Studying Multi-User Settings for Pervasive Games

Karin Leichtenstern
Institute for Computer Science
Eichleitnerstr. 30
86130 Augsburg, Germany
Leichtenstern@informatik.
uni-augsburg.de

Elisabeth André
Institute for Computer Science
Eichleitnerstr. 30
86130 Augsburg, Germany
Andre@informatik.
uni-augsburg.de

ABSTRACT

Whenever a pervasive game has to be developed for a group of children an appropriate multi-user setting has to be found. If the pervasive game does not support the children with an adequate multi-user setting, unintended situations can emerge, such as a single user can dominate the game while the other users are bored and disinterested. In our research we approach that problem by investigating various multi-user settings that are characterized by a different distribution of interaction devices. We describe three multi-user settings, a pervasive game which we used as a test bed, and a user study with 18 children to find out how the multi-user settings influence the children's social behaviour as expressed by the level of activity for all group members, the off-task behaviour and the level of task-related conversations.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*evaluation/methodology, input devices and strategies*

General Terms

Design, Experimentation, Human Factors

Keywords

Pervasive Applications, User Study, Multi-User Settings, Mobile Interaction Techniques

1. INTRODUCTION

A number of collaborative interfaces for children have been developed so far which are used rather in a pervasive than in a desktop setting [2, 7, 5, 15, 22, 4]. For instance, Cole and Stanton [4] developed three different applications which are controlled via mobile devices: a storytelling application (KidStory), an adventure game (Hunting the Snark) and an outdoor application (Ambient Wood). They conclude that pervasive game settings can increase children's attention and engagement more than traditional game settings. Despite these inspiring prospects, so far multi-user settings of pervasive games have not been sufficiently investigated. Badly deployed multi-user settings can cause negative effects on collaboration, such as the emergence of dominant behaviour. There is a need to investigate group-settings for pervasive applications to prevent such drawbacks. In this paper we describe our user study evaluating different multi-user settings for pervasive games to find out whether one of these settings can influence the children's collaboration measured based on the level of activity for all group members, the off-task behaviour and the level of task-related conversations.

Some research has been conducted to investigate multi-user settings mainly for desktop applications. One interesting study was performed by Stanton and colleagues[23]. They investigated the children's group behaviour while they were interacting with a computing system. For their evaluation they used a game-setting called KidPad, which enables children to collaboratively create stories by uploading pictures and text. The experimental setting was as follows. Groups with two children aged 6 to 7 had to interact with KidPad in two different situations. In the first setting each group possessed only one mouse. In the other setting the children used two mice to interact with KidPad. The results revealed more activity if each child had an separate input device. In this situation the children's imagination and productivity was increased, whereas with one mouse only, one group member dominated the interactions. Moreover, in this condition the results also showed less conversation among the children.

The objective of our research is to investigate the influence of different multi-user settings on children's behavior for pervasive games. In this context the following questions came up:

- Does the effect Stanton and colleagues observed for multi-user settings with two computer mice also occur in pervasive applications that make use of multiple mobile phones as interaction devices?
- Can we even increase the effect by not using a set of homogeneous devices, but employing mobile phones with different functionality to which a specific task can bew assigned?

To answer these research questions, we used the work by Stanton and colleagues, as well as their experimental setting as a basis for a new user study to investigate various multi-user settings for pervasive applications. In contrast

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to Stanton and colleagues, however, we used mobile phones as interaction devices. We used the two multi-user settings described by Stanton and defined a third new form of multi-user setting. In one setting, a group of three children could only interact with a single mobile device. In another setting, each group member possessed a separate mobile device. Finally, in the last setting, which we newly defined, each group member owned a separate mobile phone, but each of these devices only supported a subset of the whole interaction spectrum. Thus, only by using all three mobile phones together could the pervasive game be controlled and the task successfully completed. In the latter setting each group member is assigned a certain role within the game. Therefore we call this setting *Role Assignment Condition*. We expected the *Role Assignment Condition* to have positive effects on the children's behaviour because this setting provides the children with an implicit, but clear structure of the group and of the responsibilities of each of its members. We expected the *Role Assignment Condition* to decrease dominant behaviour and create a balanced level of activity for all group members. Moreover, we assumed that this setting would reduce off-task behaviour and increase social interaction. To verify these hypotheses, we conducted a user study with 18 children which is described in this paper.

The rest of this paper is structured as followed. First we describe related work which mainly addresses former studies on the distribution of input devices. Then we describe in more detail our approach to role assignment and the concept and implementation of our test bed called *The World Explorer*. The main part of the paper is devoted to the user study and the obtained results. Finally, we discuss our findings and formulate implications for the implementation of pervasive applications for children.

2. COLLABORATIONS IN MULTI-USER SETTINGS

Of particular interest to our own research are studies that investigate how collaboration between group members may be supported by the appropriate use of interaction devices. Lots of research has been conducted to evaluate multiple users interacting with a single display, which is called a *Single Display Group* by Stewart and colleagues [24, 25]. These researchers and others [17, 8, 21, 3] have investigated the behaviour of multiple users interacting with a computing system via a single mouse or via multiple mice. There is empirical evidence that children seem to be more engaged and more active once they are playing on a computer with multiple input devices and cursors than when using a computer with only one input device. Inkpen and colleagues [9] observed that giving each child an input device had a positive effect on collaboration even if only one child could interact at a time. A study conducted by Pawar et. al. [17] revealed that children show more excitement and engagement when they are interacting with applications that follow the multi-mouse paradigm.

These results encouraged us to investigate the behaviour of multiple users interacting in a pervasive computing setting. We came up with the idea of using mobile devices as interaction devices in a pervasive computing environment and investigated the effect of their usage on children's behaviour. 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 [1, 19, 20]. These interaction techniques based on mobile phones are called *physical mobile interaction* [18]. As Druin points out in [6], children enjoy the use of technologies which support their curiosity, their love of repetition and their need for control. We believe that mobile devices meet these requirements. Using mobile devices, 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. Mobility is an important aspect of collaboration [14] and novel mobile interaction techniques can support the children's interaction. Jarkievich and colleagues investigated the use of mobile devices for children [10]. They performed a combination of ethnographic observations and focus group interviews to shed light on the children's attitudes towards mobile phone usage. The results show that children like using mobile phones as a resource to interact within a group. Mobile phones and their supported technologies can inspire new game scenarios as well as increase children's physical engagement, creativity and social activity. Another study about child use of mobile devices was conducted by Mandryk and colleagues [16]. They investigated the use of handheld devices to foster collaboration between children in a game. A study revealed that children preferred playing the game with friends rather than playing by themselves and that they spent a great deal of time interacting with each other.

These results provide empirical evidence that mobile phones are of interest as interaction devices for children. We consider multiple mobile devices as a means to stimulate face-to-face collaboration between children and to give developers the possibility to balance the distribution of activities within multi-user settings. It is important to consider these aspects because tolerance, the ability to listen to others, planning and negotiation are basic requirements for group work and collaboration [26]. However, so far none of the conducted user studies has investigated different multi-user settings and the distribution of mobile phones as we do in this paper. The important contribution of this paper is to explore the behaviour of groups of children interacting in different multi-user settings via mobile devices.

3. THE APPROACH OF ROLE ASSIGNMENT

Based on the research by Stanton[23] on collaboration in multi-user settings, we came up with the idea to implement and investigate the two settings she described, but replace computer mice by mobile phones. In addition, we defined a third new multi-user setting which we call *The Approach of Role Assignment*.

To prevent dominant users and chaotic interactions in multi-user applications, we decided to split a task in more elementary user interactions and to associate with these different interactions 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 to use these three required actions to successfully complete a task and assign the three actions as user roles to children. In the example, there is the role of an *initiator* who is the requester of the information, the role of an *evaluator* who receives and interprets information and finally the role of an *executor* who selects an option.

In this vein, we force children to collaborate because only by working together can they successfully complete a task which is their common goal. We assume that by encouraging 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 their overall performance as a team and each individual's contribution.

There are a number of game-like environments which make use of roles as part of a pervasive game. Savannah [2] is a pervasive game where children take on the role of lions. Other examples are the pervasive games Paranoia syndrome [7] and Virus [5]. Paranoia syndrome defines three different kinds of role. Children can take on the roles and skills of a technician, doctor or scientist, but these definitions are not based on the supported mobile phone's functionalities and interaction technique as in our case. In Virus, children take on the role of a virus and transmit it via their mobile devices by getting within the 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. However, none of the mentioned works conducted evaluations to identify appropriate multi-user settings and to investigate whether role-play could increase collaboration by means of a balanced level of activities for all group members, and whether it could decrease the level of off-task behaviour and increase the level of task-related conversations.

4. THE APPLICATION

To validate our approach of role assignment, we implemented a pervasive game as a test bed. This pervasive game had to fulfill the following requirements. First of all, the game had to employ mobile phones as interaction devices. Secondly, it had to be based on tasks that could be accomplished using different combinations of input devices. Finally, the application had to be innovative and engaging for children aged 10 to 14, yet at the same time be easy to use. Keeping these requirements in mind, we devised *The World Explorer*.

4.1 The Concept of The World Explorer

The World Explorer is a *mobile Computer Supported Collaborative Learning (mCSCL)* application. The main objective of *The World Explorer* is to give children a platform to collaboratively work together and to attain a task as a group. Moreover, the application includes the real world surrounding the children. Users are supported with a realistic game environment. This environment enables interactions via mobile phones. Thanks to mobile phones, different interaction and presentation capabilities can be used as an interface between the real environment of the users and the virtual world of the game.

The World Explorer enables children to receive information about regional distinctions and conventions of different countries and afterwards answer questions about their acquired knowledge. The supported countries in the current prototype are Australia, Germany and France. Each country is represented by a separate board, which displays the outlines of the countries. These boards are augmented with RFID-tags and therefore become identifiable smart objects. The identification stored on the RFID-tag can be read via a mobile phone with a built-in NFC-reader.

In *The World Explorer* children always play synchronously in groups of three. Using our role assignment approach every child has its own mobile phone which represents a role in the game and is based on a corresponding functionality. During the game each child needs to accomplish a task to successfully complete the game as group. Tasks in *The World Explorer* include selecting a country and a topic, evaluating the received information and finally answering the question. Thus, we have three different actions which can be assigned to three different children via their mobile phones and meet the requirement to support our role assignment approach and enable the following scenario.

The first child can use a mobile phone with a built-in NFC-reader to first select a country. It simply needs to touch the RFID-tag of the board to pick the country. Afterwards the corresponding flag must be found and picked as well. The children can then choose one out of four different topics corresponding to the selected country.

After that point the second child and her mobile phone comes into the play. Via her mobile phone's graphical user interface the child has to indicate whether information should be requested or the question about the topic should be loaded. When the child has selected the option *information*, the third child automatically gets information in form of a multimedia presentation (video, audio, text, image). The third child can replay the received information several times to evaluate its content. This information gives useful input to correctly answer the questions. Once the second child has selected the option *question*, the question and four answers are loaded on the phone of the second child. Now, this child can scroll through the four options to select an answer. The acquired knowledge of the third child is important to find the right answer.

In the last paragraphs we have described a typical task of *The World Explorer* completed under the *The Role Assignment Condition*. Due to the flexibility of the *The World Explorer* architecture, two further multi-user settings can be enabled to play the pervasive game. In the first setting, the user-group is equipped with a single phone. In the other setting, all three users are equipped with a separate phone which supports the entire set of functionalities. Thus, *The World Explorer* supports all requirements to be used as a test bed for our user study. Actually, there is no need for a further input or output device. However, we decided to support the children in all three conditions with a further audio-visual output channel because results of former studies [13] showed that children found the pervasive game more realistic when they received direct feedback from a projected presentation. Therefore, videos are projected which give hints during the game, such as informing the children as to whether they have successfully performed an action or not. Additionally, these videos introduce the different countries and their topics as well as the questions and answers.

4.2 The Implementation of The World Explorer

In the last section we described the concept of our test bed which we called *The World Explorer*. The implementation of such an application is a time-consuming and complex task. To give an idea of how to develop a similar test bed to evaluate different multi-user settings for a pervasive game we briefly describe the implementation of *The World Explorer*. Figure 1 shows the *The World Explorer's* general architecture based on our role assignment approach. This architecture consists of four kinds of components: the real world objects, the mobile phones, the video client and finally the server.

4.2.1 The Real World Objects

The setting of *The World Explorer* includes several boards which are augmented with RFID-tags (see Figure 2). These boards represent the relevant *Real World Object* such as a country, its flag and its four different topics. Using a mobile phone which supports the NFC-based interaction a *Real World Object* can be selected by simply touching its RFID-tag.

4.2.2 The Mobile Phones

The mobile phones are the second component of the architecture which support users with different physical mobile interaction techniques [18]: the NFC-based, Keyboard-based and Push-based interaction technique.

The NFC-based interaction technique is used to select *The Real World Objects* such as a country, its flag or a topic. To implement this interaction technique, a particular mobile phone supporting the following hardware and software requirements is needed. As a hardware requirement the mobile phone needs a built-in NFC-reader. With regard to software, the support of J2ME MIDP 2.0 and CLDC 1.1. is required. Moreover, the optional *Contactless Communication API* (JSR-257) of J2ME is required to address the mobile phone's NFC-reader. Meeting these hardware and software requirements, RFID-tags can be read and *Real World Objects* can be selected. Apart from that, to interpret the read RFID-tag and to receive information about *The Real World Objects* a network connection is required. For NFC-based interaction, an appropriate mobile phone is the Nokia 6131 NFC, which we used in our application.

Once a country and a topic have been selected, the Keyboard-based interaction technique can be used to answer the question by scrolling through the listed answer options on the mobile phone's screen (see Figure 3) and select one of these options. To run this interaction technique on a mobile phone, the mobile phone has to support J2ME MIDP 2.0 and CLDC 1.1. To interact with the server, a TCP/IP-network connection is required. Thus, apart from the software requirements the mobile phone also requires a network interface which can be either GPRS/UMTS or WiFi.

The Push-based interaction is used to automatically receive information about a selected topic on a mobile phone. This information is presented as media content such as a text, image, audio or video file. For the Push-based interaction technique the software and hardware requirements are the same as for the Keyboard-based interaction technique.

4.2.3 The Video Client

The video client shows the audio-visual presentation of *The World Explorer* (see Figure 4). Only Java 5.0 or higher is required to run this video client. Once the video client has been started, it automatically connects to the server via a TCP/IP-network connection. Afterwards, the client receives information from the server which is mapped and

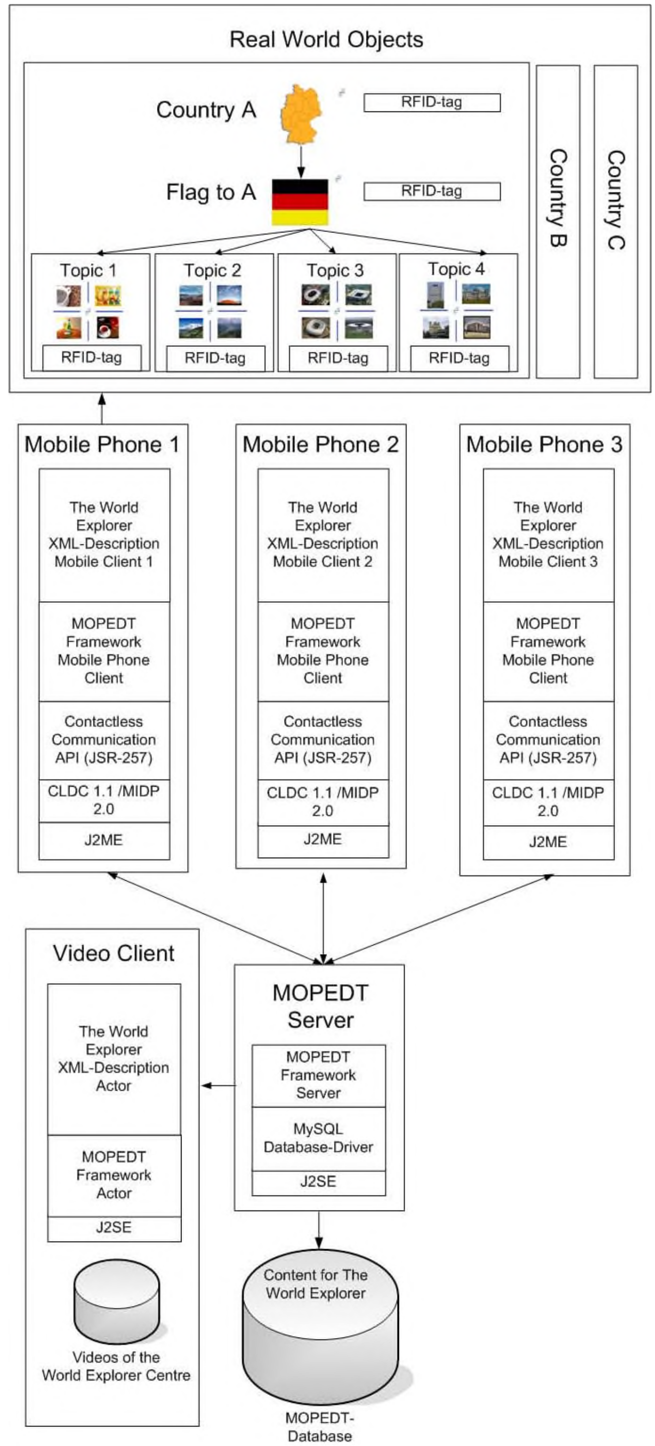

Figure 1: The World Explorer Arcitecture using the MOPEDT Framework

Figure 2: Example for Smart Objects: The Country and Flag of Germany and a corresponding Topic: Drinks

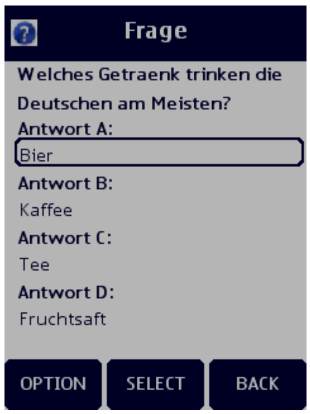

Figure 3: Screen shows a question and the four answers.

interpreted to load and play the right videos. To display the videos, media player classic is used.

4.2.4 The Server

The central part of the application is the server component. The server can handle different mobile phones and video clients to receive, forward and respond to messages. Moreover, the server is connected to a MySQL-database to process different requests from the mobile phone clients, such as the request to receive information about a selected topic. Java 5.0 or higher is required to run the server.

For the implementation of *the World Explorer* we used our toolkit MoPeDT (Pervasive Interface Development Toolkit for Mobile Phones) [11]. This toolkit provides interface developers with an architecture as well as a mobile phone framework in order to develop pervasive interface for mobile phones.

5. EXPERIMENT

In this section, we present our experiment. We first describe the experimental setting, we then report on the conduction of the user test and finally we illustrate our results.

5.1 Experimental Setting

The main objective of the experiment was finding out whether different ways of assigning mobile phones have any influence on children's group activities.

5.1.1 Hypotheses

Figure 4: The Video Client of The World Explorer

We formulated the following hypotheses, falling into three categories: level of activity, off-task behaviour and social interaction:

- **H-1: Level of Activity:** In multi-user settings, the most balanced level of activities can be reached when children interact with different phones which assign clear roles to them.
- **H-2: Off-task Behaviour:** In group settings, clear assigned roles can reduce off-task behaviour.
- **H-3: Social Interaction:** In group settings, clear assigned roles can help to increase social interaction.

5.1.2 Independent Variables

To investigate our hypotheses the following three independent variables of collaboration were defined.

1. **One Mobile Phone per Child and Role Assignment** (see Figure 5): This condition represents the role assignment approach. Each group member uses a separate mobile phone which supports a different functionality to interact with the computing system. The first child can initiate the task by picking a country and a topic, another child can receive information and evaluate it and a third child can execute the action to answer the current question.

2. **One Mobile Phone per Child** (see Figure 6): In this condition each group member uses a separate mobile phone and each phone supports the whole interaction spectrum. Thus, a single user is able to perform all interactions which are necessary to execute the complete task. A user can select a country and topic, receive information and select an answer.

3. **One Mobile Phone per Group** (see Figure 7): In the third condition there is only one mobile phone per group available. This phone supports the whole interaction spectrum to complete the task. A single user can select a country and topic, receive information and select an answer by using that phone.

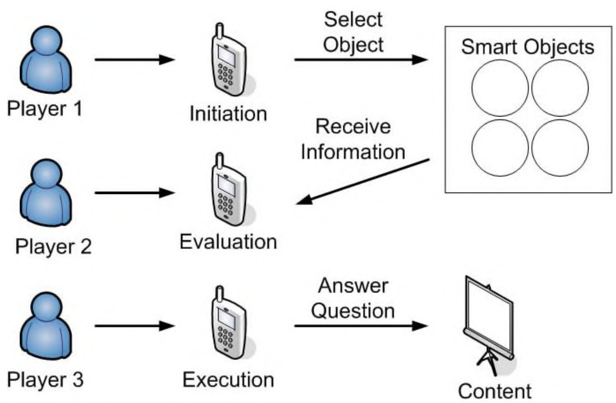

Figure 5: One Mobile Phone per Child and Role Assignment

5.1.3 Dependent Variables

We defined three different dependent variables: the level of activity for each group member, the off-task behaviour and the social interactions. In a multi-user setting the level of activity can be measured by investigating and counting the number of performed actions per group member while they are performing a complete task. For measuring the off-task behaviour we investigated the users' gaze, communication and other activities which are unnecessary to successfully perform the task. Finally, to obtain information on social interaction we counted the number of conversations about the task and activities seeking to help out other users.

5.2 Conducting the Experiment

In this section we shortly describe how the user test was conducted.

5.2.1 Pre-Experiment

Before we started the experiment, each group was introduced to the correct usage of the mobile phones and their interaction techniques. Afterwards we explained the concept of *The World Explorer*. Before we tested each setting with each group, we described all the characteristics of the different settings and the children played a test run to have a first impression of how it worked.

5.2.2 Experiment

We conducted the experiment with 18 children from a primary school aged 9 to 11. The average age was 10.8. Seven of the 18 children owned a mobile phone, and 13 had already played a game or used the SMS-service on a mobile phone. Supported by a teacher, we formed six groups with three members per group, trying to achieve a balanced level of social, mental and technical skills in order to avoid any side effects by highly varying groups.

The experiment was conducted in a separate room in the pupils' school. For the test we used a projector and some tables where we placed the different RFID-tagged flags and topics. To capture videos we positioned cameras beside the children to measure exact data of the children's behaviour. A run started with the selection of the country and the topic and finished with the correct answer to the question. We decided to perform the test by using a with-in group design.

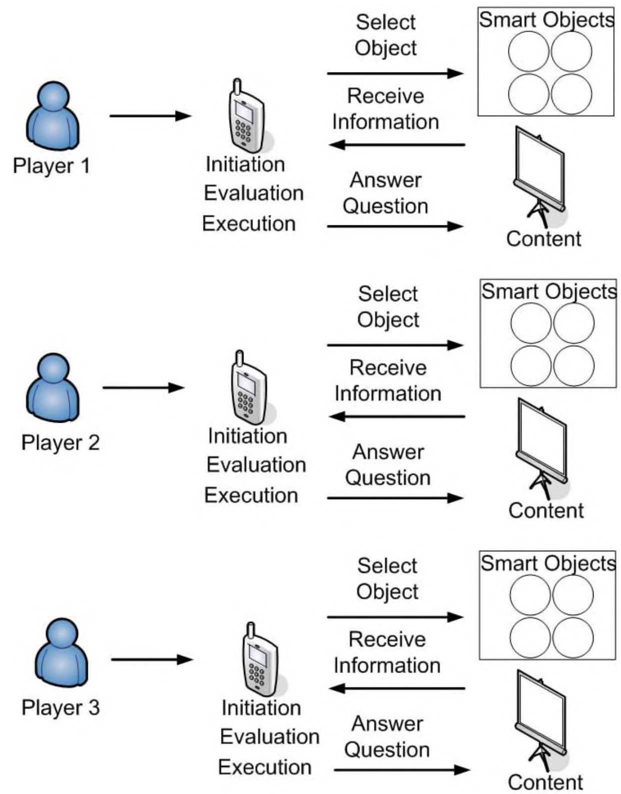

Figure 6: One Mobile Phone per Child

Thus, all subjects tested all settings twice. We alternated between settings to prevent any bias caused by habituation effects. Figures 8, 9, 10, 11 show pictures of the user study.

Overall, we found that children aged 9 to 11 have appropriate technical skills to use pervasive games such as *The World Explorer*. They performed the tasks in a mindful and concentrated manner.

5.3 Results of the Experiment

In this section we describe the results of our analyzed videos. We analyzed the 200 minutes videos on our dependent variables: level of activity, off-task behaviour and social interaction. For the video analysis we used the annotation tool ANVIL [12].

5.3.1 Level of Activity

Level of activity was measured by the number of actions performed by each group member via a mobile phone.

- **Level of Activity:** First, we analyzed the videos and counted the number of game-related activities performed via a mobile phone. Each activity was allocated to a group member. For instance, we counted the number of keyboard-based and NFC-based interactions. In the end, we identified the most active and the least active child for each setting. Figure 12 illustrates the most balanced level of activity in setting one, with one phone per group and role assignment, whereas condition two and three were found to encourage dominant usage. In setting one the most active child performed, on average, 43% of all actions. The other two children

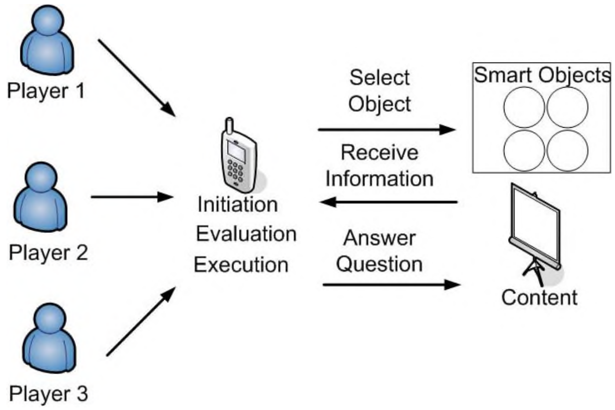

Figure 7: One Mobile Phone per Group

Figure 8: Impression of the User Study

performed 36% and 21% of the activities. In setting two, the most active child performed on average, 53% of all game-related actions and the other two children performed only 34% and 13% of these. In setting three, the dominant user performed on average 68% of all actions and the other two children only 25% and 7% of them. The increase in the amount of activity for the most dominant child from setting one to setting three was significant ($p = 0.04$; ANOVA, post hoc Bonferroni). A significant difference was also observed for the least dominant child ($p = 0.037$; ANOVA, post hoc Bonferroni). Thus, the role assignment approach seems to encourage less dominant children and discourage dominant children resulting into a more balanced distribution of activities.

Because of the specified role assignment in condition one, all children actively took part during the completion of the task. In setting two, one user tended to dominate task execution and performed most actions. This effect intensified under setting three where each group only had one mobile phone at its disposal. We observed very dominant behaviours in setting three. In one test run, one child performed all actions without ever handing over the phone to other group members.

5.3.2 *Off-Task Behaviour*

Figure 9: Impression of the User Study

Figure 10: Impression of the User Study

To determine the amount and duration of off-task behaviour, we analyzed the children's gaze, conversation and activities which were not relevant to complete a task.

- **Off-Task Gaze:** To investigate distraction, we first measured the number of times children did not direct their gaze toward the game. We counted how often children looked away from the game setting for more than two seconds. The game setting included the mobile phones, the smart objects, the projection and the other children. The results showed that distraction as measured by gaze is overall quite low. In setting one the children looked away on average 0.22 times, whereas the figure was 1.0 in setting two and 1.67 in setting three.

- **Off-Task Communication:** Another aspect of off-task behaviour is the conversation about a non-task-related topics. We counted the number of conversations which lasted longer than two seconds. Results showed even less distractions in all three settings. In setting one there was no off-task communication. In condition two (0.27 times) and three (0.39 times) the average number of off-task conversations lasting more than two seconds was close to zero.

Figure 11: Impression of the User Study

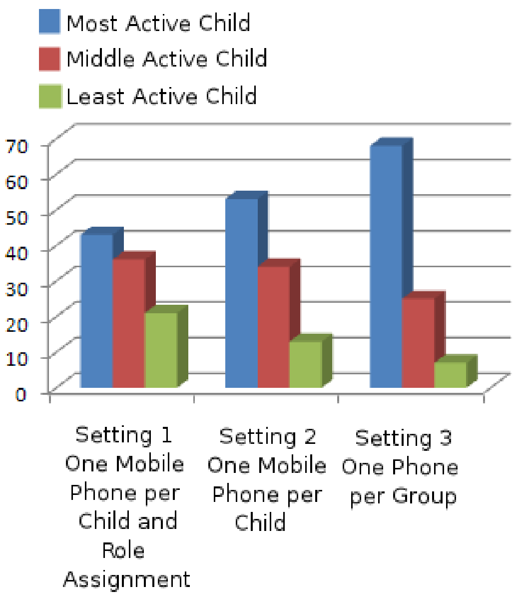

Figure 12: The Level of Activity

- **Other Off-Task Activities:** Finally, we investigated other off-task activities such as playing with the mobile phone. These activities are also an indicator for a lack of engagement. In all three settings off-task activities occurred, but distraction was quite low in all of them. In settings one and two off-task activities emerged on average 0.17 times whereas in condition three off-task activity occurred on average 0.5 times.

Setting one performed better than settings two and three in all situations. However, given how low distraction was among children for all three settings, it is hard to assess to what extent role assignment can reduce off-task behaviour. Having children play for a longer period of time might shed light on this question.

5.3.3 Social Interaction

After investigating the level of activity and off-task behaviour, we focused on social interactions. Thus, we analyzed the videos for communication about the task and mutually-supportive behaviour.

- **Communication about the Task** At first we investigated the conversations about the task. Overall, we can say that communication was relatively high in all three conditions. We observed that in settings two and three there was some discussion about role assignment because children were forced to organize on their own. Thus, children could not concentrate as much on the task as in setting one. Figure 13, however, shows that most task-related conversations occurred in setting one. In setting one a child had on average 6.5 times conversations about the task whereas the number was 4.44 times in setting two and 2.67 times in setting three. In setting three we observed dominant behaviour on the part of a single user who did not debate with the other users. We conclude that children contributed more to a conversation when they were holding a phone in their hands.

- **Mutually-supportive behaviour** A second indicator for social interaction is the amount of actions taken to help others during the game. Overall, we observed only a few cases where help was provided because it often was not necessary. In problematic situations, mutually-supportive behaviour was most often observed in settings one and two (on average 0.33 times) and least often in setting three (0.11 times).

The results support the fact that conversations about the task increase when each user owns a mobile device. Moreover, we showed that conversations can increase when the role assignment approach is used. In this setting, children do not need to talk about the group arrangements themselves. They can concentrate on discussing the task and improving their efficiency. The results about mutually-supportive behaviour showed no difference between the three settings because help was seldom required.

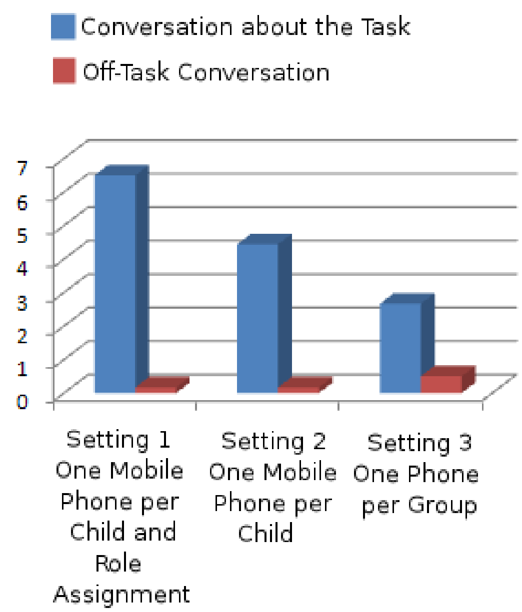

Figure 13: Conversation

5.4 Discussion

In this section the results of our tests are used to discuss the three hypotheses.

- **H-1: Level of Activity:** In multi-user settings the most balanced level of activity can be reached when children are interacting with different phones which assign clear roles to them.

The results of our tests provided evidence for our first hypothesis. We measured the level of activity and found out that setting one has a relatively balanced level of activities whereas setting three encourages very dominant users. Obviously, role assignment via mobile phones gives children a clear and easy structure within the game and prevents dominant users. In settings two and three children did not often organize their activities on their own. Self-organisation within a group-setting is difficult and time-consuming, but without it, chaotic situations can arise. In settings two we observed dominant behaviour, such as children competing to be the first to perform the next action. In setting three we observed the most dominating behaviour. Children did not often hand over the mobile device to another group member. Thus, we recommend distributing mobile phones to each member of a group. Moreover, we recommend supporting different functionalities on each phone to increase the level of activity of each child. In a multi-user setting such as *The World Explorer*, especially when users are children, we recommend implicitly assigning clear roles to the children; otherwise some children might dominate the game.

- **H-2: Off-task Behaviour:** In group settings, clear assigned roles can reduce off-task behaviour.

By analysing the children's gaze, communication and other off-task activities we tried to prove hypothesis two, according to which role assignment can reduce off-task behaviour. The results show that distraction occurs very rarely in all three settings. The gaze of the children was concentrated on the game most of the time. We also did not observe a large number of off-task conversations or other off-task behaviour. Children were very concentrated and engaged while they were interacting with *The World Explorer* in all three settings. Even though the amount of distraction was lower in setting one than in the other two settings, more experiments would be required to prove hypothesis two.

- **H-3: Social Interaction:** In group settings, clear assigned roles can help to increase social interaction.

Finally, we investigated hypothesis three. We expected role assignment to increase social interaction through enhanced conversation about the task and the game. The results show that role assignment can increase conversation about the task and prevent unnecessary discussions about role assignment. Thus, children could complete the tasks more efficiently than in the other two settings. We detected less social interaction in the form of conversation in settings two and three because the game setting encouraged children to compete with one another in order to be the one to first select an option or receive information. Whenever conversations came up in settings two and three they were generally about group arrangements and not about the actual task. We also analysed whether the willingness to help each other out was increased in any situation. The results did not highlight any significant difference in the three settings. Help was not often required thus we can not say that any setting increases significantly the willingness to help others.

The user tests enabled us to corroborate hypotheses one and three. It is advantageous for children to interact within setting one as it ensures a balanced level of activity, prevents the emergence of dominant users and increase the number of conversations about the task.

6. CONCLUSION

In this paper, we showed that an appropriate distribution of input devices may have a positive effect on collaboration in a pervasive computing environment. Dominant behaviours can be avoided and social interactions can be increased when using appropriate multi-user settings for pervasive game settings. Our paper extends earlier work which investigates the effect of using one mouse versus multiple mice in a desktop application. We observed that there are similar effects on collaboration when using mobile phones as interaction devices to a pervasive environment. In addition, we found that an even stronger effect may be achieved when allocating mobile phones with different functionalities to specific tasks. We showed that mobile phones and their different functionalities can be used to assign clear roles to each group member. The new role assignment approach we presented helps to structure interaction, ensures a balanced level of activity and thus supports a fun-to-play game for all group members. Our results not only give valuable input for developers of pervasive games but also for researcher in other areas, such as interactive storytelling. In this research community the assignment of active and passive roles via interaction devices is also an important research question. Encouraged by the results of our pilot-study, we are planning long-term studies in order to investigate what extent different multi-user settings for pervasive games can influence social aspects, such as group cohesion.

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