Lessons from an AR Book study

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ABSTRACT
We have observed children reading an augmented book aimed at early literacy education. We explored how children aged six to seven experience and interact with these novel instructional media. We here focus on issues arising from the tangibility of interface elements, the integration of physical and digital elements, on-screen and paper elements, and of text and interactive sequences.

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reading, augmented reality, interactive book, children.

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H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Considerable effort is being invested into developing Augmented Reality technologies for entertainment and education. These allow the user to view and manipulate virtual 3D objects in a real-world environment. The notion of an 'augmented book' was proposed with the MagicBook [2] and inspires researchers and educators alike as a means to enhance books with interactive visualizations, animations, 3D graphics and simulations [8]. It draws upon the genres of the picture and pop-up book, adding further textual and visual features and inviting readers to explore and manipulate its pages [5]. Educators expect augmented books with interactive 3D-visualisations to provide a better understanding of complex content that can be actively manipulated and explored, and to motivate learners and enhance engagement, supporting immersive learning [5].

Non-augmented as well as augmented books have been found to support collaborative learning [9]. Using a book as interaction metaphor, tangible means for interacting with and navigating through the story are provided by physical pages that can be flipped and moved around. Additional tangible elements add further options to interact with and actively manipulate story elements [3]. Tangibles are reported as providing innovative ways for children to play and learn, to bring playfulness back into learning and to support collaborative learning [6, 7, 9].

Despite much research, most of this has to date focused on technological development. Today we still know little about the "how, what, and why" [8] of augmented books, their effectiveness as instructional tools, or the instructional support needed. A particular challenge with new media is that it is difficult to assess their value when starting to explore them as a new genre and not yet knowing what makes for a good example. With an interactive book, a range of factors contribute to the user experience: the story itself, the visuals, the interactive sequences and how the user interacts with these, how 3D elements, interactive sequences and traditional text relate to each other, and the handling of the overall augmented book.

The British BBC conducts the AR-Jam project evaluating the use of augmented books for early literacy education (age 5-7). While a UK team focuses on classroom situations, the HITLabNZ ran an observational study focusing on children interacting with the books outside of the classroom. Our overall aims were to explore how young children interact with augmented books, and to identify interaction design issues that creators of augmented books should be aware of. We have analyzed the videos from eight pairs and six individuals, focusing on their engagement, and their interactions with the system. We will first describe the system and our study setup. Then we describe our findings, focusing on issues arising from the tangibility of interface elements, the integration of physical and digital elements, and of on-screen and paper elements.

STUDY SETUP AND APPROACH

The system and the story books
The BBC provided us with two augmented story books that have been developed for the AR-Jam. The AR technology employed is based on ARToolkit markers detected by a web-cam [2]. Physical pages (sheets of paper) and paddles carry visual markers. The paddles represent the main characters (see figure 1 and 2) and the pages the settings (and other characters) for the interactive sequences. A web-cam is connected to the computer and positioned on top of the screen. This low/no cost setup allows the technology to be used in most classrooms. However it does not provide a

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fully integrated view of real and virtual objects, unlike other AR-setups using head-mounted or hand-held see-through displays. The augmented book becomes visible on the screen when pages and paddles are in camera view. The system, detecting the markers, inserts 3D images and animations into the video image. The screen also shows text pages and buttons for navigating through the story. The physical pages and paddles are predominantly used during the interactive sequences.

The type of learning activity supported by this system can be characterized as 'exploratory' where a learner explores a given model embodied in the system [4]. "Big Feet and Little Feet" (referred to as 'chick story') tells the story of two little chickens, left outside the hen house in their eggs who have to overcome several obstacles to find home. "Looking for the sun" ('sun story') has four insect characters (thus four paddles) who try to get to the sun. The chick story had been specifically written for the AR-Jam while the other was adapted from an existing book by Rob Lewis. The stories start with text pages on the computer. If another text page follows, one clicks on 'Next'. On each text page the children can choose to read by themselves or to listen to a recording. After each text section a short instruction informs the user to close the text page, starting an interactive sequence showing the camera view overlaid with AR objects and navigation elements. Here the children interact with pages and paddles (see figure 1). The pages usually have 'hot spots' next to the markers, indicated by a grey outline. Placing paddles on a hot spot triggers story events – in figure 1 the chick will inspect the hole in the tree-trunk. After completing a sequence 'Next scene' leads to the next text page.

Study design and method

Children from a local primary school, ages 6 ½ to 7, participated in the study at the Christchurch South Learning Centre. For this first study, avid and good readers were solicited (a recent study involves pupils with reading difficulties). Pairs were well acquainted with each other. From the pair condition we expected closer insight into the children's thoughts and opinions, constructive interaction creating a naturally communicative situation and alleviating the problems of think-aloud methods [1]. We employed both stories for wider insight into relevant design issues.

Six pairs and six individual children 'read' and interacted with one of the two augmented books. After completing the story, each child was interviewed individually (semi-structured, not yet analyzed). As only the interview questions changed, we include the video data from our pilot study (two pairs) in our analysis. The children were videotaped with the written consent of their caregivers and the school. The videos have been analyzed by the authors in shared analysis sessions, taking extensive notes of children's actions, nonverbal behaviors, and talk. Analysis was open-ended, iteratively evolving and collecting instances of the issues we here report upon.

Figure 1 Example for interactive screen with virtual objects and navigation elements overlaid (front) and text page (back)

FINDINGS

We found that most children were able to interact with the books without much prompting after being scaffolded through the first two interactive sequences, and would expect them to be able to read a second book without assistance. While this is encouraging, our sample of pupils represents the top of a class and other children may have more problems. There were clear differences in whether children were acting playfully and exploring the features of the AR book (doing things for the fun of it), or whether they were acting analytical and strategically, thinking about each move first and trying to do things correct at first try. Individuals seemed to have more difficulties with the navigation flow and in discovering how to achieve things. Collaborative interaction might help children to cope with problems that they get stuck with on their own, and increase chances of alternative behaviors.

Insights on the Design of AR books

From our analysis we see that there are several elements contributing to the user experience of an AR book. These range from the overall story outline, purpose and role of interactive sequences in advancing the story, interaction design of interactive sequences, handling of AR elements, integration of paper and screen-based visualizations, handling of the flow between text pages and interactive sequences, to the use of physical metaphors.

Story Design and Integration of Interactive Sequences

Naturally the story itself determinates whether a book is engaging. While Mckenzie [5] identifies non-linear and interactive stories and activity books as options for AR-books, the provided stories followed a sequential story line. In this case classic elements of storytelling are important, such as choice of main characters, setting and plot. Here the chicken story fared better. With an AR-book it is important how the interactive sequences contribute to the story. Sequences that did not advance the plot seemed not to be satisfying for our young readers and often left them confused on whether they had completed the sequence. The interactive sequences of the chick story usually have the chicks overcome a problematic situation, getting out of their eggs or climbing through a fence. An indication of the sequence being finished is provided by the visual exchange of eggs to chicks or the chicks running off the screen. The sun story has its characters try several things in vain, leaving it implicit whether the sequence was completed. Here we often saw children staring motionless at the screen for several seconds or trying over again.

From our observations we feel that interactive sequences early in the story should engage readers and have them explore interaction with the paddles. This could involve simultaneous and coordinated use of several paddles or using paddles in relation to book pages. If the first interactive sequence was rather static, children tended to transfer their experience of sequential and isolated paddle use to the next sequence and had to be scaffolded to try different manipulations; e.g. to place paddles next to each other or to move paddles around more instead of removing a paddle from view when taking another one.

The Mirror View Creates Spatial Confusion: "Where am I"?

Positioning the camera above the screen provides a mirror view instead of an egocentric perspective. Left and right remain the same, but front and back are reversed, a view from 'over there'. This created cognitive difficulties for some of the children in moving their characters (via the paddles) forwards and backwards. Several pairs and one of the individual children struggled noticeably. This is detectable from their talk and moment-by moment analysis of their movements with paddles. Sudden stops while looking at the screen, followed by looking down at the paddles and correcting direction indicate viewpoint confusion, as well as jerky shifts of movement direction. We also find evidence in their talk, such as "what am I doing there?" and "We're over there", statements that only make sense if interpreted as attempts to figure out and re-establish spatial relationships. When the chicks reach a fence they need to get through, most children had trouble figuring out which side of the fence they were on. One child tells his partner "You are over here" and tugs at his paddle. One child wants to jump over the fence, however, she moves the paddle in the wrong direction and says: "That is weird".

This issue resulted from the straightforward approach to substitute a relatively expensive see-through device with a web-cam. While in hindsight the problems of a mirror view are evident, it only surfaced during detailed video analysis on noticing peculiar motions with the paddles. We furthermore discovered that even we researchers sometimes used trial and error to move things in the desired direction, without conscious awareness and memory of our own difficulty.

Figure 2 Children engaged in interactive sequences

The mirror-effect seemed to affect playful and experimental children stronger, in particular pairs. Children who successfully coped tended to look up and down frequently, controlling their movements by looking at the paper on the desk and checking effects on-screen. A hypothesis would be that playful children concentrate more on the screen visuals and are more immersed, becoming less strategic. Still, the mirror-effect only created minor breakdowns, forcing children to momentarily shift attention from the story and the animations to manual handling of the paddles, but did not seem to lessen the overall experience.

Expectation of 3D behavior in 3D-space

We found strong evidence of children expecting the 3D visualizations to have physical world and 3D-behavior and attempting interactions that the system was unable to recognize or react to. The current implementation has two limitations. Markers need to be visible to be recognized and paddles carry markers only on the top. Any occlusion results in the virtual object disappearing. Objects can thus not be turned upside down. Furthermore, although the markers and the corresponding images are registered and visualized in 3D, in terms of story logic (triggering of events) the marker position is interpreted only in regard to the 2D-position (x- and y- axes) and not to height (z-axis).

When the chicks were stuck in their eggs and the children were asked to help them get out, many children tried banging the paddles (which on-screen had the eggs on them) face-down to the table or head-to-head into each other, as one would do with actual eggs. Both interactions result in the markers being occluded. Often the movements with paddles were too rapid for the software to detect markers. We also saw children trying to let their chick sit on top of a (virtual) tree trunk by holding their paddle high above the tree, one child asking immediately "so what do we do, climb on it"? Often children would mimic a walking motion when moving the paddles. In one sequence, the chicks have stones in their hands and need to drop them in front of a fence to climb through a hole. The paddles need to be put directly before the fence. Several children held their paddle in a slight angle and wiggled it, as if trying to let the stone slide down. One child told her partner to "push him down" and tilted her hand and paddle downward. These observations indicate that interaction could be enriched by more explicitly exploiting physical analogue behaviors and interpreting 3D position of paddles. They also remind us that paddles need to be quite sturdy to withstand these unexpected interactions.

The tendency to refer to physical world analogy posed a hurdle for most children asked to let the insect characters 'build a tower'. Several attempted to stack the paddles, in effect hiding markers. One child asked "so do I put them all on a pile like that?". This task further posed the difficulty of translating the temporal order of putting single paddles sequentially onto the hot spot into spatial order in a tower – a conceptual break with previous interaction patterns and metaphors, and potentially overwhelming this age group.

The tangible input devices (paddles) here work rather too well in terms of encouraging physical interaction (users assuming physical world affordances and laws to transfer to the 3D elements). This inclination by users might be problematic for other kinds of tangible systems as well.

Integration of paper and screen navigation

The children repeatedly had issues navigating from page to page and sequence to sequence, especially when switching between text pages (on the computer screen and navigated by mouse) and interactive sequences (physical pages, sometimes in sequence). Although most did learn how to handle this, it required close assistance in the beginning and there were episodes of insecurity of how to go on. Children often attempted to use the wrong button or continued to flip physical pages waiting for something to happen. Added complexity was created by sometimes having two buttons for 'next' and 'close window' to start interactive sequences.

We recommend keeping navigation as simple, explicit and consistent as possible. An on-screen button might simply say 'next' and *always* continue to whatever is the next logical element (if linear sequence). Added complexity is introduced by different navigation styles when on screen and paper. Making use of the AR technology, this could be simplified by providing a paper sheet for each screen page and flipping pages (showing markers) telling the system to move on, using the book metaphor for navigating through the story. In this case, the creators of the stories deemed pattern recognition to be too unreliable in uncontrolled lighting conditions, running the risk of the system jumping to the wrong page or starting a scene all over again. Careful consideration should furthermore be given to visibility of instructions and additional visual cues when the book is distributed across screen and paper. Children that looked to the screen often did not notice additional cues on the paper pages (e.g. 'hot spots' for putting the paddle)

CONCLUSION

Most studies on the use of Augmented Reality in education related to literacy have focused on expressive activity [4], often having children create and visualize their own stories [5, 6]. Our study focused on augmented books supporting reading and working through predefined story books. Some of the issues we found to be relevant relate to the choice of stories and how interactive sequences are integrated. Navigation turned out to be an important issue when combining paper and on-screen elements, in particular if these are not integrated in one visual area and deploy tangible *and* desktop-based input devices. Some of our observations are specific to this type of activity and genre of book. Others, like spatial confusion due to the mirror view and the tendency of children to try to interact with the system akin to behavior in the real world, are likely to affect other applications with similar configurations of input devices or with tangible systems in general.

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REFERENCES

1. Als, B., Jensen, J. and Skov, M. Comparision of Think-Aloud and Constructive Interaction in Usability Testing with Children. *Proc. IDC 2005*, ACM (2005), 9-16.
2. Billinghurst, M., Kato, H. Poupyrev, I. The Magic Book – Moving Seamlessly between Reality and Virtuality. *IEEE Computer Graphics and Applications*, (2001), 1-4.
3. Kato, H., Billinghurst, M., Poupyrev, I., Imamoto, K., and Tachibana, K. Virtual Object Manipulation on a Table-Top AR Environment. *Proc. Int. Symposium on Augmented Reality*, (2000), 111-119.
4. Marshall, P., Price, S. and Rogers, Y., Conceptualising tangibles to support learning. *Proc. IDC '03*, ACM Press (2003), 101-109.
5. McKenzie, J. and Darnell, D. T*he eyeMagic Book. A Report into Augmented Reality Storytelling in the Context of a children's workshop 2003*. New Zealand Centre for Children's Literature and Christchurch College of Education, 2004.
6. O'Malley, C. and Fraser, D.S. Literature Review in Learning with Tangible Technologies. *NESTA Futurelab Repor*t 12 (2005).
7. Price, S., Rogers, Y., Scaife, M., Stanton, D. and Neale, H. Using 'tangibles' to promote novel forms of playful learning. *Interacting with Computers 15*, 2 (2003) 169-185.
8. Shelton, B. *Augmented Reality and Education. New Horizons for Learning* (2002) http://www.newhorizons.org/strategies/technology/shelton.htm
9. Tallyn, E. Frohlich, D., Linektscher, N. Signer, B., Adams, G. Using paper to support collaboration in educational activities. *Proc. CSCL'2005*, (2005).