Read-It

Five-to-seven-year-old children learn to read in a tabletop environment

R.J.W. Sluis, I. Weevers, C.H.G.J. van Schijndel, L. Kolos-Mazuryk, S.Fitrianie, J.B.O.S. Martens
University of Eindhoven, Design School of User System Interaction
Den Dolech 2
5600 MB Eindhoven
The Netherlands
{r.j.w.sluis; i.weevers; c.h.g.j.van.schijndel; l.kolos-mazuryk; s.fitrianie}@tm.tue.nl; j.b.o.s.martens@tue.nl

ABSTRACT
Augmented tabletops can be used to create multi-modal and collaborative environments in which natural interactions with tangible objects that represent virtual (digital) information can be performed. Such environments are considered potentially interesting for many different applications. In this paper, we address the question of whether or not it makes sense to use such environments to design learning experiences for young children. More specifically, we present the "Read-It" application that we have created to illustrate how augmented tabletops can support the development of reading skills. Children of five-to-seven-years old were actively involved in designing and testing this application. A pilot experiment was conducted with a prototype of the Read-It application, in order to confirm that it does indeed meet the a priori expectations. We hope that the Read-It application will inspire the development of more tabletop applications that are targeted at specific user groups and activities.

Author Keywords
Multimodal interaction, tangible interface, education, children, augmented table, reading methods

ACM Classification Keywords
D.2.2: User Interfaces, input devices, interaction style; H.5.1: Augmented reality

INTRODUCTION

The augmented tabletop environment has demonstrated its potential value in the past ten years. Many different research projects, including Ishii and Ulmer [9], Fitzmaurice et al. [5], Rauterberg et al. [15] and Aliakseyeu et al. [2], have studied the required technology, the usability and several possible applications of augmented tables. The major advantages that have been identified in those studies are that tabletop environments can support collaboration, and that they can be used to create more natural interaction styles, based on tangible interaction. Still, up till now, tabletop systems do not seem to pose a serious threat for the widespread desktop environment. We think that there are at least two important reasons for this.

IDC 2004, June 1-3, 2004, College Park, Maryland, USA

First, current augmented tabletop applications are mostly designed for (computer-minded) adults and for specific expert domains. As a result, the proposed applications look very inspiring, but the question remains as to whether or not such systems are of real use to the much broader population of non-expert users. To truly demonstrate the potential of augmented tabletop systems, we need applications that are also accessible and useful to first-time, inexperienced users. In our view, applications for young children fit this requirement. On the one hand, children are obviously non-expert computer users. On the other hand, we believe that they can benefit greatly from the advantages offered by augmented tabletop applications.

In Dutch schools, for instance, the personal computer has become an important supportive tool in the educational environment. Desktop computers are however based on a single-user/single-computer paradigm [20], which restricts the children in their behavior. Scott et al. [19] have for instance shown that forcing children to share one input device leads to boredom and off-task behavior. Children rather enjoy technology that supports concurrent activities. These findings are coherent with the results of Inkpen et al. [8]. They found earlier that children exhibit a significantly higher level of engagement and activity when working alongside each other. Such findings are especially relevant for one particular activity that most children share: education. A collaborative environment is more likely to elicit increased intrinsic motivation, which is an important factor in productive learning of new skills.

Second, the acceptance of new hardware platforms is strongly influenced by the availability of useful content, i.e., of software applications that exploit and illustrate the unique benefits of the new platforms. To become competitive with the desktop environment, the development of tabletop applications should become easier, i.e., be accessible to a much larger community of application designers. To open the door for a wide range of new applications, the user interface software should be separated from the driver software that deals with the tabletop architecture and hardware. In addition, the software interface should preferably comply with a well-established standard. Such an interest in software toolboxes for augmented reality platforms is only recently starting to emerge.

The case study that we provide in this paper, which consists of the design, development and evaluation of the Read-It prototype, contains two contributions to the development of tabletop applications. First of all, the final result is a tabletop application that supports learning to read for children of 5-7 years old. The application trains elementary reading skills using collaboration and a multi-modal, tangible interface. The fifteen children that tested the application approved the new, stimulating way of doing a reading exercise. Second, in order to realize the Read-It prototype, we transformed the Visual Interaction Platform (VIP) [2] into a flexible host for tabletop applications. The development of Read-It required the definition of an intermediate software layer (based on XML-messages) that was accessible from within standard designer tools such as Macromedia Flash. In this way, a designer could develop applications without an in-depth knowledge on how the tracking software operates within the augmented tabletop environment.

In this article we first describe the conceptual design of the Read-It prototype. The requirements for Read-It were derived from the user profile and from the existing reading method that Read-It was intended to support. Second, we provide a hardware description of the VIP platform, and of the software communication between the driver and application software. Last but not least, we discuss the pilot experiment that we carried out with 5-7 year old children on the Read-It prototype. The results demonstrate that the children enjoyed using Read-It, that they could deal with the augmented reality as we applied it, and that Read-It has the potential to make a true contribution to learning to read.

USER PROFILE

Children in the Netherlands start primary school at the age of five to seven. Before this, they usually go to kindergarten, where the main focus is on playing, rather than learning. Such young children enjoy being physically active, to shout, touch, move, and share experiences with friends [4]. Body movements, the ability to touch, feel, manipulate and build sensory awareness of relationships in the physical world are crucial to the children's development [7]. Therefore, educational environments should support those physical activities.

Our intended user is hence a normally developing, 5-7 year old child that just started to attend primary school in the Netherlands. For our application it is important to describe this intended user from a psychological perspective and to describe their knowledge and experience in computer usage.

Psychological perspective

According to Piaget, the targeted children are in their pre-operational stage [13]. This means that they think bipolar, intuitive and can hardly think in terms of causal relationships. Anything is possible in their view.

Another important characteristic is their egocentrism. Their needs in stimulation are direct. They are easily involved in spontaneous play and their humor is on the level of slapstick [1]. Children at this age want to continue to play without interruption, they are competitive, they try to be bossy and are unhappy if they lose, they are sensitive to personal criticism and do not know how to accept failure. At this age, they do however start to think about their own behavior and sharing with friends [13] [14]. Therefore, an application that invites collaborative behavior can potentially strengthen such social behavior.

Knowledge and Experience

From the perspective of computer usage, our user group can deal with the mouse, if the targets are relatively big. The keyboard is usually avoided [3], because:

- there are too many buttons on the keyboard to remember all their functionalities;
- most of the children at this age are not familiar with letters and numbers; and
- the symbols on the buttons do not explain their function and therefore cannot help the children to understand their use.

Interviews with some primary-school teachers have also confirmed the findings of Smets et al. [20], i.e., that a separated action (mouse handling on a table) and perception space (visual feedback displayed on a monitor) causes difficulties for children at this age. These factors should be taken into account when designing an input device and an interface that can be used by these children.

We conducted a preliminary context analysis by sending 27 questionnaires to parents of 5-7 year old children. The responses from 24 parents revealed that the children have ample experience in using programs on the (desktop) computer. Accomplishing more complex tasks that require a sequence of actions, such as starting up a program by means of the "start" menu, are much more difficult, which complies with their pre-operational way of thinking.

The questionnaires also revealed that children perform their jobs and tasks behind the computer mostly on their own. However, in class, cooperation is stimulated and teachers indicated that children can indeed achieve a goal together. The main reason that children do not work together a lot behind the computer is that the current software and hardware is not designed for such a purpose.

EDUCATIONAL APPLICATION

In the first class of primary school, learning language is one of the major subjects in the curriculum. It is one of the, if not the, most important skill to achieve in a literate society. We hence designed an application, entitled Read-It, that supports learning to read. In the Netherlands, a number of different reading methods are used. To choose one, we assessed the eight most-frequently used methods on the following five aspects:

- having a quality that is well recognized (for instance, in the literature);
- being used in a large number (the majority) of schools;
- being up-to-date;
- complementing the world of the target group;
- including the use of computer-supported exercises.

The method Learning to Read Safely (*Veilig Leren Lezen-VLL*) [12][16] satisfied the requirements best. It is a so-called 'structure method'. This means that it explains how to read by teaching elementary reading processes. Elementary reading processes are for example the graphical analysis of words into graphemes (elementary units of letters) and the grapheme-to-phoneme mapping. In addition to the core of the VLL method, the publisher has developed exercises that can be offered to the children at moments of free-play.

These exercises are implemented within the *speelleesset* (a set of games that combines playing and reading) and within computer exercises (for a standard desktop computer).

The *speelleesset* is recommended for its playful enforcements in collaboration, in competition and in fun. However, there are also several drawbacks attached to it. First, all the games are visually oriented, since sound is hard to add to card and board games. Second, if the children play together, the orientation of the letters limits the children in their freedom of movement. They have to share a common orientation in order not to get confused while learning letters such as /p/ and /d/ that are each others mirrored images. Third, not all the games are self-corrective, so that the children need supervision to have their performances checked.

The exercises on the desktop computer, on the other hand, are great in direct feedback, slapstick humor and automated checks on the user's performance. The drawbacks to these computer exercises are mostly related to the physical limitations of the desktop environment.

The recent developments in tangible and multimodal interfaces offer the opportunity to avoid those drawbacks and to design an application that combines the strengths of both the *speelleesset* and the computer exercises. Only one project we know of has until now proposed to use tangible interfaces for creating collaborative learning experiences for children: TICLE [17]. TICLE was developed for children that are "*turned off by math and science*". Describing the development Scarlatos states that the tangible interface should "*use computers to enhance a physical collaborative learning environment, rather than dominate it*" and "*respond to student actions (or inaction) as it attempts to guide students without giving them answers*". The results[18] show positive outcomes for their tabletop application, hence we will apply and extend these design principles to the domain of 5-7 year old children who start to learn to read.

THE VISUAL INTERACTION PLATFORM

Read-It was implemented on an existing augmented tabletop system, the Visual Interaction Platform [2]. Figure 1 illustrates the main components in the system. The platform consists of a computer, two beamers, an infrared light source, an infrared-sensitive camera and a table with a reflective surface. One of the beamers projects (part of) the computer screen output on the horizontal table. In case of a dual-screen output, the second beamer projects the second part of the computer screen output (called the communication space) on a vertical screen or wall. Only a single-screen output on the horizontal action-perception space is used for the Read-It prototype. The infrared light source illuminates the action-perception space on the table. The light is reflected towards the infrared-sensitive camera by means of retro-reflecting tags (that are not shown in the picture). The computer runs computer-vision software to analyze the images from the camera. The software output consists of tag positions, orientations and identifications. The use of tags allows great flexibility in the size and shape of the tangible objects that function as interaction elements. The tags can be attached to many different objects, provided that the objects do not hide the tags from the camera. The VIP system currently recognizes the positions and orientations of rectangular tags (with a typical size of 20x10 mm). It also recognizes the positions, orientations and identities of square tags of around 50x50mm with an internal identification pattern of up to nine circular holes (in a 3-by-3 pattern).

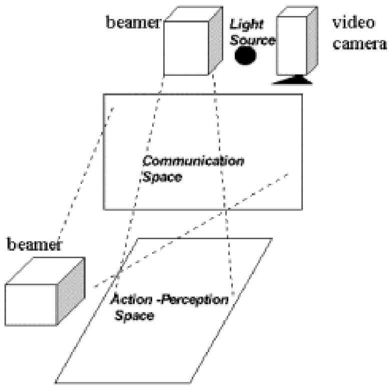

Figure 1. **The Visual Interaction Platform**

The system runs a Microsoft Windows operating system. Up till the development of Read-It, the platform ran only applications in Visual C++ that had immediate access to the image-analysis library. Such applications handled the output from the computer-vision analysis and translated it into changes in the projected application. To design new applications in a more flexible way, i.e., using alternative software development tools, required a change in the software architecture.

The software that we chose to develop the Read-It application in was Flash, by Macromedia. Within Flash, it is fairly easy to design applications that are visually appealing and that include sound. An application developed in Flash can however only receive external information in XML-format. This implied that the location, orientation and identity of the interface elements on the table needed to be presented in this format to our application. A C++ program was created on the VIP for this purpose. Every time that this program detects a new tag, or a change in position or orientation of an already-established tag on the table, it exports the new or updated information into a message in XML format. Figure 2 provides a graphical scheme of the processes involved.

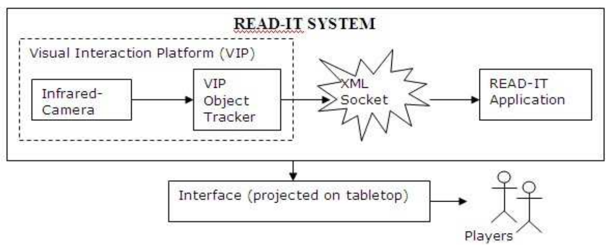

Figure 2. Components in the Read-It application.

The consequence of redesigning the platform into a server of object information in the XML format is that many of the development packages that are popular among software engineers and graphical designers can now be used to develop new applications for the tabletop. Macromedia Flash is just one example; there are many other development tools that also include support for the XML format, i.e., C++, Java and php. Together with the flexibility of attaching tags to a range of interaction objects, this implies the possibility of a much more flexible development of tabletop applications. Read-It has become the first application that uses the new software architecture. However, as explained above, Read-It has two objectives. Besides being a test for the new software architecture, it is also intended to demonstrate the potential added value of tabletop applications in a learning environment for 5-to-7-year-old children.

DESIGN RATIONALE

A redesign of the classic game 'Memory' provided all the features needed to show the potential of our tabletop environment. In the *speelleesset* of VLL, the goal of the game is to find matching pairs of pictures. Two pictures match if their related words start with the same sound (or letter). For example the Dutch word /maan/ ("moon") matches the word /mier/ ("ant") because the pronunciation of both words start with the sound [m] or letter /m/. The purpose of this game in terms of reading education is to enhance a child's consciousness of the phonological units in spoken language and to enforce their already established reading skills [6][12].

An augmented tabletop environment allows to combine the strengths of the *speelleesset* game with those of a computer-supported reading exercise. Audible cues can be used alongside visible cues. Performance monitoring and game modifications can be performed easily, while the cooperation between players can be promoted.

Collaboration

The potential of augmented tabletop applications especially shows in the support of parallel activities and the encouragement of collaboration. Inkpen [8] describes how children (age 9-11) show more involvement and participation in a (desktop) computer application that allows for parallel interaction. However, the classic rules of memory prescribe strict turn taking and encourage competition. For Read-It, we altered the rules such that players have to complete a turn together[10]. They can collaborate both mentally and physically towards this purpose. They are stimulated to help each other to remember the locations of wanted cards. They can also cooperate physically by separately reaching for two matching cards and by pressing the confirmation button. Whether the players turn the cards in parallel or sequentially does not matter.

Memory on the Visual Interaction Platform

Appearance

The memory game consists of twenty tangible brick elements. Each brick is tagged on both sides with infrared reflecting tape. The system tracks and identifies the bricks using computer vision. The application associates each brick with a virtual memory card. The virtual cards are projected on top of the physical bricks. The sides of the bricks that are exposed when the game starts are associated with the blind sides of the virtual cards. The covered sides are associated with the pictures. The playing area is a colored area projected on the reflecting tabletop. On the left or right side of the playing area there is a large button (The BIG Button from RJ Cooper and Associates) that the children use to indicate to the program that they have found a pair of matching cards. A personal workspace is associated with each player. It is used to provide textual feedback. More on the rationale behind the personal workspace is discussed in the paragraph on orientation.

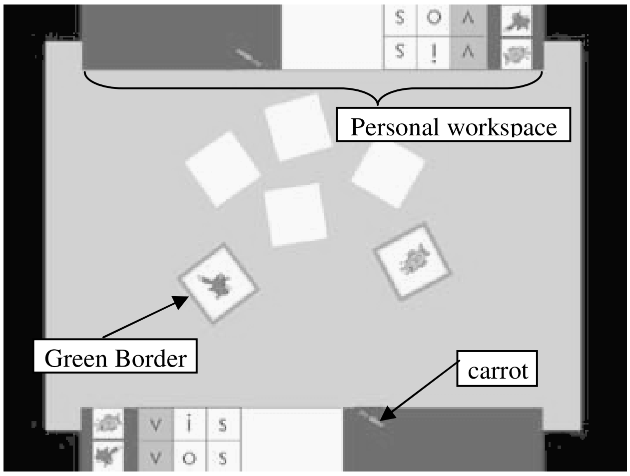

Figure 3. The playing area of the Read-It application.

Interaction

By flipping a brick, the virtual memory card is flipped and the system shows or hides the corresponding picture. When two pictures (or rather: sounds) match, the children have to press the big button positioned next to the game. The system does not evaluate two cards straight away. If it would, the children would not have to think on whether or not the cards match and the challenge would be spoiled. The system evaluates the children's decision. If it is correct, it rewards them with a picture of a carrot in their personal workspace. The matching cards flash with a green border for a couple of seconds, before becoming inactive. The players can subsequently remove the inactive bricks from the table. If their decision is wrong, the system shows red borders around the non-matching pictures. The players have to flip the cards back to "hide" the pictures before continuing the game. The game ends when the children have found all the matching pairs. A large, animated carrot is shown as a final reward. Figure 3 shows an example of the Read-It playing area, setup for face-to-face players. The cards are in the shared area in the middle, while the personal workspaces are on the top and on the bottom. Notice the border (normally a green color) around the two cards faced up and the scored carrot.

The interactions that are implemented in the Read-It application are considered natural for two reasons. Firstly, the interactions between the children and the system are similar to interactions with regular objects, for example toys, amongst others, because of the shared action-perception space. They can control what they are doing because they can use conventional eye-hand coordination skills (as opposed to operating a mouse). Second, because sitting around a table together allows a more natural setup for collaborative interaction between the children. They can exploit their (verbal and non-verbal) communication skills without being hindered by, for example, a vertical screen.

Cheating and Error Feedback

Cheating is a temptation in any game. In a computer environment, it is however possible to control the flow of the game actions to a certain extent, so that some attempts at cheating become impossible. We recognize two situations as attempts to cheat:

- turning a new card face up, while one or both of the cards of the previous turn are still facing upwards;
- subsequently turning the same (new) card face up and face down.

In the first case, the new card at hand will be shown with a red transparent layer. The red layer is transparent to retain a visible relation with the associated picture. In the second case, red arrows, pointed towards the centre of the card, appear to indicate that the players should proceed with this card faced up.

Orientation problem

Reading the same text from different sides of a table is problematic, especially for children at this age, who are not yet well trained in identifying the characters that form a word. Feedback that supports the children in achieving their task should preferably be provided in an optimal orientation. Therefore we divided the playing area into two areas: a shared workspace and one or more personal workspaces. The shared workspace is where the memory cards reside. The personal workspace is a small area that provides pictorial and textual feedback on the flipped cards. Although this division could encourage the players towards a more individualistic game strategy, the quality of learning should prevail over the collaboration. Also, if one player has clear dominance over the game and is skipping the feedback, the personal workspace provides clear feedback for the less-dominant player. The collaboration is associated with the shared workspace, where the core of the game takes place: finding cards that match.

When children flip a card to reveal a picture, the word representing the picture is displayed in the personal workspace, spelled one letter at a time. The phonemes that correspond to the displayed graphemes are pronounced simultaneously by the system, followed by a pronunciation of the complete word. The personal workspace also includes thumbnails of the pictures on the flipped cards, so that the identified pictures remain closely associated with the related words. This enforces the relation between the displayed object and the word representing it.

Tangible objects

The interaction with the Visual Interaction Platform relies on the detection of objects that are tagged with retro-reflecting tape. In Read-It all the necessary memory cards are represented physically. As a result, the game is played in a way that is very similar to playing with real cards, so that the children do not have to learn a new interaction method.

A card-shaped interaction element has the additional advantage that it suits the children's motoric skills better than mouse handling. Some of the teachers we interviewed indicated that this kind of shape complements the current experiences of the children in dealing with brick toys such as LEGO. The system required a tag size of 55x55mm for reliable recognition, but other shape aspects could be designed to the benefit of the user. We tested bricks with varying thicknesses (2, 6, 8, 16, 18 and 22 mm), with and without a notch. Adding a notch to a brick element makes it potentially easier to grasp and turn. On average, the 37 five-to-seven year old children preferred a brick with a thickness of 6 mm and with a notch. Figure 4 illustrates the final design of the brick elements.

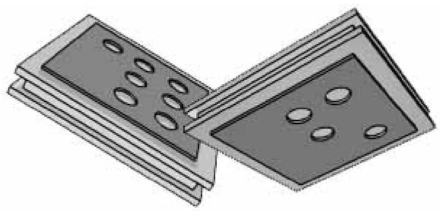

Figure 4. **Brick elements with front and back sides.**

Benefits in reading education

Collaboration elicits intrinsic motivation, which is important in educational applications. Read-It however has more features that stimulate the children in their learning experience.

Multi-modal stimulation

Stimulating all different senses of the child also enforces the learning process. In early reading education, children need to attach distinctive pieces of graphical information (the letters, or rather: graphemes) to distinctive pieces of audible information (the corresponding sounds, or rather: phonemes). Read-It offers feedback that enforces this process step by step. Once a card is flipped, a word is displayed grapheme by grapheme and at the same time pronounced phoneme by phoneme. At the same time their fine motoric skills are trained by the use of the brick elements.

Direct stimulation

To keep the children focused, they need direct stimulation as explained in the section on the user profile. Read-It requires a constant shift of attention during the course of the game. To select the cards the children have to focus on the shared area and more in particular on the card they want to flip. Once a card is flipped, the personal workspace attracts the attention by displaying the graphemes and showing the thumbnails. If two cards match, then the children have to press a confirmation button outside of the game area. The feedback on pressing the button is subsequently displayed in both the shared workspace (green or red borders) and the personal workspaces (the score consisting of collected carrots). With Read-It, children do not need to keep still and concentrate continuously on the same thing. According to Acuff [*], we expect this to favor their engagement.

Differentiation and Repetition

Read-It recalls lessons taught before and is designed as part of an existing method. It rehearses the elementary reading processes that the children have acquired in class. Especially the weaker children are expected to benefit from this extra repetition.

A computer-supported reading exercise like Read-It allows to tailor the training of the children to their needs. Read-It can be modified to support different levels of difficulty. The memory game can for instance be configured to match the first sound, the middle sound or the last sound in mono-syllabic words. The selected mode is reflected in the renderings of the personal workspaces. More specifically, all characters in the personal workspace are rendered on a white background, except for the character that should be matched (i.e., the first character in Figure 3). In addition, aspects such as the visual or auditory feedback can be switched off to train particular reading processes in isolation. In this way, the game can remain a challenge for the stronger readers.

Read-It can support two to four players. Children that manage to collaborate with one other child can be challenged to play the game with three or four children.

EXPERIMENT

The potential of the Read-It application was recognized by both the publisher of the VLL method and by some teachers of Dutch primary schools, which resulted in their willingness to cooperate not only in its design but also in an experimental evaluation. To substantiate that the a priori requirements set for Read-It were indeed met, we needed to test them with target users. In the future we would like to show the effects of Read-It on learning to read. However, this would require a large-scale longitudinal study that was beyond the scope of the three-month project that we engaged in. The pilot experiment that we did perform instead examined whether or not the five-to-seven-year-old children were able to understand and work with the augmented reality as applied in Read-It. We also looked for indications of collaboration between the children.

Experimental Design

The experiment involved 15 children (6 couples and 3 individuals) between five and seven years old. It was attempted to keep the number of boys and girls approximately equal to prevent an effect of gender. The participants were recruited from primary schools in Eindhoven and 's-Hertogenbosch (the Netherlands) that use the VLL reading method. The participants were invited together with their parents to the laboratory at the Eindhoven University of Technology where the Read-It prototype was located. It was unfortunately not possible to conduct the test in the children's classroom environment, because the Read-It system could not be transported.

In cases where a single child participated, a research group member participated in the test to play the game. For reasons of good comparison, these children were left out of the collaborative observations. The reason that there were single children in the study was that the parents did not succeed in all cases to couple their child to a friend, brother or sister in the same age group.

As explained before, the rules of the classic memory game were changed slightly in order to create a collaborative game. To train the children with the new rules before they started the session with Read-It, they first played a paper version of the memory game with the adjusted rules. This avoided that 'not knowing the rules' could be a confounding factor in the experimental session. When the children finished the game, they were taken to another room where the Read-It application was stand-by. The children played an introductory Read-It game with three card pairs to get used to the environment and to the behavior of Read-It. After that the children played a complete (ten pair) memory game. When the children finished playing the parents were asked to join the children in the laboratory, at which time the children were encouraged to demonstrate and explain the game to their parents. In this way, we tried to elicit feedback from the children about their understanding and opinion of the Read-It game in a natural way.

Observations

The Read-It sessions were taped with three cameras. Two cameras were aimed at the individual children, while the third camera recorded the actions in the workspace. The tapes were used to analyze the children's collaborative and explorative behavior using coding schemes.

The *collaborative behavior* was scored in two categories:

1. Collaborative behavior:
   a. discussion which BEL (Brick ELement) to pick up;
   b. discussion about which begin letter to match with;
   c. making a gesture to point the other player to a BEL;
   d. looking at each other for confirmation.
2. Non-collaborative behavior: grabbing a BEL without discussion.

The first two indicators of collaborative behavior are explicit clues of the fact that the children want to get to the end together. Discussing which card to turn next indicates collaborative working, as does discussing which begin letter to look for. The last two indicators point towards more moderate forms of collaboration. They for instance occur when a child point out which card s/he think contains the correct information, or when checking with the other child whether or not a card is the correct one. These observations imply that the children are playing together rather than individually.

Explorative behavior can indicate that the children do not completely understand the augmented reality as it is applied in Read-It. Upon first confrontation with the system, the children typically start to explore the system's properties and behavior. As they increase their understanding of the new environment, the explorative behavior is however expected to decline. The following indications of *explorative behavior* were used:

1. peeking under a brick (BEL) before turning it;
2. picking up a BEL, removing it from the projection area and/or looking at the reverse side of the BEL;
3. matching the BEL to the projected virtual card.

The explorative behaviors were divided across four timeslots. The total time was determined by the number of turns taken, since not all couples needed the same number of turns to complete the game. One turn started with flipping the first of two cards face up and ended when all remaining cards were again faced down. One timeslot corresponded to a quarter of the total number of turns.

To deduce whether or not the features that are expected to support the learning environment (see *benefits in reading education*) are indeed used, we observed the number of times the children (1) looked at the personal workspace, (2) spelled together with the audio and (3) waited for the spelling to be finished before pushing the button or turning another card. We also questioned their understanding of the error messages.

Results

Explorative behavior

A measure for understanding the concept of augmented reality as applied in Read-It was the explorative behavior that the children demonstrated during the game. The average number of turns for a whole game was 23 turns. If we look at the average number of explorative moves of the children, it was 22 explorative moves in the first two quarters of one game. In the last quarter the children only performed 11 explorative moves, on average. This is a decline of 50%. These numbers are depicted in figure 5.

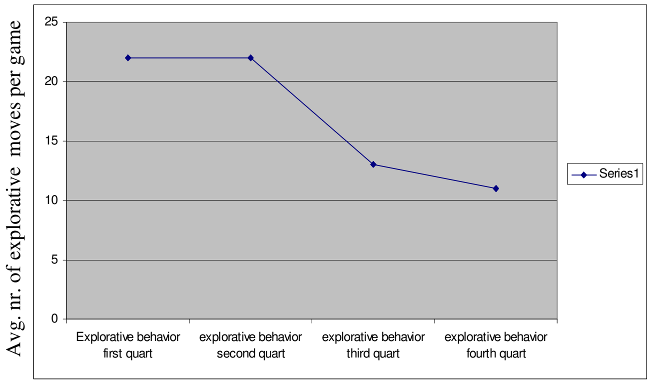

Figure 5. Results on Explorative Behavior

This implies that the children understood enough concepts of the system to use Read-It without serious problems.

Collaborative behavior

On average, the children made 6 collaborative moves per game and 20 moves without any discussion. Although we lack normative data, the children clearly made an attempt to collaborate.

Added value of Read-It

The added value of Read-It is demonstrated by the fact that 66,5% of all cards that were turned triggered a look at the personal workspace. Of these observations, 60,7% corresponded to the first card of a pair being turned, while 39,3% corresponded to the second card. The results regarding the spelling were that in 68.8% of the game children waited until the spelling was finished before doing anything else. On average children spelled the letters together with the audio during 25% of the game. These results indicate that the children do use the functions that were implemented as an added value for Read-It.

Read-It is also easy to learn. This is shown by the learning curve of the explorative behavior. It is also supported by the way in which the children reacted to the error feedback from the system. This feedback was incorporated to prevent the children from cheating. It however turned out that the children within the experiment never cheated but just played by the rules. They quickly realized that the few error messages that did occur were a consequence of some false recognitions that occurred in the system.

The explanations that the children supplied to the parents revealed that they understood the concept of augmented reality as applied in Read-It very well. They knew that the computer put something in or on the cards in the shared workspace. They could explain the rules and definitely liked this version over the paper version. All of the children wanted to play the game again. Reasons for playing again were: the sound, pushing the button and the carrots as a score and the carrots as a reward at the end of the game.

DISCUSSION

We think that children are ready for tabletop environments like Read-It. The results show clearly that they can play the game and that the augmented reality is not an obstacle for them. The possible effect of Read-It on learning to read in the long run is an interesting question for the future. The results discussed in this article support an optimistic view. There are other issues, such as the issue of collaboration, that will require additional research in order to answer them satisfactorily.

Ideally, the tabletop application should allow for natural collaboration. Although we tried to avoid a fixed location of our lively intended users, to ensure a correct orientation of the graphemes, we had to create the fixated personal workspaces. From our experiment, some questions remain. For example, in what position do young children collaborate best? Literature reports on working together both shoulder to shoulder [21] and face to face. Apparently the ideal position around a table is flexible. Then what is the correct orientation for the objects in a tabletop application? And how is the ideal orientation maintained throughout the collaborative processes? By the time this project was finished, Kruger et al. [11] published some guidelines for tabletop applications and the implications for orientation management. Maybe the effortless interaction of Read-It is partly explained because our implementation decisions appear to meet most of their findings. However, collaboration and tabletop applications is an interesting topic for further research.

Another issue is the future of our application. Can Read-It become an application in class? From the point of view of the tabletop game itself, the answer is definitely yes. The objections against it are of a more practical nature. The current hardware and software set-up is not yet sufficiently robust. Although the recognition software was robust enough to withstand the children's liveliness in the recognition area, it was not error-proof on all occasions. One way to increase stability would be to relocate the recognition processes underneath the table and/or to replace the visual (camera) recognition by another technique (for instance using radio-frequency tags). If we take a look at the costs, the entire setup seems expensive. However, the application runs on a single pc, which has become a common good in primary schools. The projector has not reached that status yet, however, its usefulness in school is recognized, for both education and entertainment.

Therefore the only piece of equipment that needs to be purchased specifically for the tabletop application is the recognition device (consisting of the camera and light source). If Read-It proves to be a successful concept also in the long run, we think that Read-It can become affordable.

CONCLUSION

Read-It is a multimodal, tangible and collaborative tabletop application that supports learning to read in a novel way. From the development of Read-It we can draw two conclusions.

First of all, it was shown that children in the age of 5-7 year old can indeed benefit from learning to read with the support of an augmented tabletop application. Read-It combines the strengths of physical tabletop games and desktop exercises in a multimodal, collaborative and tangible tabletop environment. The game uses tangible bricks to improve interaction and it uses different strategies to support the learning process – recall, rehearsal and collaboration.

Second, we made a useful technical contribution to the development of tabletop applications. The XML communication between the driver and the application software within Read-It allowed designers with little knowledge of visual recognition and C++ to create an application on the Visual Interaction Platform. As far as we know, Read-It is the first application to use such an approach.

We have illustrated the above points of view with an in-depth design of an application that supports learning to read. Strong supportive features are the tangible interface, the multimodal feedback, the opportunity to solve tasks in collaboration and the compliance with the standards of a well-recognized reading method. Altogether, Read-It provides a good starting point for further research and development.

ACKNOWLEDGEMENTS

We would like to thank Fr. Mommers for his support and his comments on the educational aspects of the implementation of Veilig Leren Lezen. The support of publisher Zwijsen was highly appreciated for providing us with the original pictures and sounds needed for the application's content. Lastly we would like to thank the schools that allowed us to interview teachers and parents and the University of Eindhoven for their resources.

REFERENCES

[1] Acuff, D.S.(1997) *What Kids Buy and Why: The Psychology of Marketing to Kids*. Detroit: Free Press

[2] Aliakseyeu D., Martens J.B., Subramanian S., Vroubel, M. and Wesselink, W(2001), "Visual Interaction Platform" in: M. Hirose (Ed.), *Human-Computer Interaction INTERACT'01*, pp. 232-239, Tokyo.

[3] Brukman, & Bandlow, HCI for Kids, In Julie Jacko & Andrew Sears (Eds.), the HCI handbook: Fundamentals, Evolving Technology, and Emerging Application, NJ: Lawrence Erilbaum Associate, 2002.

[4] Ferris, K. & Bannon, L.(2002), …A load of ould Boxology!, in: *Proceedings of Designing Interactive Systems 2002*, British Museum, London. June 25-28 2002.

[5] FitzMaurice, G.W., Ishii, H. & Buxton, W. (1995), Bricks: Laying the Foundation for Graspable User Interfaces in: Proceedings CHI 1995, New York: ACM Press, 170-177.

[6] Geudens, A. (2003) *"Breaking through the rime /raIm/", An inquiry into the relevance of the onset-rime structure in children's phonological awareness and early reading development*, Geel (Belgium): Print-it.

[7] Healy, J. M. (1999). *Failure to connect: how computers affect our children's minds--and what we can do about it.* New York, NY: Touchstone.

[8] Inkpen, K.M., Ho-Ching, W., Kuederle, O., Scott, S.D., Shoemaker, G.B.D. (1999) "This is fun! We're all best friends and we're all playing.": Supporting children's synchronous collaboration in: *Proceedings CSCL 1999* New York: ACM Press, 252-259.

[9] Ishii, H., and B. Ulmer (1997) Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms. *Proceedings CHI 1997*, New York: ACM Press, 234-241.

[10] Johnson, D.W., Maruyama, G., Johnson, R.T., Nelson, D., Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta analysis. *Psychological Bulletin, 89*, 47-62.

[11] Kruger, R. Carpendale, S., Scott, S.D., Greenberg, S. (2003) How People Use Orientation on Tables: Comprehension, Coordination and Communication in: Proceedings international ACM SIGGROUP 2003, New York: ACM Press

[12] Mommers, C., Verhoeven, L., Linden, S. van der, Lucas, H. & Thomas, A. (1999) *Veilig Leren Lezen*, Tilburg: Zwijsen

[13] Peterson C.(1996), *Looking Forward Through the Lifespan: Developmental Psychology*, 3rd Edition, Sidney: Prentice Hall Australia Ltd.

[14] Piaget, J (1970), *Science of Education and the Psychology of the Child*, New York: Orion Express

[15] Rauterberg, M., Fjeld, M., Krueger, H., Bichsel, M., Leonhardt, U. & Meier, M. (1997) BUILD-IT: a video-based interaction technique of a planning tool for construction and design.: Proceedings of Work With Display Units -- WWDU'97, p. 175-176.

[16] Reitsma, P. & Verhoeven, L.(1990), *Acquisition of Reading Dutch*, Dordrecht (The Netherlands): Foris Publications, Dordrecht

[17] L.L. Scarlatos, Y. Dushkina, S. Landy (1999). TICLE: A Tangible Interface For Collaborative Learning Environments, CHI 99 Extended Abstracts, pp. 260-261.

[18] L.L. Scarlatos (2002). TICLE: Using Multimedia Multimodal Guidance to Enhance Learning, *Information Sciences* 140 (2002), pp. 85-103.

[19] Scott S.D., Mandryk R.L., Inkpen K.M. (2003), Understanding children's collaborative interactions in shared environments, *Journal of Computer Aided Learning*

[20] Smets, G.J.F., Stappers, P.J., Overbeeke, K.J. and Van der Mast, C., Designing in virtual reality: Perception-action coupling and affordances. In: Carr, K., and England, R. (eds.), *Simulated and Virtual Realities. Elements of Perception.* London: Taylor & Francis (1995), 189-208.

[21] Stewart, J., Bederson, B., & Druin, A. (1999) Single Display Groupware: A Model for Co-present Collaboration in: *Proceedings of CHI'99*, New York: ACM Press.