children helped each other whenever a child had problems using the phone and on the other hand children had both verbal and non-verbal social interactions when interpreting

Fig. 7. Children are interacting with our Application

Fig. 8. Children are using the Physical Mobile Interaction Technique *Touching* and *Tilting*

Fig. 9. Child is getting information in *The Escape*

Fig. 10. Social Interactions

hints and answering questions. At each point children had to select an option, they were very attentive and discussed intensively the single options before executing a selection to prevent failures in the game. We also achieved a balanced level of activity and attentiveness. Obviously, the application setting helped to avoid that some users took on a very dominant behavior. Moreover, we observed hardly any off-topic activities. Overall, the video recordings provide evidence that role assignment via physical mobile interaction may help to ensure that all users in a multi-user application will be involved actively. Furthermore, role assignment gives an interaction structure to the game. Each child knows about its role within the game which prevents chaotic situations.

6 Conclusion and Discussion

We presented a concept of multi-user applications for children in an ambient intelligence environment which can be controlled via different mobile phones and their supported physical mobile interaction techniques. We assigned different user roles via these physical mobile interaction techniques namely: the initiator, the evaluator and the executor. Each of these roles is required to fulfill a common objective and we expected that the associated physical mobile interaction techniques help to structure the interaction and prevent dominant users. In order to provide evidence for this assumption, we developed and evaluated two applications: *The World Explorer* and *The Escape*.

Our user study showed that children enjoyed group activities and the usage of different physical mobile interaction techniques. Children found our applications curious and engaging, in particular they liked the application *The Escape*. Our user study also identified the children's preferences for specific physical mobile interaction techniques and provides further evidence for the results of the study conducted by Rukzio and colleagues [2, 20]. Most children preferred *touching* over other mobile interaction techniques which was independent of the used application. Children liked having an active role in a game. In particular, they enjoyed performing different physical interactions with real world objects and at the same time doing it quick and easy. We consider physical mobile interaction techniques as feasible interaction techniques for children when supporting a high activity level and being intuitive and quick to use.

Our user study also showed that social interactions arise in forms of group activities. Our applications stimulated social interactions such as discussing and agreeing on the choice of different options but also helping each other. Moreover, observations showed that role assignment via physical mobile interaction techniques can help to structure interactions within a game. Children are assigned a clear role by giving them a specific mobile phone which helps to avoid chaotic multi-user interactions. The distribution of different roles to children can prevent dominant users and balance the level of activity between the involved children.

Overall, our results showed that different mobile phones enable promising new interaction techniques in multi-user applications for children. On the one hand they address the children’s needs for fun, curiosity and control which is important for children’s willingness to interact with a system and on the other hand they also stimulate social interactions.

In our future work, we plan to conduct further experiments to find out how specific role assignments support group activities. Therefore we plan to conduct tests that evaluate role assignments in different combinations to find out how they influence the distribution of interactions, on- or off-topic activities, social interactions and engagement.

Moreover, we plan to develop further prototypical multi-user applications that combine embodied conversational agents with physical mobile interaction techniques in the context of the eCircus project [19]. These different mobile multi-user applications are planned for different age groups including adults.

Apart from that, we recognized a need to simplify design and evaluation processes of applications, such as *The World Explorer* and *The Escape* and see benefits in automatically annotate and analyze captured user tests. Thus, we are currently specifying an adapted design process and a tool addressing these issues to make evaluations of such application more efficient.

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